SKETCH OF THE BRIDGE OVER THE
RIVER MAHAVILLAGANGA.

PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS.

R. E.

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JOHN WEALE, 59, HIGH HOLBORN.

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INTRODUCTION.

In laying the Third Volume of the Professional Papers before my brother Officers, I beg to call their attention to the great improvement that has taken place in the general appearance of the work. The Plates have in most instances been executed on copper instead of on stone; the paper and type is improved, and generally a change for the better has taken place in the mechanical execution of the Work, which is to be attributed principally to the arrangements made with Mr. Weale, who has got up the Work in a manner creditable both to himself and to us.

I trust also that while the appearance of this Volume has been altered for the better, the Papers which it contains will not prove of a less interesting character than those of the former Volumes. The first, that of Sir J. Jones on the Lines of Torres Vedras, is already known to most Officers, but as copies of the original edition are not to be procured, and even the French Translation is, I believe, out of print, Sir J. Jones has kindly permitted me to reprint the work, and allowed me to make use of the copper-plates engraved for the original edition.

The other Papers are printed in this Volume for the first time, and will afford a variety of useful information on subjects connected with the Military and Civil branches of our profession.

I was in hopes of being able to give a detailed account of the different systems of Pontoon Equipment proposed by Sir J. COLLETON, Lieut.-Colonel BLANSHARD, and Colonel PASLEY, but this must be postponed till another Volume, for which I have already a mass of material.

W. D.

Woolwich, Sept. 2, 1839.

PROFESSIONAL PAPERS.

I.—*Memoranda relative to the Lines thrown up to cover Lisbon in* 1810.

By Colonel John T. Jones, *Royal Engineers.*

Il est des militaires qui demandent à quoi servent les places fortes, les camps retranchés, l'art de l'ingenieur; nous leurs demanderons à notre tour comment il est possible de manœuvrer avec des forces inferieures ou égales sans le secour des positions, des fortifications et de tous les moyens supplementaires de l'art.—*Conversations des Napoleon, par Montholon.*

The retrenched positions covering Lisbon, known under the denomination of the Lines of Torres Vedras, have gained so much celebrity, as having formed the barrier from which the tide of French conquest first receded, and moreover possess so many peculiarities of defence, and are so free from the objections usually urged against lines, that some observations on their nature, construction, and mode of occupation, can scarcely fail to be interesting to professional and other officers seeking military information; and happily, since the first edition of this work was penned, in 1813, the affairs of Europe have so changed as to admit of some degree of descriptive detail being without impropriety substituted for the former eulogium of the general merit of the lines.

The determination to commence these works may be dated from the battle of Talavera. The offensive movements which led to that action having put to the test the value of Spanish co-operation, and having fully demonstrated the utter inefficiency of their armies, from want of organization, want of discipline and skilful officers, it became apparent to the Duke of Wellington that the contest would, in the next campaign, devolve on the small body of veteran British and newly raised Portuguese troops under his command, and a defensive system of warfare ensue. To prepare for a final struggle was thenceforward the great object of consideration; and as the hope of successfully

defending an extended and open frontier, like that of Portugal, against a very superior and highly skilful enemy, could scarcely be entertained, it was decided to seek out some position in the lower part of Estramadura, not liable to be turned or passed, and having an assured communication with the sea, which should command all the approaches to Lisbon, and which position, being retrenched in the strongest manner, would offer a point of concentration for the whole of the defensive forces of Portugal, army, militia, irregulars, &c., where they might, in conjunction with the British, be victualled and supplied with ammunition for any period of time, whilst occupying a most favourable field for deciding the fate of the capital and the kingdom in a general action.

With these views, whilst the army was cantoned on the Guadiana, Lord Wellington, in the month of October, 1809, attended by his quarter-master-general, Colonel Murray, and his chief engineer, Lieutenant-Colonel Fletcher, made a personal reconnoissance of the country in front of Lisbon, and judging the scheme practicable by means of a chain of fortified posts to extend across the peninsula, directed the officers of engineers to examine and minutely delineate the various strong features of ground between the sea and the Tagus, on a breadth of several miles, in order to enable him to decide on the most eligible line of defence, whenever he should deem the moment arrived for commencing the work. In the meanwhile the defences of Fort St. Julian at the mouth of the Tagus were to be extended to cover and ensure a communication with the fleet; and ground was to be occupied as retrenched posts or positions at Castanheira, Monte Agraça, and Torres Vedras, to support the manœuvres of the army while retiring on the meditated line, or place of embarkation. (1)

These labours proceeded uninterruptedly till the commencement of February, 1810, when, the preparations of the French for the conquest of Portugal having assumed a decided character, Lord Wellington, during the march of his army from the Guadiana to the Coa, revisited Lisbon to give final orders respecting the works to be erected for its protection. A few days were sufficient to ride over and decide on the ranges of hills convertible to his views; and having fixed the principal points and grand outline of his defensive system, he rejoined his army on the frontier, leaving the plan, trace, and execution of the works to Lieut.-Colonel Fletcher, whose sound military knowledge and indefatigable zeal were pledges for the details being worthy of the design.

At this time it was presumed that the invading army would be nearly double

the strength of the defensive force, and equal to manœuvre, in two formidable bodies, on the right and left of the Tagus, so as to throw back their opponents hastily on Lisbon; or, if parried in strategy, likely to attempt wearing them out by a succession of sanguinary combats. Expectation of a successful resistance was therefore very doubtfully entertained, and the object of primary interest and attention was to secure places for re-embarking the army in case of disaster, or if the enemy should advance before the lines could be rendered of sufficient strength to make it prudent to occupy them. The next consideration was to establish such strong enclosed works to block up the passes as should enable indifferent troops to delay or check a hostile column, in its endeavours to interrupt the retrograde manœuvres of the regular army; and these paramount objects being attained, every effort was to be used to strengthen the selected ranges of hills to the utmost that time would admit.

From the rocky nature of the coast of Portugal, there are very few spots favourable for maritime communication; and in the space to be covered by the projected lines, only one suitable point could be found, being a small bay, not two hundred yards in length, and very partially sheltered from the ocean by Fort St. Julian at the mouth of the Tagus; and even at that spot, at intervals, such a sea rolls in for days together that no boat can with safety approach the shore.*

The works to cover an embarkation were therefore to be traced of a threefold nature: first, to form a position of such extent that the whole army might sustain itself and protect its artillery and stores, during any period of bad weather which might retard the commencement of the embarkation; secondly, with an enclosed work within the principal trace, of such size and strength as might admit of diminished numbers defending themselves, should a gale of wind come on after one portion of the troops had been embarked; or should the army have met with such severe loss on its retreat, previously to reaching the point of embarkation, as to preclude the possibility of occupying

* Even in the advanced season, between the end of April and middle of June, 1810, at the large fishing town of Ericeira, such a surf prevailed that the boats could not be launched for a single morning.

In 1811, four jetties, to cover the place of embarkation at St. Julian, were constructed by Captain Holloway, at an expense of £15,000, which, notwithstanding every local and nautical opinion being unfavourable to their stability, resisted the most furious gales of wind throughout the war, and rendered an embarkation practicable in all seasons and weather.

the outer line; and lastly, with a small post on the shore sufficiently strong to protect the rear guard, and ensure its safe embarkation.

The first object was obtained by means of a line of detached redoubts and intermediate defences, appuying its right on the Tagus, near Fort das Maias, and its left on the ocean behind the canal at the little fort or tower of Junquiera. The works of this exterior line commanded the town of Oeyras, and included within their trace, the contour of which measured 3000 yards, the whole promontory, at the extremity of which stands Fort St. Julian. The second was effected by the construction of a large irregular enclosed work, occupying the summit of the height immediately in front of Fort St. Julian. The last object was found in Fort St. Julian itself, which, from its extravagantly high scarps and deep ditches, can never be successfully assaulted against the slightest opposition.

As a secondary point of embarkation, and looking to the probability of a series of operations terminating on the left of the Tagus, a line of works was to be thrown up at Setuval, to cover the right bank of that harbour, and keep open its communication with the sea. These works were to be formed partly of a connected trace and partly of detached redoubts, their right being closely supported by Fort St. Phillippe, and their left resting on a scarped cliff. The front of defence rather exceeded 1500 yards, and, besides occupying the ground most favourable for the erection of batteries to annoy the transports, formed, with Fort St. Phillippe, a strong post, in which a division might maintain itself during the embarkation of the main-body of the army, and ultimately effect its retreat by the sacrifice of a small rear guard in the Fort.

The principal line of defence, denominated subsequently the second line, was formed on the knowledge that only four great paved roads lead to Lisbon, between the sea and the Tagus, below the point where that river, from its increased depth and breadth, becomes, in a military sense, impassable to an army—that three of those roads, at nearly parallel points, pass over or between heights of extraordinary strength, viz. at the passes of Mafra, Montachique, and Bucellas, and that the fourth, bordering on the Tagus where the ground is less bold, passes under a strong range of heights at Alhandra, nearly two leagues in advance of the right of the above-mentioned line of passes; and further, that the country between the paved roads being hilly and broken could not, without the utmost delay and difficulty, be crossed at any part by an army with its

artillery. It was proposed to block up the passes with formidable works, and to support their defence by forming the different ranges of heights between them into one uniformly strong line, so as to ensure a connected barrier across the peninsula, which an invader must force through by a front attack before he could reach Lisbon.

Nature had done much in aid of this design: commencing on the left from the sea at the hamlet of Ribamar, in front of Ericeira, and following up the course of the little river St. Lorenzo to Cacheca, adjoining the pass of Mafra, a distance of seven miles, a deep, rugged, and in many parts impracticable, ravine leaves scarcely a favourable point for a battalion to advance in column. This flank therefore presents no inducement whatever for an invader to select it for his principal line of operations, and it was considered that, in the first instance, the destruction of the peasants' tracks, and establishing artillery in secure enclosed works, 88 to 94, on the projecting points, to flank the most accessible part of the ascent, would be sufficient to enable a small corps of observation to secure this portion of the line till reinforced.

The pass of Mafra was strengthened with peculiar care, and considerable labour; for although the main ascent, viewed as an isolated feature, possesses great strength, there is much ground on its right enclosed with a wall as a royal park (tapada), the features of which are but very moderately bold; and moreover two roads run nearly parallel to the northern and southern boundaries of the tapada, which offer great facilities to an enemy to manœuvre and carry the pass by a flank attack. The main ascent being rendered secure by means of redoubts and emplacements for artillery, so disposed as to enfilade the road and concentrate their fire upon points of it where deep and broad cuts, and other artificial obstructions, were marked out to be formed at the required moment, the principal labour was directed to secure the flanks of the pass. The wall of the tapada, or royal park, had a banquette added to its interior, and efficient flanks were created along its front, either raised for field-pieces or loop-holed for musketry; and a chain of redoubts, 74 to 77, was thrown up on the most commanding points within the enclosure, to sweep the ravines and interdict the passage along the road in its rear. Further, each feature of the ground overlooking the approach to the tapada was occupied by a redoubt, well furnished with a powerful and commanding artillery, 62, 63, 64. The strong heights above Gradil, called the Serra de Chypre, so situated on the road from Torres Vedras as equally to obstruct the march of a column by the main pass of Mafra

and the collateral branches on the left of Morugueira, was also strengthened to the utmost, by redoubts 78 to 81.

A little in rear, and to the left of the village of Morugueira, works were established, 82, 83, and 84, for the defence of the minor pass by Cacheca, and as a communicating link of the chain between Mafra and the left extremity of the line.

Further, to guard against these important points being turned with artillery on their left, and that the security of the strong corps likely to be allotted for the defence of the main pass of Mafra should not be altogether dependent on a successful defence of the extensive line of the ravine between Morugueira and Ribamar, a retired post was established at Carvoiera, on the left of the Chilleros valley, 96 and 97, to command the only coast road from Ericeira to Cintra, St. Julian's, and Lisbon, in its descent of the opposite bank of the valley; and that road where most under fire of the redoubts was to be mined for destruction. No. 95, situated on a strong feature of ground on the right of the valley, co-operated in these objects.

Lastly, the town of Mafra itself was formed into a defensive post towards Ericeira, and was covered on that side by a chain of works, 85, 86, 87, blocking up the only lateral approaches practicable for artillery.

The next object of attention was the pass of Cabeça-de-Montachique. The heights forming the immediate flanks of that pass being naturally as strong and favourable for defence as can be desired, little labour was bestowed on them, and the principal consideration was to block up the road. For this purpose twenty-five pieces of artillery were secured in redoubts (No. 52 to 61 inclusive), situated on strong features, mostly in advance of the principal range of heights to the right and left of the great paved communication from Torres Vedras and from Sobral through Zibriera, which, completely enfilading a considerable length of the approach, were considered to render a direct attack along the road hazardous in the extreme. This disposition of the redoubts was caused by the advanced features of the ground intimately connecting with each other, and being deemed to form a chain of posts collectively stronger than the main features of the pass. It is, however, an example of fortifying to be followed with great caution, it being contrary to all just principles of defence to extend a chain of small posts in advance of a main feature—that is, to court an action in detail, and is utterly inadmissible in the defence of a pass, wherever the approach is such that an enemy can act off the great road.

The defensive features of the country, from the pass of Mafra to that of Cabeça-de-Montachique, are less distinctly marked than along any other portion of the line; but the hills, though not continuous or precipitous, are high, steep and salient, affording the means of covering a parallel road which connects the two passes. These hills were occupied by isolated redoubts, 62 to 73, overlooking the difficult country in their front, commanding every approach to the lateral road, and securing that communication to the defenders—they were consequently both outposts and guards to a chain of rather formidable heights in rear of the road; and which heights, thus covered, were considered to offer a favourable field of action, should an enemy think it worth while to attack a re-entering line, from whence only one indifferent road for artillery exists to facilitate his further movement, and against which artillery could only be brought by previously forcing the works near Gradil (Serra de Chypre), or the advanced defences of the pass of Montachique.

From Montachique to the pass of Bucellas the heights are of a nature to preclude the necessity of works, except for the purpose of blocking up a road for cavalry, and perhaps cars, over the ridge at Freixal, which was effected by retrenchments, 49, 50, 51.

The pass of Bucellas is of the strongest description, the road running between two high and steep mountains, through an opening of only a few hundred yards: the defence of the pass consequently hinged on the troops maintaining possession of the flanks of the mountains, and all an engineer could do was to establish secure emplacements for artillery to enfilade the pass, to mine the bridge at its entrance for destruction, and create other obstructions on the road to detain the advancing columns under their fire. The approach was thus guarded by works, 43 to 47, and in case of disaster 45 was intended to cover the retreat of the defenders.

From the pass of Bucellas towards the Tagus, the Serra de Serves, a high and extremely difficult ridge with scarcely any break, occupies a front exceeding two miles to the road, which crosses it from Villa de Rey. Its right flank then overlooks and gradually falls on the low ground bounding the Tagus. This space of two miles and a half between the right of the mountain and the river presented full scope for art and labour, and advantage was taken of every feature of the ground to give it strength. Works were multiplied along its centre, No. 34 to 39, in front of Via Longa, and also on the bluff extremity of the Serra de Serves, above Portella, 40, 41, and 42, forming its left flank.

Its right flank, resting on the Tagus and closed by a strong redoubt, No. 33, it was proposed further to secure by deep and broad cuts through the salt-pans in its front, made in a direction to be enfiladed by the fire of gun-boats; but notwithstanding all the labour thus bestowed on this portion of the line, it was confessedly much the weakest, and great dependence was placed on the aid it would derive from a peculiar chain of strong heights, forming almost an isolated feature, about five miles in its front, at Alhandra. These heights it was proposed to dispute with an advanced corps, and works, 1 to 4, were established to enfilade the main road, flank the low ground, and equalize the strength of the front; and redoubts, 5, 7, 8, were thrown up as impediments to the position being turned with artillery.

The above-mentioned features of country (occupying 22 miles of front), thus connected and strengthened with 59 redoubts, mounting 232 pieces of artillery, and requiring 17,500 men for their garrisons, formed the principal line of defence across the peninsula, and fulfilled all the conditions sought for in a position to cover Lisbon. The works which, under the first view of the army retiring into Estramadura, had been thrown up on the heights of Torres Vedras and Monte Agraça, 14 to 17, and 20 to 27, served as valuable outposts to this defensive line, from six to nine miles in its front, blocking up the principal approaches, and assuring the troops time to take up their ground and occupy the new defences before they could be attacked in force. These advanced works were completely isolated posts, except that the country on the left of Torres Vedras being open, and offering an inviting facility to an enemy to turn that defile and the works for its defence, the passage of the little river Zizandra was guarded or rather watched by three redoubts established on its left bank at St. Pedro de Cadeira, and in rear of Ponte de Rol, 30, 31, and 32; and with the same view, as respects Monte Agraça, redoubts 9 to 13 were thrown up in the pass of Arruda.

Two strong isolated features of ground which command the main roads at the intermediate points of Ajuda and Enxara dos Cavalleiros were also retrenched, Nos. 18 and 19—28 and 29, as additional impediments to the rapid advance of an enemy on the principal line.

Signal posts for the purpose of instant communication between these various detached works, and generally along the whole front of defence, were established on the points best uniting an extensive view with perfect security.

Lisbon, the prize to be disputed, situated twelve miles in rear of Via Longa,

fifteen miles in rear of the pass of Bucellas, twelve in rear of the pass of Montachique, and twenty-three in rear of the pass of Mafra, is of great size, and advantageously placed for defence and subsistence on the right bank of the Tagus. Its buildings are of such an incombustible nature as to render bombardment almost harmless; and the approaches being generally narrow and sunken, and flanked by stone houses having the doors and windows secured with iron gratings, and other defensive expedients, render the suburbs peculiarly susceptible of an irregular defence. It was not therefore deemed necessary to fortify the enceinte, but the Portuguese were encouraged to erect barriers and traverses at the several entries, to create interior posts, to mount guns on the castle, the Peña convent, and other domineering and strong points; and by their exertions the city was expected to be placed altogether beyond a coup-de-main when occupied by such forces as it was intended at the moment of danger to throw into it.

St. Julian, the point of embarkation in the event of defeat or discomfiture, is situated twenty-four miles in rear of Carvoiera, and twenty-seven miles in rear of the pass of Mafra; the high road to it from the other passes being through Lisbon, though it may be reached from either of them by tolerable cross-country communications without passing through that city.

These extensive works were pressed forward by Lieut.-Colonel Fletcher and his officers with the greatest zeal and ardour, and they were liberally supplied with means. A detachment of infantry was selected to act as overseers, directors, and artificers; two regiments of Portuguese militia were allotted as pioneers, the peasantry of the surrounding districts were put into requisition as labourers, and no petty cavils about official forms of expenditure were allowed to impede the supply of materials and stores. (2)

Napoleon had proclaimed early in the year, with more than his usual arrogance, that he was collecting a force of 110,000 invincibles on the frontiers of Portugal to drive the English out of the Peninsula; and it was naturally concluded that he would act at least with his wonted celerity and enterprise—that he would push forward to the main object, regardless of isolated fortresses, and strike a final blow before means of resistance could be matured.

The several works of the lines were in consequence thrown up in haste, and of a construction requiring the least labour, compatible with a certain degree of strength: the redoubts were generally made of a field profile of a

size to require from 150 to 250 and 300 men for their defence, and were armed, according to the importance of their fire, with three, four, five, or six pieces of artillery.

The main works at Torres Vedras, Monte Agraça above Sobral, and Oeyras, being considered independent forts, or rather species of petty fortresses, were made larger and stronger than the works at other places; particularly those of Torres Vedras, which, blocking up the most direct road to the point of embarkation, and being moreover on the spot of former enterprises, were regarded with peculiar jealousy: they were of a trace to be tolerably flanked, and of a magnitude to require a garrison of 2,200 men with 40 pieces of cannon, independently of the number required to guard the lines of communication with the convent of St. Joa, and the castle in the town, which latter were formed into good posts, Nos. 25 and 27, and mounted with seven pieces of artillery.

The main work on Monte Agraça, which was made roomy and spacious, required a garrison of nearly 1,000 men, and was armed with 25 pieces of ordnance; it was, however, very imperfectly flanked, and the profile was almost the same as that of the small redoubts. In advance of this main work, at various points of the ridge, the dependent redoubts, 15, 16, 17, mounting 19 guns, and requiring above 1,000 men for their defence, (the whole being considered to form only one post, occupying the summit of Monte Agraça,) were thrown up to flank and see the ascent. The enclosed work on the height between Oeyras and St. Julian's was sufficiently flanked, and of a magnitude to require a garrison of 1,340 men, and on it and its dependent redoubts and batteries above 50 pieces of ordnance were mounted.

The above-mentioned three principal works were furnished with 160 rounds of ammunition per gun, thirty of which were grape, and 200 hand grenades: the other redoubts were supplied with 60 rounds per gun, eight of which were grape shot, and from 12 to 16 hand grenades each.

The artillery mounted in the several works were 12, 9, or 6 prs. with two or three $5\frac{1}{2}$ inch field howitzers in the larger forts; they were all Portuguese iron ordnance, on carriages of a most primitive construction, with such low trucks as to be perfectly immoveable over broken ground, and consequently not to be immediately rendered useful to an enemy on carrying a redoubt. The artillery of every work, being mounted with the view to guard some fixed object, fired through embrasures.

It has been stated that the works of St. Julian,[1] Monte Agraça,[2] and Torres Vedras,[3] were the first commenced in the autumn of 1809, as isolated points, with the view of having some defence prepared for the army, should the invaders instantly advance as they threatened. The works for the defence of the passes were next undertaken,[4] and ultimately, in the spring of 1810, the whole were in progress. With the same feeling the works at St. Julian's were originally confined to the heights between the fort and the town of Oeyras: in the spring, and early in the summer of 1810, the advanced line of redoubts 103, 104, 105, 106, 107, 108,[5] was thrown up; and in the autumn, the exterior points were occupied, and the advanced defences completed.[6]

Such was the original plan and construction of the lines, which, when nearly brought to the degree of perfection that the aspect of affairs seemed to admit, were given over to the charge of Captain John T. Jones, by Lieut.-Colonel Fletcher, on the 6th of July, 1810; and the advance of the invaders being momentarily expected, himself hastened to the scene of active operations on the Coa.[7]

It would appear that, soon after Col. Fletcher's arrival at Lord Wellington's head-quarters, the proposed mode of occupying the lines underwent consideration, and some change was contemplated, (probably in consequence of the invaders engaging in the siege of Almeida, which gave expectation of the rains commencing previously to the final struggle, which, as will be hereafter shown,

[1] On the 3d November, by Capt. Wedekind.

[2] On the 4th ditto, by Capt. Williams.

[3] On the 8th ditto, by Capt. Mulcaster.

[4] Viz. Mafra, on the 17th Feb. by Capt. Ross;—Ericeira and Carvoiera, 19th Feb. by Lieut. R. Jones;—Montachique do. Capt. Mulcaster;—Via Longa, 24th Feb. Lieut. Stanway;—Arruda, 17th March, Lieut. Forster;—Ponte de Rol, 26th March, Lieut. Thomson.

[5] Principally by Capt. Squire.

[6] It will be seen from the above dates that, except at Monte Agraça, a point quite out of the beaten track, and almost unknown to the British, the works of Torres Vedras were undertaken three months before any other part of the lines, which accidental circumstance, added to the previous celebrity of the pass, caused their name to be given to the whole system of defence.

[7] "COMMANDING ROYAL ENGINEERS' ORDERS.

Mafra, 6th July, 1810.

"As Lieut.-Colonel Fletcher, Captains Chapman, Squire, and Goldfinch are about to join the army, Capt. Jones will be left in the immediate command and superintendence of all works and

would materially change the relative strength of some portions of the country;) for, on the 17th July, orders were issued to strengthen, as far as possible, the right flank of the advanced ground, on which the posts of Torres Vedras and Monte Agraça had been established, and to throw up additional works for the further security and strength of its left flank; also to add various exterior defences to the position, covering the place of embarkation on the right of the Tagus.

In consequence of these orders, renewed exertions were made on the lines, and as many workmen as could be advantageously employed were collected at each point to be strengthened. The young officers now, for the first time, placed in charge of extensive districts, exerted themselves with a zeal which knew no limits, and every where throughout the lines a spirit of honourable emulation proved highly advantageous to the progress of the work.

On the right, the musketry trench No. 1, across the marsh between the Tagus and the heights of Alhandra, and the trench No. 2, ascending from the marsh to the summit of the heights, were converted into strong lines; and the left of the former was so far thrown back as to admit of the ground in its front being generally and closely flanked by retired batteries, which were excavated in the flank of the mountain. These batteries were of a very powerful nature, and being completely covered from all ground in their front, could not be cannonaded, or even seen by an enemy, till almost on the glacis of the defences across the low ground, and consequently rendered any effort to force that line utterly hopeless.

From the right of the mountain of Alhandra, two miles of front were, as a

duties connected with the Engineer Department in this part of Portugal, and he is therefore to be obeyed accordingly.

(Signed) R. Fletcher,
Lieut.-Colonel Commanding Engineer."

Memorandum of officers left under Capt. Jones's orders.

Captain	Holloway,	
	Williams,	
	Dickenson.	
Lieut.	Stanway,	
	Thomson,	
	Forster,	
	Trench,	
	Piper,	
Lieut.	Tapp,	
	Reid,	
	Hulme.	
Captain	Wedekind,	King's German Legion.
Lieut.	Meinecke,	King's German Legion.
	Lorenzo Homen,	Portuguese Service.
	Sousa,	Portuguese Service.
	Britto,	Portuguese Service.

field position, rendered strong to an excess, for along the face of the mountain, near its summit, a scarp almost perpendicular, from 15 to 18 feet in depth, was cut or blasted; every part of which was closely flanked by a covered musketry fire, and generally flanked by artillery, secured in enclosed works constructed on the salient points of the heights—all these flanking works being seen, and plunged into by larger and stronger redoubts, situated on commanding interior peaks of the mountain, 114 to 120.[8]

At this time, Alhandra being considered an advanced position to the line of Via Longa, in order to prevent its being turned on its left, the heights above Calhandrix, at a spot where they narrow to a rocky ridge, not exceeding six hundred yards in breadth, were, on the representations of the executive officer, ordered to be occupied with a chain of redoubts supporting each other. Fifteen hundred men commenced these works, 121, 122, 123, and 124, on the 6th September, and miners being at the same time employed to scarp the flanks of the ridge, it soon formed a strong detached position across the only range of heights over which artillery could travel to turn Alhandra.

In order to block up the valley between the heights of Alhandra and Calhandrix, and to connect the defence of those positions, a strong abattis, with a covered communication in its rear, was formed across the valley, at a retired point between 121 and 6, where its front could be generally swept by the artillery of the works on the Alhandra heights, and could also be closely flanked by a fire of musketry from some stone buildings, situated on the sides of the valley, which were converted into fortified posts.

Ultimately time being found, an additional post was established in rear of Mata Cruz, 125, which thoroughly connected the defence of Alhandra with that of the Serra de Serves, at its strongest point; and the front of that mountain from the bluff extremity above Portella to the pass of Bucellas, wherever deemed most accessible, was commenced to be scarped near its summit, in imitation of Alhandra.[9]

[8] Could it have been foreseen in July, that time would have been allowed by the invaders for carrying the scarps and other defences of Alhandra to the degree of strength they ultimately attained before the army entered the lines, the flanking guns on the salient points of the scarped ridge would have been placed in open batteries instead of strong redoubts.

[9] These several works were superintended by Lieutenant Forster, having at different periods under his orders Lieutenants Trench, Piper, Tapp and Reid.

On the left flank of the advanced defences, following up the course of the Zizandra (which in summer is an insignificant stream) to Torres Vedras, additional redoubts were thrown up to form a chain along the left bank of the river, and obstructions were created at points under their fire to the flow of the current, so that when the autumnal rains commenced, which happened the day that the advance of the army entered the lines, the river overflowed its banks, and in a short time more than half the valley became so complete a bog that no reward could induce any of the peasantry to attempt to pass over it; and that portion of the front which in summer had been the weakest, became, during the winter, in some degree secure from attack.

These two advanced flanks being thus strengthened, attention was naturally directed to a communication with the centre, and the invaders granting time, an interior line of road, for infantry and cavalry, was traced to connect Alhandra and Monte Agraça. All unnecessary access from the front was blocked up, and several bridges and paths leading to this ground were destroyed, but no additional enclosed works were proposed. Indeed, from the left extremity of Alhandra, along the valley of Arruda to Monte Agraça above Sobral, the hills being naturally bold and precipitous, and the communications from more than two-thirds of the salient features of the ground converging to a point, and passing over a narrow interior ridge, give this space a contracted second defence, which admits of limited numbers guarding its extended circumference; consequently the destruction of a few roads, blocking up the gorges of the ravines, and providing short lateral communications from the right and left to this interior line, were sufficient, in addition to the three or four redoubts previously established on the flanking points of the exterior ridge, to give great strength to this space, and ensure an uninterrupted communication from the Tagus to the great work on Monte Agraça.

On intelligence reaching Lisbon at the end of August, of the premature fall of Almeida, and the consequent retrograde movements of the protecting army, when the prospect of invasion seemed immediate, and the danger imminent, the fears of the public authorities induced ready attention to the urgent requisitions of the engineers for additional labour, and generated a momentary spirit of emulation to aid in the completion of the lines, now become the last bulwarks of the national independence. The conscription for labour was extended to a distance of more than fifty miles around; no

excuse was admitted for withholding personal service—even women and boys took their share in the labour—and at one period, although the middle of harvest, the workmen on the lines were augmented to more than seven thousand. In consequence of such abundant labour, the months of August and September were most profitably occupied, besides erecting the new defences, in strengthening various points and works of the rear line, necessarily left imperfect when time appeared so very limited in the early summer; particularly at the position in front of Fort St. Julian's, covering the place of embarkation, at Mafra and the pass of Morugueira, and along the ravine to the left of that pass;[10] also on the position of Via Longa, and the low grounds bordering the Tagus.[11] At the former place, the eastern side of the valley in front of the quinta of the Marquis de Pombal was occupied by a detached work, No. 109, of strong profile, more than usually flanked, and the advanced heights were so shaped and scarped, as to bring nearly all their reverse under fire of the artillery on the flanks of the defences. In aid of this measure, and to equalize the strength of the eastern front, the advanced defences of the main position beyond the little rivulet called Foz-de-Oeyras were joined by a line, No. 110, to the Tagus, so as to rest on Fort das Mais, by which additions the town of Oeyras was covered, and included within the exterior line of defence. On the left, the redoubts 106, 107, 108, were connected by a covered road or musketry trench to shelter infantry from a cannonade; but which being without a ditch in its front, and its parapet unreveted, admitted of a forward movement of the troops on any front, not exceeding the interval between two redoubts, or nearly 800 yards.[12]

As the army fell back on the lines by the most leisurely movements, time was also found to complete various services, which, interfering with private establishments, or the public convenience, had been deferred to the latest moment, such as levelling obstructions to the fire of the works, felling the trees in their front, and forming substantial abattis with their stems and arms, breaking up roads, destroying bridges, preparing and charging mines, &c.; and on the 7th of October, every preparation for defence was as complete as any longer delay could have rendered it.

[10] By Lieutenant Meinecke, King's German Legion, and Lieutenants Hulme and Reid.

[11] By Lieutenant Stanway.

[12] By Captain Wedekind, King's German Legion.

The disposition of the irregular troops and the arrangements of the commissariat were also perfected during the leisurely retrograde movements of the army. The militia, ordenanza (national guards), and gunners, being assembled on the line of defence, and apportioned to the different works, were made to exercise the guns, and practise various defensive exercises; and depôts of provisions, tents, and stores were formed at points named from head-quarters. (3) The position and working of the signal stations were also perfected; and a party of seamen, supplied by the navy, now passed and received intelligence from one extremity of the line to the other in seven minutes, with undeviating accuracy; and as a further measure to ensure the communication of orders, arm telegraphs, constructed at Lisbon, were placed at each post in readiness to be used in the event of any disaster occurring to the masts or yards.

At this time also, the whole of the country which had been strengthened by works, was divided into six districts of nearly equal extent, and a regulating officer of engineers was appointed to each district for the purpose of explaining the nature and intention of the several fortified posts, to enable the general officers to take up their allotted ground in the most expeditious manner. (4) Mounted guides perfectly acquainted with all the localities were held in readiness at the most advanced points of each district to meet the columns, and assist the regulating officers in pointing out the several villages, bivouacs, &c. and afford such information respecting the various roads and communications as should prevent either confusion or mistake, should the enemy be pressing the columns.

The army, consisting of 22,000 British infantry, and 3,000 cavalry, with about a similar number of Portuguese infantry, entered the territory thus prepared for their reception and support, on the 8th of October, with the expectation of taking up the ground to dispute the principal passes of Mafra, Montachique, Bucellas, &c.; but their movements not being pressed by the invaders, (in consequence of the steady discipline preserved amongst the retiring troops, and the lesson they had given him at Busaco,) an embarrassment was felt about the points retrenched in advance, at Torres Vedras and Monte Agraça. To occupy them properly, would be to isolate and sacrifice a number of good troops without any object; whilst, to abandon, or leave them with inefficient garrisons to fall or capitulate, would be to furnish subject of triumph to the invaders, likely to produce the worst effects on the feelings of the troops

and of the population. Lord Wellington, aware of the great strength which the heights of Alhandra, Calhandrix, &c. on the right flank of these posts had attained, and that the rains then pouring down with their accustomed autumnal violence must swell the Zizandra on their left flank, and soon render it a formidable defensive obstacle, when there would remain from the sea to the Tagus only a space of about seven miles on the south of the valley of Runa, between Torres Vedras and Monte Agraça, without artificial defence, decided to halt at Sobral. The space last described, presenting a most excellent field of battle for an army with an inferior cavalry, from having a strong and intersected front, and both flanks secure, he destined as the central point of his defensive manœuvres, placing the main body of his troops upon it, fixing his personal head-quarters at Pero Negro, immediately in its rear, and communicating with all parts of the line, from the telegraph on the elevated point of Monte Agraça forming its right flank. (5)

The redoubts and other defensive works being garrisoned with militia or ordenanza, the troops composing the active army were thus distributed: General Hill's corps (two divisions) to guard the position of Alhandra; the light division, under General Craufurd, to occupy the front from the left of Alhandra, through Arruda, to the great work on Monte Agraça; the third division, under General Picton, to occupy Torres Vedras, and watch the line of the Zizandra; the fifth division, under General Leith, to take post on the reverse of the heights of Monte Agraça, with General Pack's independent Portuguese brigade, in the great redoubt on the summit of that mountain; and the first, fourth, and sixth divisions, under Generals Spencer, Cole and Campbell, to occupy Zibriera, Ribaldiera, Runa, &c., their left communicating with General Picton at Torres Vedras, and their right being in immediate contact with General Leith.

A corps of Spaniards under the Marquis de la Romana, about 6,000 infantry, which it had been arranged should cross the Tagus from Badajos at the same time that the army entered the lines, were to be placed on the intermediate post of Enxara dos Cavallieros.

The main body of the cavalry, which scarcely amounted to 3,000 men, were to be cantoned about the rear line, principally on the flanks, ready to act on the plains bordering the Tagus, or in the least broken tracts between the two lines, should a column of infantry have the temerity to penetrate into them by paths impracticable to cavalry and artillery.

The defence of Lisbon for some days, in the event of a total or partial discomfiture on the lines, was amply secured, without making any deduction from the effective force of the retiring army, by means of a powerful squadron collected in the Tagus, and a fine body of Marines sent from England, which, in addition to the civic corps, the militia, and the ordenanza of the district, and the ordinary garrison, directed by the British General Peacocke, formed an efficient as well as imposing force.

The army, which, during the retreat from Coimbra, had fallen back on one road, separated into two bodies at Pombal; General Picton's division marching from thence directly on Torres Vedras, and the remainder by the roads of Rio-Major and Alemquer on Sobral, or Thomar and Santarem on Alhandra. On the 8th October the advance under General Hill reached the latter place. The previous night the autumnal rains had begun to fall in torrents, and continuing throughout the two following days, the newly formed communications became heavy and deep with mud; nevertheless, in consequence of the good arrangements previously made, the succeeding divisions marched directly on their allotted points of occupation, and separated at the fixed turnings, into brigades and battalions to their several villages and bivouacs, with as much celerity and order, as if re-entering their cantonments from a review.

On the 10th, the rear division, only distantly followed by the enemy, marched into Arruda, the preceding divisions took up ground on and beyond Monte Agraça, and a distribution of force was made for all the intermediate and rear defences.

During the succeeding night an unusually violent storm of wind and rain, thunder and lightning, prevailed, which almost overwhelmed the troops in open bivouacs, and impeded the communication of orders; still, at daylight, on intelligence of the approach of the French, all were under arms in good order at their respective points of assembly, the garrison of the works complete and on the alert, the field artillery horsed, or in position, and every other arrangement made to repel an attack. It was however late in the afternoon before the enemy began to act: Marshal Massena then with a strong body of cavalry dislodged the English post at Sobral, and ascended the height above the town, from whence he had a full view of the works opposed to him; and judging from their extent and formidable appearance that it was the intention seriously to dispute the ground, he withdrew his

cavalry in the night, and Sobral was next morning re-occupied by strong British piquets.

The several divisions of the allies, as soon as posted on their ground, diligently employed themselves further to strengthen their respective fronts, particularly those forming the main body of the army between Monte Agraça and Runa, along which space no artificial defences had been previously established; the support of the advanced works by troops not having been contemplated in the original project for the lines. Indeed, from this cause even the great paved communication from Sobral to Zibriera, and the road from Sobral to Ribaldiera, had not been blocked up by any work; so that in the position occupied by the allies the two armies might have come into contact without the invaders being under the necessity of forcing any defensive post.[13]

On the 13th, the French infantry having closed up, Marshal Massena directed a great effort against Sobral, which town, not being within the line of defence, was abandoned to him without a struggle. He immediately filled it with troops and closely supported them by other large bodies bivouacked in its immediate vicinity; these bodies communicating with the remainder of his army on the road of Alemquer. Having thus concentrated his whole force in readiness to act on the weakest point of the line, he pushed some strong patrols along the road of Zibriera and Ribaldiera to feel the allies, but these being quickly driven back, the advanced posts of the hostile armies arranged themselves almost in contact along the valley by Duas Portas towards Runa. The French cavalry piquets took post on the road between the town of Sobral and Monte Agraça, with their videttes on the lower knolls of the mountain immediately under the great redoubt; and the remainder of the French army formed their bivouacs in the tract of country from Sobral to the Tagus, so as equally to threaten every part of the line from Zibriera to Alhandra, and their right being actually in contact with the weakest portion of it.

To strengthen the heights on the left of Monte Agraça consequently became an object of primary interest, and large working parties of the troops, fre-

[13] To have placed the invaders under the necessity of storming, or otherwise reducing some work before they could bring forward their artillery, the height immediately in front of the town of Sobral de Monte Agraça should have been occupied.

quently relieved, were unceasingly employed to throw up strong redoubts on the commanding points above Ribaldiera and Runa, 128, 129, and 130. The valley in rear of Gosandiera and Zibriera was blocked up by a well flanked abattis, field batteries of position were established on various flanking points of the same ground, and roads of communication formed to them, so that in a short time this open portion of the front quite changed its face, and appeared little less formidable than the other parts of the line.

Further, to parry this skilful disposition of the invading army, eight battalions from General Hill's corps were on the 14th formed in reserve on the second line, near the pass of Bucellas, in readiness to move at any moment to the support of Alhandra, or of the main body of the army by the roads of Zibriera and Sobral.

A redoubt, armed with 9-pounders, was also commenced on the ascent of Monte Agraça, on a lower level, and to the right of the main work, more effectually to enfilade and block up the great road from Sobral; and subsequently No. 149 was established above Matacaes, more completely to interdict the use of the road through the pass of Runa to the invaders, and the heights above Portella and Patameira were scarped, and strongly occupied by works 150 and 151. At the same time the defences behind the lower Zizandra were greatly augmented.

Every morning, two hours before day-break, the troops stood to their arms at the point of assembly of their several cantonments, as did also the garrisons of the works; Lord Wellington, in person, being in the fort on Monte Agraça, in readiness to direct any general movement, according to the exigencies of the moment. The army thus remained under arms till a communication from every portion of the line, and ocular demonstration, had assured their commander, that no change had taken place in the disposition of the hostile troops, nor any preparation been made for immediate attack; the several divisions and brigades were then ordered to resume their daily labours of strengthening their respective fronts, making lateral communications, improving the roads, sheltering and securing their outposts, &c. The weather was generally wet, and the duty irksome—still all supported it with cheerfulness, in the full confidence of annihilating their opponent, whenever the threatened attack should take place; but after a week had elapsed, expectation would no longer support itself, and the hope of an immediate and brilliant triumph subsided.

Marshal Massena made, in person, a very close reconnoissance of the right of the lines, and on the 16th, having remained an unusual time with a numerous staff examining the entry of the valley of Calhandrix, a shot was fired at the party from No. 120, which striking a wall whereon the Marshal was resting his telescope, he acknowledged the warning by taking off his hat, and moving on.[14] This reconnoissance served to convince the French commander of the inadequacy of his means to attack an army so posted and supported; he therefore turned all his views to subsist his forces till he could be reinforced; and after remaining in his original bivouacs till he had exhausted the country, and his troops were becoming sickly, he retired on the night of the 14th November towards Santarem, and was next day closely followed by Lord Wellington.

Marshal Massena took up a defensive line behind the Rio-Major, entrenching a corps at Santarem, and the allies went into cantonments at Cartaxo (head-quarters), Alcoentre, Azambuja, Alemquer, Villa Franca, &c. one division being left at Torres Vedras, and the whole kept in readiness to fall back whenever the French should be greatly reinforced; under which expectation every exertion was ordered to be made to keep up and improve the works of the lines.

In aid of a protracted defence of the peninsula of Lisbon, Abrantes had been enclosed with works, and the fortifications of Peniche had been repaired and augmented. The good effect of these measures now became apparent, as frequent sorties from Peniche kept the cantonments of the invaders in a state of watchfulness and alarm; whilst Abrantes, blocked to the French, and kept open to the allies, the best communication across the Tagus.

Peniche was in all respects a fortress; but there being no possibility of transporting heavy artillery across the Serra de Estrella, for the attack of Abrantes, its defences were limited to a resistance against a coup-de-main, or an attack with twelve-pounders.[15]

[14] There was no wish to injure Marshal Massena, but merely to make him retire, or a dozen guns might as readily have been discharged at him as one. Napoleon, who always spoke and reasoned well on military subjects, has left recorded, in Count Las Casas' Journal, an excellent observation on the folly of firing a single piece of ordnance at an individual where injury is meditated.

[15] The armament of the place was limited to the calibre of a 12-pounder, to prevent the invaders forming a battering train in the event of their capturing it.

The garrison of Abrantes was composed altogether of troops in the service of Portugal, commanded by a Portuguese governor. The only British in the place were the engineers, the senior of whom, Captain Patton, (the officer who had constructed the defences,) being a man of peculiar gallantry and firmness, was, by order of Lord Wellington, made one of a council of defence, and any proposition for surrender was forbidden to be tendered or received without his name being signed in approval of the measure.

Marshal Massena early saw the importance of Abrantes, to secure a communication with and enable him to draw supplies from the Alemtejo; and, previously to retiring from before the lines, caused the works to be closely reconnoitred, when they were deemed too strong to be attempted by a coup-de-main.

To prevent the invaders communicating with the Alemtejo by any other point, the right corps of the allies, under Marshal Beresford, had, on the change of position of the hostile armies, been passed over the Tagus in boats, and cantoned at Barcos, Chamusca, &c.: floating bridges were now established on all the small rivers in its rear to the ferry opposite Alhandra, to ensure its re-occupation of that point, should it become necessary.

In the beginning of December, some movements of the French troops in the south of Spain leading to the belief of a diversion being intended in the Alemtejo, in aid of renewed operation against the lines, the promontory of Almada, on the left of the Tagus, opposite to Lisbon, which commands the navigation of the river, and from whence shells will range over a great portion of the city,[16] was retrenched under the superintendence of Captain Goldfinch.

The left of the position rested on the broad basin of the Tagus, on the heights immediately above Mutella; its centre was on Monte de Caparica, Lugar de Monte, and its right on the rocky cliff called the Altos da Raposeira, rising above the sea, the whole extent of its front being about 8,000 yards. A chain of redoubts, 17 in number, flanking each other, and having flèches in their front, more completely to see into the ravines, was established on the most prominent knolls of this line, their defence being united with, and supported by, several country-houses in their rear, which, being built of stone, with stone enclosures, might at any moment be rendered formidable posts. A sunken road, which extended nearly throughout the position, in rear of

[16] The Tagus, opposite the castle of Almada, is only 2,200 yards in width.

the redoubts, formed a secure communication between them, and was ingeniously made by the executive officer to add to their defence, by cutting a banquette, and dressing off the slope in its front so as to form it into a regular covered way, with places of arms at points which gave the best flanks, and could best be supported from the stone buildings.[17]

The dilapidated castle of Almada was repaired and armed for defence, so as to form a species of interior citadel, which should preserve the communication with Lisbon till the latest moment; and as a means of ready communication between the fleet and the several parts of the position, roads were carried up various parts of the cliff, forming its gorge.

It being proposed to entrust the defence of this position to the seamen and marines of the fleet, with the militia and civic corps of Lisbon, the redoubts were made of unusual magnitude, many being capable of containing 4, 5, or 600 men, and from 6 to 10 pieces of artillery; the calculated garrisons for the whole when completed being 7,500 men and 86 pieces of ordnance. Any attack of Almada at this time could only have been a secondary operation; for, even if successful, the Tagus would still have interposed an impassable obstacle between the victors and Lisbon, and their retention of the promontory must have been altogether contingent on success in front. Therefore any mode of occupation of Almada, which should have prejudiced the defence of the lines, could scarcely have been justified; but it was an object of the greatest value thus, by means of strong works and a force which could not otherwise have been rendered serviceable, to have done away the possibility of a small corps annoying the fleet, creating alarm and confusion in the capital, and perhaps spreading a panic throughout the country in rear of the army, at the moment of the lines being attacked.

During the winter the posts of the two armies remained as first arranged on either side of the Rio-Major, the advance of the French being retrenched at Santarem, and that of the allies occupying the village of Val; the hostile sentinels being only separated by the bridge at the south-western extremity of the long causeway across the marsh between the two places. Each stood unremittingly on the alert, the allies trusting to a mine, which they kept ready

[17] After a certain portion of this road had been formed, the completion of the remainder was suspended, in consequence of the inconvenience it occasioned to the occupiers of private dwellings, and the knowledge that the road could, by due attention, be finished whenever required, in less time than an invader could collect a force, and march through the Alemtejo.

for explosion under the principal arch of the bridge, to prevent a sudden rush; and the French to the artillery of a redoubt, which they had constructed on a height enfilading the whole length of the communication. On the left flank the armies were not in such immediate contact, the allies being entrenched at Alcoentre with a piquet of observation in the town of Rio-Major, and the principal force of the French being at Alcanhede; nevertheless the same vigilance was maintained as on the right. On the left of the Tagus, besides lining the bank of the river with piquets of observation, batteries were thrown up to command the mouth of the Zezere, where the French had collected many boats, and the ruined castle of Tiancos was converted into a military post.

During this time unremitting care and attention was also paid to strengthen the several defences of the lines, add to the scarps, and perfect the lateral communications; for which latter object a paved road communicating with the rear by Pero Negro, was ordered to be formed along the rear of the heights last retrenched on the left of Monte Agraça, and a communication for carriages was made from the left of Alhandra across the valley of Calhandrix by St. Romeo, and in rear of the pass of Matos, to Monte Agraça; and subsequently, similarly ready and short communications were perfected throughout the whole tract of fortified country. As the spring advanced additional works, mounted with 56 pieces of ordnance, were completed behind the Zizandra, No. 131 to 144, and the left bank of that river was scarped to compensate the fall of the waters and preserve the equilibrium of defence.

The bridges on the great road from the rear of the cantonments of the army to the front of the lines were mined for destruction, those on the lateral communications destroyed, and all obstructions to the fire of gun-boats on the road or ground bordering the Tagus were levelled.

It is almost unnecessary to add, that no renewed effort against the lines was made, to put the value of these labours to the test. The invaders, after remaining in their cantonments till the commencement of March, retired out of the country, closely pursued and harassed by the allies; offering the first and only instance of a military enterprise planned and matured by Napoleon, whilst in the plenitude of his power, being defeated by the steady perseverance and superior foresight of an opponent. It is not, perhaps, too much to add, that this failure before Lisbon gave a fatal blow to the general belief of French invincibility, and taught oppressed Europe to resist and become free.

GENERAL OBSERVATIONS ON THE LINES COVERING LISBON.

From the foregoing description it will be seen that the lines covering Lisbon consisted of two distinct ranges of hills, or rather tracts of country, extending from the sea to the Tagus, modelled into strong fields of defensive action and defensive manœuvres; each line in some degree aiding the other, but their occupation and defence being perfectly distinct and independent.

On a comparison of the two lines, it must be admitted that, looking to operations during summer, the rear line appears to have been judiciously selected for the arena of defence, as it contains the greatest portion and most equal distribution of strength of front. Thus the greater part of the ravine from Ribamar to Mafra is very strong, whereas no portion of the banks of the Zizandra below Torres Vedras is otherwise than tame. In like manner the passes of Montachique and Bucellas are of the strongest nature of mountain pass, whilst the corresponding inlets of Zibriera and Monte Agraça derived their strength chiefly from works. The rear defences have also the advantage over the advanced line of covering four or five miles less ground; the former, following the principal features of defence, measuring 24 miles, and the latter 29 miles: the distance in a direct line between their flanks being 22 and 25 miles respectively. Further, under the belief that the invaders would approach in sufficient force to act in two bodies, and the impression then general throughout Europe, that the French could not fail of success, it was an advantage of the rear line not to be despised, that its strongest flank was nearest the point of retreat and embarkation, and consequently that least likely to be forced.

In any extremity arising from an overwhelming pursuit, and a harassed retrograde march, the rear defences would therefore in all probability have formed the field of proffered combat; but, under the favourable circumstances of the young Portuguese troops having proved themselves trust-worthy, a triumphant retreat, and an advanced season, with an enemy acting only on one point, to have left the advanced works to their garrisons, and to have abandoned to the invaders 150 additional square miles of country contained in the space between the two lines, would have been a sacrifice of character, feeling, and confidence, far beyond what any increase of physical strength could

have compensated; and here, as ought to be in every case depending on judgment, previous arrangement was modified, and made to give way to circumstances.

From the distribution of the troops in the lines it appears that Lord Wellington, under the expectation of fighting a battle which should decide the fate of a kingdom, spread an army not amounting to 50,000 men along a front of 29 miles. This extended arrangement is so contrary to the spirit of modern warfare,[18] that to prevent any erroneous conclusions being drawn from it, it is deemed necessary to mention that the allotment of the force for the several portions of the line was calculated on a peculiarity of the features of the country, as well as on the extraordinary degree of strength which had been given to the flanks, rendering them rather fortresses of support than points to guard. The peculiarity alluded to is the projection of Monte Junto, which stretches out fifteen miles in front of the centre of the lines, and is of so rugged and precipitous a formation, as to preclude the march of an army with artillery over its summit; nor can the ridge of Barregudo, which nearly connects Monte Junto with the position, be crossed with artillery without a publicity and delay which would have deprived the movement of every advantage; and the ridge can only be avoided by passing along the road of Runa, which was included within the line of defence. These Serras consequently divide the attack and defence of the front line into two portions, giving the assailants a very long and tedious march to move a corps from opposite Alhandra to the line of the Zizandra below Torres Vedras; whereas, from the position of the main body of the army between Torres Vedras and Monte Agraça, a very short march would enable the defenders to succour either the right or left, and compensate inferiority of numbers by superiority of movement.

It may also be observed, in further justification of this unusual extension, that the celerity and accuracy with which, by means of the signal stations, orders could be sent and intelligence received from the most distant points of the lines, obliterated distance with respect to communication, and ensured a well timed combination of movement amongst the whole body of the defenders,

[18] It is remarkable, that the most striking example of concentration also during the late wars should have been afforded by this same commander, who, at Waterloo, placed and manœuvred 60,000 men on a front little exceeding a mile and a half.

enabling them to derive every advantage from partial success, and protecting them from overwhelming disaster in the event of partial discomfiture.

As a general character of the lines, formed from unprejudiced consideration of their merits and defects, it may be stated that they derived their strength and value primarily from their peninsular situation on the sea, which precluded the possibility of an enemy manœuvring on, or turning their flanks, and assured their rear being constantly open for the defenders to receive supplies and reinforcements; secondly, from the unusual degree of natural strength of the ranges of hills and ravines forming their front; and lastly, from the judgment with which the engineer connected the several strong features of the country into an equally defensive line. Art and labour were judiciously exerted to improve natural advantages, to strengthen and cover the weak points, to diminish the length of accessible front, to block up the approaches, to facilitate the movements of troops within, and to cramp and confine the movements of those without; in short, to give such powers of defence and communication to every portion of the front, that the army might remain concentrated in a body, keeping only detached corps of observation on its right and left, which, from the natural and artificial strength of their positions, might repel a weak, or sustain a serious attack, till succoured; and that at no point should a corps engage, but under the favourable circumstances of a strong front, secure flanks, facility of movement, and an open, but inattackable rear.

The redoubts, generally speaking, were merely securities for artillery in those situations where a fire of that nature was demanded by some specific object, such as to interdict the free use of a road, delay the repair of a bridge, or sweep along the entry of a pass; and in no instance were the guns considered as defensive weapons of the works in which they were placed, except at the position on the height of Calhandrix, where three redoubts in line were made to cross their fire with each other, and mutually support a fourth redoubt in advance. All the other redoubts were perfectly independent of each other, and were made of a strength of profile to resist an assault, and placed on points where artillery could with great difficulty be brought to cannonade them. Their number was justified by the peculiarity of the contest, which placed, on the same position with a good army, half the same amount of militia, ill-organized peasantry and gunners, who, though totally unfit to act in the field, still being possessed of innate courage, were equal to defend a

redoubt and work its artillery. Throughout the whole front there was not a continuity of artificial line necessitating a single efficient brigade to be kept out of column, and the works may be regarded as so much additional strength given to the army, without subtracting a man from its effective force. Indeed the artificial defences of the lines altogether present a most favourable example of the just application of the engineer's art in furtherance of, but invariably subservient to tactics, creating pivots and supports, but never a tie or restraint on field-movements.

In appreciating the defensive power of the various portions of the lines against the efforts of an invader only moderately superior to the defenders, this consideration of the defensive army being a compact and manœuvring body totally independent of the works should have great weight; as, in consequence, it would not have sufficed for the ultimate triumph of the assailants that a column should manœuvre successfully so as to fall on some weakly guarded point, before the defenders could be reinforced. By such a movement the assaulting force would only have lent a flank, and offered a most advantageous opportunity for the attack of an army, ready to engage with it; or even should the assailants by a rapid and powerful effort have broken through any point of the line, it would have served merely to place them between an efficient army, and a city which, though not fortified, was assuredly far beyond a coup-de-main.[19]

Therefore, notwithstanding their many natural and professional merits, it must be acknowledged that the troops were to the lines as life and health to the body, giving them strength and efficiency in exact proportion to their own; and that a successful defence of the lines hinged altogether on the unremitting vigilance, able disposition, and rapid movement of the defenders. One single error of judgment, or one single miscalculation of time or distance, might have rendered the whole line of works useless; for field-redoubts left to their own garrisons, even when thickly studded, can only be expected to

[19] In order that an army covering a capital should preserve due latitude of manœuvring, it is indispensable that the city should be rendered capable of several days' resistance when left to its own powers. A variety of instances might be adduced in proof of this statement; but two very recent and well-known examples will suffice:—In 1813 Napoleon, by his foresight and activity in throwing up works on the banks of the Elbe, preserved Dresden during one of his manœuvres, and in 1814 lost Paris during a similar manœuvre from having too tardily and insufficiently fortified it.

impede, turn, or disorganize a column of march with its artillery, but never to oppose an impenetrable barrier to the advance of a powerful and determined army.

OBSERVATIONS ON LINES AND RETRENCHED POSITIONS GENERALLY.

Ceux qui proscrivent les lignes, et tous les secours que l'art de l'ingenieur peut donner, se privent gratuitement d'une force et d'un moyen auxiliaires jamais nuisibles, presque toujours utiles, et souvent indispensables.

Until recent experience, it was fast becoming an axiom, that an army receiving battle in position must be beaten, and that no skill in occupying and strengthening, nor firmness in disputing and maintaining ground, could balance the advantage of free and concentrated movement, and the moral confidence arising from being the assailant. The recorded sentiments and feelings of many celebrated commanders and tacticians are in unison with this opinion; and with the solitary exception of the battle of Fontenoy, the page of history uniformly supports it, from the actions of Blenheim and Ramilies, through the operations of Frederick and Napoleon, to the campaigns in Egypt and the Peninsula. There the reverse was for the first time exemplified in a succession of brilliant triumphs on the defensive fields of Alexandria, Corunna, Talavera, Albuera, Fuentes de Honor, the Pyrenees; and in front of Lisbon, the exploded opinion, after the interval of a century, was revived and happily exemplified, of lines being able to check and paralyse the efforts of a powerful invader.

Whether these successes should be ascribed to the ability with which the several positions were occupied or retrenched, to the superiority of the troops, or to the *impassible* nature of Englishmen, as our opponents state; or whether there be advantages to be derived from defensive combat not understood by other armies, it is not deemed necessary to inquire. But as from the inadequate force with which we usually carry on continental operations, defensive warfare sustained in defensive positions must continue to be resorted to, some general observations on the subject of retrenching ground and positions have been thrown together, with the view of leading the young officer to form a correct judgment as to the value and proper application

of field-defences: that he may neither despise them as altogether useless to an army, nor trust to them as never-failing sources of strength.

On the first of these points it must be recollected that, although during the early part of the last war field-works fell into discredit, and almost into disuse, such aids were previously very highly estimated by those best able to judge of their utility. Frederick II., Marshal Saxe, Count Daun, and all the best generals of the last century, frequently and successfully availed themselves of redoubts and retrenchments to strengthen their positions or support their movements; and it is a well-established historical fact, that a few earthen redoubts at Pultawa marred the fortune of Charles XII. and fixed the wavering destinies of the great Muscovite empire.

It is, however, unnecessary to revert to past history to show the value of field-works, as in the battle of Borodino, a few simple redans hastily thrown up to cover the left flank of the Russian position paralysed for hours two French corps d'armée, and had nearly proved equally fatal to the fortunes of Napoleon as the redoubts at Pultawa to those of his prototype Charles. Indeed the attack of Dresden, which failed in consequence of the assailants being opposed by a slight field-retrenchment, and many other events of the recent campaigns, leave no doubt that field-works judiciously disposed may still be rendered valuable auxiliaries, even to the most numerous and most active armies.

To effect this, and apportion works justly to cover a country, or strengthen a proposed field of battle, is the most difficult application of the engineer's art, being subject to no fixed rule, but merely founded on general principles, requiring to be modified on each occasion from an innumerable variety of circumstances, both physical and moral.

A just idea of these principles can only be acquired through a knowledge of tactics, and of the powers of troops under different orders of formation and movement; which, well understood, can scarcely fail to produce a feeling that works ought in every situation to be accessaries and aids to the manœuvres of troops, and never principals of any defensive field-system.

Posting troops to fight a general action, or strengthening the front of an army when so posted, are details founded on the foregoing principles, which for the same reasons scarcely admit of theoretic elucidation, and the knowledge of them can only be fully attained by long service with an active corps.

Considerable insight into such details may, however, be gained by studying

the principles on which various fields of defensive combat have been occupied by skilful commanders.

In these it will be seen that a rocky height, a knoll, a wood, a village, and even a single house, have frequently formed the prominent flank or defensive posts; and instances might be adduced where each of the above obstacles have mainly contributed to the repulse of the assailants; and on the contrary, where such posts, injudiciously occupied or ill-supported, have led to discomfiture or the loss of entire divisions of the defensive force.

These extremes are found in the battles of Blenheim in 1704, and of Ligny, in 1815.

In the former action, the village of Blenheim, on the left flank of the defensive army, being well retrenched and occupied with twenty-four battalions and twelve squadrons, proved an insurmountable obstacle to the Duke of Marlborough's efforts in the early part of the action; but that commander skilfully transferring his attack to a point near the centre of the defensive line, which was beyond molestation from the troops in Blenheim, they, from principals in the action, became merely spectators of the defeat of their friends when they had no alternative but to surrender prisoners. At the battle of Ligny, on the contrary, the town and villages in front of the Prussian line on the heights of Sombref were so strongly occupied with men, and so closely supported each other, that Napoleon did not dare to leave them in his rear or on his flanks, but wasted his time and exhausted his strength during many hours in an attack of advanced posts, till too late to force the Prussian line, which retired without loss as soon as it became dark.

But to leave these higher points, as also the best formation of troops, the situations of the artillery, and the dispositions of the reserve, which are usually settled in all their details by the general in chief, and confining ourselves to the consideration of the best means of strengthening troops already posted, we may adduce the battle of Waterloo as a happy exemplification of natural defences being turned to profit.

In that action the line being formed along the crest of a range of easy heights, the country house of Goumont was very strongly, and the farm buildings of La Haye Sainte moderately, occupied as posts in advance of the line; the former being in front of the right flank, at the distance of four hundred yards, and the latter nearly in front of the centre, at the distance

of three hundred yards, the interval between them being thirteen hundred yards.

Napoleon did not think it prudent to pass through this space, or leave two such posts in rear of his attacking columns, and as a preliminary measure to advancing against the line, made a great effort to possess himself of Goumont.

The column for the attack was of a magnitude, and advanced with an intrepidity, which seemed to command success, as did a second and third, supported by a powerful fire of artillery; but the battalions of Guards which occupied the building, being experienced as well as brave troops, had most judiciously loop-holed the garden walls to the front, and otherwise so opened their fire, that they maintained the post, and covered the right flank of the position throughout the day.

The Germans in La Haye Sainte behaved with similar firmness, and long disputed the passage of the chaussée; but their communications being cut off,[20] and their numbers too few to be formidable to the rear or flank of an advancing column, Napoleon concentrated on their left a most powerful body of troops, which advanced to attack the line with apparently matchless force; but a slight bank and hedge enabled a very inferior force to check their progress till troops came up from the second line and utterly routed them.

It is evident that on the field of Waterloo, or on any other field of defensive combat, with time, artificial defences might have been prepared on or near the sites of the buildings or hedges occupied by the troops in advance of the main line,[21] which would have afforded an equal or better defence; and thus we discover at once the position in which works would positively have aided an army.

[20] Their communications and the post itself were ultimately lost from neglect of the simple precaution of blocking up the entrance gate at the side, and forming an opening through the rear enclosure wall; which would have admitted of the ammunition of the defenders being renewed, and their casualties replaced.

[21] In order to prevent any misconception from the above observations, it is necessary to state that no artificial cover or retrenchments of any nature aided the firmness of the troops, and that the battle of Waterloo was fought on ground untouched by the spade.

The present appearance of the field, however, seems to contradict this fact, and will, after a few years, afford plausible arguments for historic doubts on the subject. The excavations recently made along the front of the position, to obtain soil to raise the artificial mountain on which the Belgic Lion now peers over the field, have the precise trace and appearance of a well-flanked

Other battles are equally illustrative of the use of strengthening the most prominent or marked features of defensive ground, either with the view of covering a weak front by an advanced or flanking fire, or preventing an assailant from establishing his artillery on points favourable for cannonading the defensive line previously to using his bayonet; and even where such marked features of the ground do not exist, their place may readily be supplied artificially by the erection of flanked works, or a system of redoubts flanking each other, in such situations and force as experience will soon teach an officer to be necessary.

There is, however, a very serious obstacle to the employment of the art of retrenching positions, which is, that after an army has taken up its ground, and a battle becomes inevitable, there is seldom time to throw up works of sufficient strength to be depended upon; and it is scarcely possible, in any moderately open country, to select a position to be fortified in advance for the protection of a frontier or a capital, which an enemy will not find roads to turn and render useless. Thus, in allusion to the battle of Waterloo, had the ground been strongly retrenched during the spring, Napoleon would naturally have avoided it by marching on Brussels by the road of Hal, and therefore such preparatory labours seem only advisable in peninsular situations, or to block up the entry, or dispute the sortie of a mountain-pass, occupy the interval between two fortresses, or for some other specific and very limited object.[22]

Even in such favourable situations, attention should be directed rather to the improvement of natural obstacles, than to the erection of artificial lines of defence; and where works cannot be dispensed with, they should, as far as

retrenchment; and further, the artificial mountain itself forms a strong and commanding feature, which, if viewed as part of the position, takes away nearly all the merit of its defence.

Indeed it is truly to be regretted that the good citizens of Brussels should, in the gratification of civic vanity, have had the bad taste to destroy a lasting and indisputable memorial of the valour and firmness of their countrymen and their allies, merely to substitute a perishable trophy of their own loyalty, which will in all probability be thrown down on the first ephemeral success of a French army.

[22] The Duke of Wellington, in his defensive campaigns, felt this so strongly, that on some occasions (near Campo-Mayor, in 1811, for instance) where he strengthened open ground with the intention of giving battle, he caused the parties to labour during the obscurity of night only, and the excavation to be covered at break of day with boughs, so as not to be recognised as works by the enemy from the neighbouring heights.

practicable, be enclosed, independent, and capable of defending themselves. Nothing can be more vicious than to cover an extensive tract of country with a regular system of bastions and redans, as recommended in most treatises on field-fortification. Such long systematic lines of defensive works, besides the great expense, labour, and publicity attending their formation, have the serious defect of being of no strength, unless equally guarded throughout; and further, when attacked, the defenders have, in consequence of their flanked trace, to man an alignment of nearly double the length of the front to be defended, and are utterly incapacitated from making any instantaneous or powerful forward movement; they therefore necessitate the worst possible disposition of troops for offence or defence, and must be regarded as inadmissible under the present system of tactics. Indeed, such long defensive lines, even when most in repute at the end of the seventeenth and commencement of the eighteenth century, were invariably forced as often as attacked, and it is difficult to conceive on what foundation their popularity so long sustained itself.

Field-defences, however, are not to be indiscriminately condemned or rejected, because they are continuous or systematic. In order to strengthen the front of an army with judgment, it is necessary to consider every feature and every portion of the ground separately, and arrange such mode of occupation as shall best combine its particular defence with the general defence of the position. Thus, in parts unfavourable for manœuvring it may be advisable to form a continued line of considerable extent covered with every nature of obstacle, and having none but the most confined outlets, on the principle that a range of difficult heights would be scarped, or low ground inundated, to lessen the number of men on those points, and leave a superabundance of force for other points favourable for offensive movements. Again, since the employment of artillery in masses has been introduced, and that an irresistible fire, sometimes of hours' duration, now invariably precedes the advance of the columns of attack, it will frequently prove a good measure, in situations where natural cover cannot be formed from a cannonade, to create it artificially between all the prominent defensive posts.[23] Thus each furlong

[23] This might be effected by means of a sunken trench, like a parallel at a siege, made to connect a whole chain of redoubts. Such an expedient would cover infantry from the fire of guns, without impeding their forward movement in line, and openings might be left for the advance of the cavalry and artillery, or they might act in masses on the flanks.

of ground being duly considered, and the nature of defence best adapted to the locality being formed, the whole front of an army may occasionally be covered with lines of works, which, while they augment its defensive powers, leave its movements perfectly free.

Continuous lines, of the short extent of a mile or two, may frequently be resorted to with advantage, in situations where the flanks can be naturally or artificially secured, as on a river or a fortress.

Such lines, in communication with a fortified town, when composed of fronts of fortification or other flanked trace, and made of a profile not to be assaulted, are well suited to facilitate the defensive manœuvres of an inferior army, and also to augment the defensive powers of the fortress itself, by occupying important tracts of ground which could not be included within the permanent works. In such cases they are usually denominated retrenched camps, as at Setuval, Bayonne, Antwerp, &c. under which character they form a medium of defence between field-works and permanent fortifications, which can be resorted to on any pressing emergency arising from defeat, and may be generally recommended by an officer without hesitation; for if it be not convenient to man them fully, their evacuation after a show of resistance neither compromises the retreat of the defenders, nor detracts from the original strength of the fortress.

Experience affords many proofs of positions of two or three miles length of front, which could not be turned, when retrenched on a field-profile, being capable of an excellent defence; and our own annals furnish a remarkable instance, in the attack by the Duke of Marlborough, of a small corps hastily and imperfectly retrenched at Donawert, in June, 1704, when an incomplete victory cost the Duke 8 general officers, 1,500 men killed, and 4,000 wounded,[24] being a greater loss than he experienced in the July following, in forcing Marshal Villeroy's extensive lines of Tirlemont, defended by 70,000 men: and on this point it should be recollected, that the most sanguinary and least complete victory of the same celebrated commander was over an army in a retrenched position of short front at Malplaquet.

It is apparent, however, that isolated and unsupported field-positions of this nature, retrenched on a field-profile, besides being liable to be turned, and the defenders shut up as in a trap and made prisoners, partake of all the

[24] See Life of Marlborough, by Archdeacon Coxe, vol. i. p. 259.

defects of longer continued lines in proportion to their extent, and are in the same proportion objectionable. They are, consequently, inadmissible whilst hostilities are carried on with the numerous and powerful armies of the present day, and would scarcely have demanded an observation, had not the most prominent example of a retrenched field-position ever formed in England been of such nature.

None of the objections to continuous lines, however, apply to retrenchments formed of enclosed and isolated works, each capable of a good resistance, as the intervals between them do not require a line of supporting troops, and after furnishing garrisons for the works, the army may remain in masses sheltered from cannonade by some irregularity of the ground near the summit of the heights; or if such be not found, on their reverse immediately below the crest, ready to move in compact and formidable bodies on any menaced point, or form into line or manœuvre on the posts taken up, so as best to parry the efforts of the assailants; a good specimen of which nature of position may be studied in the defences of Almada.

It seems to be an indispensable condition of such field-works in aid of an army, whether prepared at leisure or during active operations, that they be of a profile and capability of defence to resist an assault, that they be securely closed in the rear, placed sufficiently near to and so disposed as to flank each other, and armed with sufficient artillery to prevent heavy columns passing between them without being thrown into disorder from severe loss; or else made of a size to contain a force likely to prove formidable to the rear of a column which should venture to pass them. In this case, indeed in all cases, the outlets from, and intervals between works, should give every freedom for the movement of troops, compatible with security from assault or being passed.

On this point it may be as well to observe, that detached enclosed works, in front of an inferior army acting on the defensive, ought to be regarded as vital points performing certain functions of themselves, and their garrisons be considered as integral parts of the works destined to share their fate—to triumph or fall with their post, and not as portions of the army to be protected and withdrawn. Under this view, the defensive corps being left unshackled in their movements, and their part being confined to the discomfiture of the enemy, they will be prepared to seize the favourable moment, and advance to the attack when the redoubts shall be most warmly engaged, or

their fire have thrown the assailants into confusion; so that to derive full benefit from works, as much judgment is required in posting and manœuvring the force to be strengthened, as in placing the works themselves.

This leads to a consideration of the just proportion between the garrisons of detached works and the army they cover, and also of the length of front along which works may be allowed to extend for given numbers of men. On the first point it may be observed, that the better the troops composing the defensive army, the fewer should be the works, for it can seldom be advisable to confine any considerable body of a manœuvring and steady force in an enclosed work, unless it be the key or main support of a position;[25] but when an army is composed in great part of ill-disciplined and unsteady troops, artificial defences can scarcely be too numerous.

The extent of front which works may cover need in strictness only be limited by the power the army possesses of succouring, in sufficient time, any and every work that may be pressed, so that a ready or difficult communication will frequently decide the eligibility of occupying a distant point; but as strength is invariably gained by concentration, no ground should be occupied that is not intimately connected with the main object of defence, even if invitingly convenient. On this head no better rule can be followed than to inquire, previously to occupying any point, whether it be essential to the support or safety of the main body of the army; and on each occasion, an officer must exercise his judgment, to modify and turn local circumstances to advantage on the unchangeable basis of science. It cannot however be too strongly borne in mind by those planning defensive expedients, that troops are the principals, works the accessaries of defence,—that the latter must invariably be dependent on and limited by the former, and consequently that every point superfluously retrenched is an unnecessary source of distraction and division of force. Field-works can never without hazard be left to their own garrisons; and, reverting to the lines of Torres Vedras, which would seem to warrant the creation of an unlimited number of defences, it may be confidently predicted that any commander not possessing the utmost promptitude, decision, and skill in manœuvring troops, who, trusting to that example, shall attempt to defend against a superior, or even equal force, a tract of four-and-twenty miles of

[25] Such, for instance, as the occupation of Goumont by the Guards at Waterloo.

country as a fortified position, will infallibly be beaten; and that an engineer who should, on any ordinary occasion, copy the extended system of isolated redoubts and retrenchments practised in front of Lisbon, would, instead of adding to the strength, altogether cripple an army.

But whenever, by the foresight and skill of the general, and the exertion of the engineer, the arrangements of the troops and works shall be in happy unison, and a defensive army well posted shall have its front covered with works constructed on just principles, its force will be incalculably augmented, and its defeat rendered almost impracticable. Even a few works, thus judiciously disposed on the principal features of the ground, or to sweep the approaches, could not fail to add materially to the powers of movement and resistance of a defensive force;[26] as will frequently the most trifling efforts of labour, such as loop-holing buildings, barricading streets, blocking up or opening communications, destroying bridges or roads, or the fords of a river, felling abattis, forming emplacements for field-guns, or the slightest cover from cannonade; and an active and zealous engineer will generally find opportunity on the eve of a battle to strengthen, by some of these various labours, the fronts and flanks of a defensive force.

In making this statement it is not forgotten, that since the improved organization of armies has given them an increased facility of movement, and a consequent celerity and boldness of enterprise, placing legs almost on an equality with arms in war, time is rarely allowed to a defensive force for perfecting defensive expedients; but this consideration, so far from being deemed to excuse the attempt, should only stimulate an engineer to increased exertion. The country naturally expects some return for the liberal arrangements recently made to improve the engineers' service, and increase the engineers' means, and every officer is interested to show that the sappers and their field-equipment, which now form an integral part of each division of an army, are available auxiliaries to its force. The most simple exercise of his art will occasionally prove their paramount utility; and as it not unfrequently occurs, even after hostile armies come into view, that days pass in reconnoitering or

[26] Napoleon was so highly impressed with the value of these preliminary labours, even where armies are nearly balanced in strength, that on the morning of the battle of Austerlitz he went at the break of day to the retrenchment of Santon, and remained there for a considerable time on foot, encouraging and urging on the exertions of the working party.

preparation for attack, who can say on such occasions, to what extent activity and intelligence may not gain artificial strength for a field of defensive action, and consequent character and reputation for an officer?

MEMORANDA RELATING TO VARIOUS DETAILS OF FIELD-WORKS AS THROWN UP ON THESE LINES.

(Plates 1, 2, 3, 4, and 5.)

Les principes des fortifications de campagne ont besoin d'être perfectionnés : cette partie de l'art de la guerre est susceptible de faire de grands progrés.

Les fortifications de campagne sont toujours utiles—jamais nuisibles, lorsqu'elles sont bien entendues.—*Conversations de Napoleon, par Montholon.*

Workmen.—The manual labour of the lines was performed by the peasantry of the country and two regiments of militia. The former were obtained by conscription and were relieved weekly; the latter worked as a permanent duty. The peasantry were paid six vintems per day as labourers, and twelve vintems per day as mechanics, and the militia at one-third those rates.[27] Subsequently, as the work increased and lengthened almost into a permanent occupation for the peasantry, their rate of wages was augmented to ten vintems per diem for labourers, and sixteen for artificers, the militia continuing to be paid at the original rate. In August, 1810, when more than 2,500 men were working in a body at Alhandra, and the ordinary supply of the town would not furnish sufficient provisions for such augmented numbers, the officers of engineers took upon themselves to make requisitions on the neighbouring districts for bread sufficient to supply each workman with a pound per day, and saw that the value was regularly stopped from the men's wages at the end of the week. In the winter of 1810 and 1811, when the country was totally exhausted of provisions, this system was improved into a regular supply of a pound of biscuit per man issued by the British commissariat, for which three vintems per day were deducted from the wages of the peasantry.

[27] A vintem is 5·4 farthings.

Superintendence.—The number of officers of engineers employed on the lines never exceeded seventeen at the same time, viz. eleven British, two Hanoverian, and four Portuguese, and the number of their own soldiers never exceeded eighteen rank and file; but they had the assistance of more than 150 soldiers of the line, principally artificers, selected from the regiments at Lisbon. The latter were under the charge of a captain stationed at Mafra, and a subaltern at Alhandra, but were divided into parties of two and three each throughout the whole extent of the country to be retrenched. In some of the districts a subaltern officer of engineers with that small number of English soldiers, utterly ignorant of the language, directed and controlled the labours of a thousand or fifteen hundred peasantry, compelled to work, many at the distance of forty miles from their homes, whilst their own lands lay neglected, and no Portuguese ever attended of higher authority than a cabo, equal, according to military classification, to a serjeant; nevertheless, during a twelvemonth of this forced labour, not a single instance of insubordination or riot occurred, and the great quantity of work performed, should, in justice to the Portuguese, be more ascribed to regular habits of persevering labour in those employed, than to the efficiency of the control exercised over them.

Mode of Payment. —On commencing the lines, the officers of engineers were made public accountants, contrary to the regulations of the service, which strictly prohibit it; and they had, in consequence, to take charge of large sums of money (all in silver) and make the weekly payments of the labourers' wages.

Every moment of the engineers' time being devoted to the works, and no officer having a secure place to lodge the cash, nor any competent person to keep his accounts, many were considerable losers by this duty, and the active service of the senior officer of each district was altogether lost one day in the week whilst settling with the workmen, each of whom individually received and signed in triplicate for his 4*s*. $1\frac{1}{4}d$., which useless formality rendered the payment of 1,500 or 2,000 men the labour of many hours.

After some months, the impolicy as well as injustice of making the engineers paymasters becoming apparent, an officer of the commissariat, with efficient clerks, was named for that duty, and made a regular round of the districts, paying the workmen on lists prepared and certified by the engineers. In a similar manner during the latter periods of the war, in carrying on works in

detached situations, the officer of engineers was relieved from the responsibility of being a public accountant, by the duty of paymaster being allotted to an ordnance clerk or conductor of stores, who received a sum of money to cover the intended service from the commissary-general, and disbursed it on the order of the engineer in charge of the work.

Materials, Stores, &c., how obtained.—All materials, stores, implements, &c. were purchased by the commissary-general on requisition from the commanding engineer, and the officers in charge of the several districts only gave receipts for the quantities delivered to them, being in no way responsible for, or consulted respecting the price.

Lieut.-Colonel Fletcher had a general authority from the commander of the forces to make these demands on the commissary-general, and when he gave over the charge of completing the lines to Captain John T. Jones, and made him responsible for the future expenditure, he also transferred his authority to order materials, &c., which authority, so delegated, was found efficient. In like manner, Captain Goldfinch was subsequently invested with similar delegated powers and responsibility, whilst retrenching the position of Almada; and generally speaking, each officer, when employed in charge of a distinct work, had authority to make demands on the nearest commissariat station.

The gunpowder, used for blasting during the formation of the scarps of the lines, the quantity of which was very considerable, also that used for mining the bridges and roads, was obtained from the ordnance commissary at Lisbon as wanted, on requisition addressed to the commanding officer of artillery.

When mining was ordered in situations distant from any artillery depôt, it was at first customary to draw cartridges from the nearest brigade of guns: but as this was invariably found to be a source of vexation to the artillery officers, a supply of gunpowder was latterly transported with the engineers' stores, with cases ready prepared for given charges.

Trace of the several works.—The redoubts were made of every capacity, from that of fig. 7, limited by want of space on the ground it occupied to 50 men and 2 pieces of artillery, to that of fig. 10, for 500 men and 6 pieces of artillery, the importance of the object to be attained being the only guide in forming the dimensions. Many of the redoubts first thrown up, even some of the smallest, were shaped like stars (figs. 3 and 9), under the idea of

procuring a flank defence for the ditches; but this construction was latterly rejected, it being found to cut up the interior space, and to be almost fallacious with respect to flank defence, the breadth of the exterior slopes being in some cases equal to the whole length of the flanks so obtained, as in fig. 9. Even when, from the greater size of the work, some flanking fire was thus gained, the angle formed by the faces was generally so obtuse, that it demanded more coolness in the defenders than ought reasonably to be expected, to aim along the ditch of the opposite face: and further, this construction prevented the fire of the work being more powerful in front than in rear.

In order to decide on the proper trace of a work, it is necessary to consider whether its object be to prevent an enemy establishing himself on the ground on which it is to be placed, or whether it be to ensure a heavy fire of artillery on some other point in its vicinity. In the first case, every consideration should be sacrificed to that of adding to its powers of self-defence, by flanks or other expedients. In the second, its powers of resistance are secondary to the establishment of a powerful offensive fire, and its trace cannot be too simple. Latterly, the shape of the redoubts was invariably that most fitted to the ground, (figs. 4, 6, 10, 11, 12, 13, 14, 15,) or such as best parried the enfilade fire or musketry plunge of neighbouring heights, care being taken to present the front of fire deemed necessary towards the pass, or other object to be guarded; and such will generally be found the best rule of proceeding.

This recommendation, however, is not intended to apply to isolated works of large dimensions, and more particularly to those considered the key of any position. No labour or expense should be spared to render such works capable of resisting the most furious assault, either by breaking the parapet into flanks, or forming a flank defence in the ditch; for the experience gained in the Peninsula shows that an unflanked work of even more than an ordinary field-profile, if skilfully and determinedly assaulted, will generally be carried—for instance, redoubt Renaud, forts Picurina and Napoleon, &c. Nor does the serious evil of curtailing the interior space, which renders any breaks in the outline to procure flanks so objectionable in small works, apply to works of large dimensions; for it must be recollected, that in similar figures, whilst the length of the outline increases only in the simple ratio of the double, triple or quadruple, the interior space or surface increases as the square of their like sides. Under this view, the great work on Monte Agraça (fig. 2), must be considered as very defective, the flank defence being confined to an occasional

break of a few feet in the trace, caused by a change of direction in the contour of the height, whilst the interior space is more than doubly sufficient for the number of its allotted garrison to encamp.[28]

Interior and other defences.—This work, however, had some of its most exposed salient points, or those most easy of access, or most likely to be assaulted, cut off by earthen lines of parapet, steeply reveted externally, and so traced as to serve for traverses to the interior. It had also three or four small enclosed posts formed within it; and the work at Torres Vedras, (fig. 1,) had each of its salient points formed into an independent post. These interior defences and retrenchments were intended to guard against a general panic amongst the garrison, which would necessarily be composed in part of indifferent troops, and also to prevent the loss of the work by the entry of the assailants at any weak or ill-defended point. Such interior lines to rally on are absolutely essential to the security of a large field-work. They serve as substitutes for the block-house or tower, placed in the interior of all well constructed permanent earthen works, and merit far more attention than they generally receive.

The small circular windmills of stone, which were frequently found occupying salient knolls selected for the site of advanced flèches, were readily converted into admirable interior posts of that nature; and many mills situated on the elevated points of the main defences were made to add greatly to their security by a similar conversion. (Figs. 24, 25, and 26.)

Redoubt, No. 109, occupying a very important, and very exposed point in advance of the position of Oeyras, was deemed of so much value, that being commanded by a height between 6 and 700 yards in its front, in order to ensure some power of resistance after its parapet and scarps should have been destroyed, its artillery dismounted, and its interior ploughed up by a cannonade

[28] It was understood at the moment, that General Junot strongly urged Marshal Massena to permit him to advance up the mountain with a division just before the dawn of day, and make a desperate effort to carry the large work by assault. This was good counsel abstractedly, and the assault would probably have been crowned with success, had the garrison been isolated; but there being a division of infantry bivouacked in rear of the heights, which was under arms every morning long before daybreak, and had a ready communication all round the counterscarp, they would have marched on the flank of the assailants on the first musket being fired, and have rendered the attempt abortive and highly destructive.

from the height, a gallery, loop-holed for reverse flanking fire along the ditch, was formed behind the counterscarp at the salient angle of the front faces, and a communication made to it from the interior, under the bottom of the ditch. The soil being of a hard chalky substance, which stood without support, fixed the adoption of this means of defence in preference to the ordinary caponnière, which requires so much less labour. (Figs. 11 and 23.)

The parapet of No. 109 was also cut en crémaillière to throw a musketry fire on the salient angle next the heights, and to screen the defenders of its left face from the enfilade fire of the heights. This mode of indenting the parapet, however, was not thought a good measure generally, it being found to add very much to the labour, and to abstract from the direct fire of the work an equal quantity to that it threw in a different direction; besides making the defence of the parapet rather complex for militia. Therefore, latterly, in those redoubts where any particular trace was not imperious, it was always preferred to make an additional face to the work, than to leave a salient angle so acute as to necessitate such extra support; and at Almada, this principle was carried so far as to render the contour of some of the redoubts almost circular. (Figs. 14 and 15.)

Situations of the works.—Many of the redoubts were placed on very elevated situations on the summit of steep hills, which gave them a most imposing appearance; but it was in reality a defect highly prejudicial to their efficiency and defence, for the fire of their artillery on the object to be guarded became so plunging, as to lose half its powers; the musketry could not be made to scour the face of the hill sufficiently; and during the night both arms became of most uncertain effect.

The domineering situation of the redoubts, however, gave confidence to the young troops which composed their garrisons, protected them from a a cannonade, and screened their interior from musketry, unless fired at a high angle, and consequently at random. These considerations perhaps justified the unusually elevated sites, selected for most of the redoubts on the lines, though they cannot induce an approval of them as a general measure. Indeed, the ill consequences arising from height of situation was so strongly felt on the lines, that on very elevated points, particularly at Monte Agraça, in order to command the face of the mountain, flèches, or small redoubts, were established in front of the main work, (fig. 2,)

on the projecting knolls, which afforded the best flanking points. These advanced batteries were made of the same strong profile in front as the redoubts, and their gorges were equally secured, except that the rear parapets were formed as mere screens, so as not to give cover against the fire of the main work; and for the same object, the counterscarps of the rear ditches were sloped into the plane of the parapets of the commanding work. Even these flèches, though nearly doubling the garrison, saw the face of the hill less perfectly than the main work alone would have done, if placed on a height of a more moderate and more regular ascent, which shows that very elevated situations for works are seldom to be preferred.

At some points, where it was deemed likely that the troops would act in combination with redoubts occupying the summits of very elevated knolls, flèches, or field-batteries, were prepared for the field-brigades in the best flanking or enfilading situations, much lower down on the face of the hill. This seems the most judicious mode of occupying a height as a field-position, when the artillery can be placed under the effectual musketry fire of the redoubt; but on these lines, it being impossible to foresee which part might or might not be occupied strongly by troops, it was made a rule to put no artillery in battery, except within works capable of defending themselves. At some points, where space could not be obtained within the redoubts, the guns were placed on a lower advanced level, connected on its flanks with the defences of the redoubt. (Fig. 8.) Some of the flank defences were limited to one or two guns, which could only be justified by the difficulty an enemy would find in passing the object they fired upon. It ought to be received as a general rule, that no flank can be formidable to infantry which does not contain at least three pieces of ordnance; and even to render a flank of three pieces very destructive, it must be in a situation of tedious approach, or in a work which cannot be run into.

Profiles.—The profile of the several works varied on every face and flank, according to its liability to be attacked or cannonaded, the only general rule enforced, being, that all ditches should be at least 15 feet wide at top and 10 feet in depth, and the crest of the parapet have at least five feet command over the crest of the counterscarp.

No parapet exceeded 10 feet in thickness, unless exposed to be severely cannonaded, and few more than 6 or 8 feet; and some, on high knolls, where

artillery could not by any possibility be brought against them, were made of stone or rubble less than two feet in thickness, to gain more interior space, and allow full liberty for the use of the defenders' bayonets. Many of the rear enclosures, when supported on precipices, were merely screens; and in some few cases, on the position near Ribaldiera, they were left to the precipice itself. (Fig. 5.) The rear of advanced flèches and other small works, situated within good musketry-fire of the main defences, were generally closed with a very open but strong stockade. (Figs. 24, 25, and 26.)

In elevated situations, many of the banquettes were raised within four feet of the crest of the parapet, it being the rule to fix the level along each face at such height as would admit of the musketry plunging down the face of the hill, or at least seeing some yards of the glacis.

The exterior slopes were made greater or less, according to the tenacity of the soil; but it was found after the first winter, that no slope cut through the natural ground had sustained itself at a greater angle than 45°, and in made ground, the exterior slopes were washed away at that angle. Indeed, in consequence of the heavy rains in southern climates, it is almost essential to form some kind of revetment to works to keep them defensible during winter; and in 1811, most of the exterior slopes of the works of the lines were retained with dry stone walls. To ensure an efficient system of drainage should always be a principal consideration with an officer on commencing a work. Some redoubts deeply excavated, with the view to screen the defenders, particularly Nos. 101 and 102 at Oeyras, from neglect of this precaution, literally filled with water in September, 1810, and the labour of forming drains to keep their interior dry was little less than that of constructing the redoubt.

The interior of the parapets were retained with fascines or sand-bags: the former stood perfectly well, except that those originally made, being composed of the smaller branches and twigs, became, during the summer, so readily combustible as to be considered unsafe, and latterly, only the larger branches, completely divested of their leaves and twigs, were worked into fascines, intended for interior revetments. The sand-bags rotted and burst after the first winter.

A drawing is given of the profile of several of the works in different situations (figs. 16 to 23); that of the redoubts, on the heights of Almada, (fig. 20,) deserves particular attention, as those works stand in situations open

to be violently cannonaded, and the hills forming the position are such as are most frequently occupied with works, and the profile was fixed after the experience gained in making the lines: it was as follows:

	Feet.	In.
Height of interior crest of parapet	7	0
Height of parapet above banquette	4	3
Thickness of parapet	14	0
Berm	2	0
Breadth of ditch at top	16	0
Depth below surface of ground	12	0
Crest of glacis below crest of parapet	5	6

In the profile of lines of flanked works, in low situations, where the interior space was not limited, the crest of the parapet was generally fixed at 10 feet above the level of the ground, for the purpose of a better command in front, and better covering the troops; and this height was thought to be the best adapted for attaining a good defence with moderate labour. Even with this elevation, no covered way was formed to any line, but the crest of the glacis was kept six feet or six feet and a half below that of the parapet.

The redoubts of the lines being mostly thrown up as secure emplacements for guns, and to procure an open field for the fire of their artillery being the principal object attended to in their construction, they were mostly placed on the summit of the heights they occupied, so that each face might have a full command of the ground in its front, or of the point it was intended to protect; but, in other situations, where the object of a redoubt was merely to prevent an enemy occupying a particular spot, it was, wherever practicable, constructed on an inclined plane on the reverse of the height, so that only its most salient point, or, perhaps, its front faces, rose over the crest of the hill. (Fig. 22.) This defilement gives the work considerable protection from cannonade, and causes the front parapet to cover the rear lines and the defenders far better than if constructed on a horizontal plane, and should generally be adopted in situations where an enemy cannot establish batteries in its rear; and invariably in the construction of lunettes or flèches in advance of a fortress, as, beyond the advantages above mentioned, it causes the interior of the work to be completely seen from the place.

In this construction the rear enclosure, whether palisades or a wall, should be made of a strength to resist light howitzer shells pitched over the

parapet, but not so strong as to afford cover against the heavy guns of the place.

Stores and provisions.—In each redoubt wholesome casks were provided and placed in security to contain four quarts of fresh water per man for the calculated garrison, besides the tubs with water for the use of the artillery; and a depôt of intrenching tools was also provided in the following proportions.

	Shovels.	Pickaxes.	Felling Axes.
Works for 400 men	10	6	3
300	8	4	2
200	7	4	2
Smaller	6	3	2

Monte Agraça, proportion for 1,500 men.

Magazines.—The magazines were formed of splinter-proof timbers, about 10 inches by 8, placed at an angle between 45 and 50° against a substantial traverse; and wherever an efficient drain could be made around them, their floors were sunk one, two, three, and even four feet below the level of the interior of the work; which excavation, and the relative height of the redoubt with respect to the ground in its vicinity, served to regulate the length of the timber, so as to have the top of the magazine sheltered from direct fire.

The magazines were lined internally with plank, and strengthened externally with two feet of earth in sand-bags, over which tarpaulins were spread; and thus protected, these magazines were found sufficiently dry.

Platforms.—The platforms, as originally laid down, consisted merely of a plank for each truck, but during the summer and autumn of 1810 they were all replaced by platforms of the ordinary construction. Many of the redoubts being on undulating heights, and the guns being mounted on extremely low carriages, it required undeviating attention to keep the front of the platform on a sufficiently high level to ensure the guns clearing the intermediate swell of the height, so as to strike an object at the foot of the slope. In such situations the eye will frequently attain an object which the gun on its lower level will not.

Palisades.—The palisades in the ditches were mostly young fir trees from

four to five inches in diameter, roughly pointed, and fixed three or four feet into the ground with a riband very low down, and, when the ditches were broad, much nearer the counterscarp than the scarp.

In the last campaign, the palisades of the redoubts thrown up near the Montagne de la Couronne in the Pyrenees, where wood was plentiful and cost nothing, were made of trunks of trees placed close together at the foot of the escarp, and were found almost equal to a masonry revetment.

The best disposition of the ordinary palisades in works with wide ditches was thought that adopted for the advanced redoubt, No. 109, at the position of Oeyras (fig. 23), where they were fixed as fraises along the counterscarp, about two feet below its crest, with an inclination towards the bottom of the ditch. Fraises in that situation are little likely to be injured by a front fire of cannon or howitzers, and the manual operation of cutting them away is extremely difficult, besides the men, whilst so employed, being exposed to the fire from the parapet of the work. This mode of fixing fraises was also partially applied to some salient angles, on the approach to which little fire could be brought.

It should be observed, however, that fraises, being much more liable to be broken down by vertical fire than palisades, are more adapted for field than reveted redoubts, as vertical fire can seldom be brought against the former, and it ought to form the basis of attack of the latter.

Barriers.—Each redoubt was closed with a barrier-gate, and a bridge of joists and planks.

For these four last-mentioned services more than 50,000 trees were received between the 7th July and 7th October, 1810; the greater part however being firs from the royal forests no payment was made for them.

Abattis.—The abattis were formed solely of the stems and boughs of whole trees well pointed, all the smaller branches being cut off, so that the front of the abattis afforded neither cover nor concealment to an assailant, although it presented a barrier of spears five, six, and seven feet in height. The abattis were usually placed from twenty to thirty yards in front of the work, each stem and large branch being firmly staked down into the ground, and, when practicable, the trace was so disposed as to be flanked along its front by some of the defences.

Obstacles in this situation are undoubtedly the best means that can be devised for aiding the defence of works, and are seldom sufficiently attended to.

The great object of defence should be to contrive some expedient to check the assailants, and cause them to halt, if only for two or three minutes, under a close fire of musketry from the parapet. Such an advanced obstacle has ten times the effect of one of equal difficulty opposed to an assailant, when he has closed with the defenders of a work. He knows that in the latter case he has but to overcome one difficulty to obtain complete success, whereas in the former case the troops exhaust their ardour, and lose their formation on a mere preliminary effort; and every one must have felt how extremely difficult it is to revive confident boldness, and restore order for a second effort after a check.

Fir trees were found the least, and olive trees the best, adapted to form abattis.

Trous-de-Loup.—The trous-de-loups were at first made of the ordinary dimensions and numbers, but subsequently an increased number of rows (eight or ten) of pits, only 2 feet or 2 feet 6 inches in depth, well staked at bottom and in the intervening spaces, were considered preferable, as affording no cover within them for men to fire on the work before which they might be placed, and presenting great impediments to the advance of an assailant.

During the occupation of the lines, trous-de-loups were formed in front of part of the position of Via Longa, consisting of a triple row of inverted cones, 9 or 10 feet in diameter at top, and of the same depth.[29] These were found to be a most formidable obstacle, but were perhaps larger than absolutely required, as it is only necessary that trous-de-loups should be of a depth to prevent an assailant getting into them and firing over their tops, which 7 or 8 feet will effect.

Whenever practicable, from the height of the profile or the fall of the ground, the rows of trous-de-loups were concealed and protected from cannonade by forming an advanced glacis with the earth excavated from the pit.

Artillery.—The provision of artillery, ammunition and artillery stores, was

[29] By Captain Burgoyne.

arranged by the Portuguese in the arsenal at Lisbon, on memoranda sent from time to time by the commanding engineer, and the guns were mounted by parties of Portuguese gunners detached from thence, as the works were prepared to receive them. It was gratifying to observe, on these occasions, by what persevering and patient labour the peasantry, with their rude means of transport, (merely the common cars of the country pushed forward by oxen,) succeeded in transporting 12-pounders into situations where wheels had never before rolled, and along the steep sides of mountains where horses would have been useless.

Although the armament of the lines ultimately amounted to nearly double the number of pieces of ordnance originally contemplated, the zeal and perseverance of the Portuguese general Rosa smoothed all difficulties, and his activity and resource seemed to render the supply of guns, ammunition, and the means of transport, inexhaustible; and, highly to his credit, every thing supplied, though rude and inconvenient, proved efficient and substantially good. The Portuguese officers and gunners employed on this duty were also zealous and active, and took extremely good care of their stores and ammunition. Their numbers assembled on the lines amounted to 3,208, regulars and irregulars.

Calculation of garrisons.—As a general rule, the garrisons of the redoubts, and the number of troops required to man the retrenchments, were at the commencement calculated on an allotment of two men per yard running of parapet for all lines; but after some time, this calculation was deemed too considerable, and the numbers were fixed at two men per yard running for all front lines, and one man per yard for all rear lines, deducting for the spaces occupied by the artillery; an addition to or deduction from these numbers being made by the commanding engineer in all cases where deemed expedient from local causes.

Admitting each man to require three feet to enable him to use his musket freely, this latter calculation will, (whatever be the figure of the work,) ensure the parapet being sufficiently manned, and leave a reserve to supply the place of those killed, or in large works to charge the first of the assailants who may penetrate into the interior. It was therefore deemed preferable to the more scientific formula for allotting a man to a certain number of square feet of the interior space, which rule, though well calculated to apportion the

garrison of every sized work in a similar ratio between its interior space and its length of parapet, seems too much the result of theory, which requires that each man of a garrison should have a certain space for his accommodation; whereas in practice such does not appear to be essentially necessary; for till the moment of being menaced with an attack, many of the garrison of each work will be kept on the watch on the face of the hill, and others be permitted to amuse themselves in its rear. All cooking, &c. is also performed outside of the work, so that it is only at night, or during the action which decides the fate of the position, that the garrisons are closely shut up, and then at least one-third should be kept constantly standing or sitting under arms on the banquette. Besides this, every figure from the triangle to the circle varies in the proportion the content bears to the periphery, and it is on the latter only that the defence hinges.

Scarps.—The scarps were formed by cutting the front slopes of ranges of heights near their summit as perpendicularly as the soil or rock of which they were composed could be made to stand, or on such irregularity of level as presented the greatest facility for making a perpendicular cut.

The chief difficulty in tracing a line to be scarped was to find portions of the ascent sufficiently steep, that when cut to the required angle, the base should not form a road, which might serve as a breathing and rallying point, and unless flanked, a secure communication to an assailant. Fig. No. 27 is a section of a scarp of nearly two miles in length, formed along the summit of the front of the position of Alhandra, in August and September, 1810. Much of the upper twenty or thirty feet of that range of heights was found to be a ledge of precipitous rock only covered with a few feet of earth; which covering being removed and thrown down the face of the hill, the rock behind it was readily made insurmountable to infantry by means of blasting. At other points a species of sandstone, which, when cut through, stood nearly perpendicular, afforded great facility to the formation of the scarps; indeed, without some such natural aid, scarping will seldom be found practicable.

It never was presumed that scarps could be trusted to without defenders; but it was considered a great point gained to have rendered portions of ground of such difficult access as to be safely left to the guard of a small corps, or to unsteady troops, such as the militia and ordenanza on the lines. For the purpose of better watching, and to ensure the ready approach of troops and

field artillery to all points of the front scarped, a line of interior road was formed nearly parallel to the scarps of Alhandra and Picanceira, at the shortest convenient distance from the front.

Roads and communications.—The military roads generally were traced along the rear of ranges of heights on the shortest line, concealed from the view of the ground in front; they were perfected during 1811, so as to form a ready communication along the front line from the sea to the Tagus, with direct communications from the rear line.

Several miles of the lateral road were entirely new, as also most of the direct communications from the lateral road to the works: but the intermediate communications between the advanced works and rear line were merely the original car roads of the country widened and rendered practicable for military purposes. Many of the communications along the valleys were of necessity paved to keep them in a state to be used; but generally the heights over which the main communication passed were rocky or abounded with loose stones and other materials which readily formed into firm roads. Fig. 21 is a section of the covered road commenced at Almada, and intended to be carried from the right to the left of that position.

Telegraphs.—The telegraphs were composed of a mast and yard, from which latter balls were suspended; the vocabulary used was that of the navy, many sentences and short expressions peculiar to the land service being added. These telegraphs readily communicated with each other, at the distance of seven and eight miles; but in consequence of the ranges of hills interrupting the view, it required five principal stations to communicate along the front line, viz. at Alhandra, Monte Agraça, N. S. de Socorra, Torres Vedras, and redoubt No. 30, in rear of Ponte de Rol.

The telegraphs were worked by a party of seamen under Lieutenant Leith of the Royal Navy.

Ground, how obtained.—The ground required for the site of works, roads, abattis, scarps, &c. was taken possession of without a reference to, or complaint from the owner or occupier, or any estimate being made of its value, which however was seldom considerable. Compensation was made to the proprietors for the olive trees cut down, also for trees felled in private woods,

and for crops destroyed before the advance of the invaders. The owners of mills dismantled in consequence of being on knolls selected for the site of works had a monthly payment equivalent to their previous average gains, and also a sum of money for the restoration of the machinery; but otherwise, the principal injury sustained by private property being inflicted when the lines became the seat of war, the loss fell on individuals.

Conduct of the Portuguese.—The British officers of engineers, spread singly over a space of 150 square miles of country, and billeting themselves in the best or most convenient houses, were every where treated with civility and kindness by the inhabitants; and a general readiness was shown by the upper classes to admit them to the familiar society of their families, which led to many sincere and disinterested friendships being contracted between individuals of the two nations. Indeed, it is but a tribute of justice to the Portuguese gentlemen and peasantry of Estramadura to state, that, during many months of constant personal intercourse, both public and private, the latter ever showed themselves respectful, industrious, docile and obedient, whilst the former in every public transaction evinced much intelligence, good sense and probity, and appeared in their domestic relations, kind, liberal, and indulgent, both as masters and parents.

Secrecy with respect to the extent and nature of the works going forward was enjoined, and it is highly creditable to all concerned that scarcely a vague paragraph respecting the lines found its way into the public prints; and notwithstanding the magnitude of the works, the invaders remained ignorant of the nature of the barrier raising against them, till they found the army arrayed on it to stop their further advance.

Total of Retrenchments and Garrisons.—The length of retrenchment completed at the period the army occupied the lines, including the periphery of 126 enclosed works, when calculated on the data before mentioned, required 29,751 men for its defence, and there were mounted on it 427 pieces of artillery, independently of the works to cover an embarkation at St. Julian's, which were calculated for 5,350 men, and contained 94 pieces of artillery. It is however evident from the description of the lines that little more than a third part needed to be kept fully manned at the same period.

In 1812, when the lines were considered as perfect as they could be

made, they consisted of 152 distinct works, armed with 534 pieces of ordnance, and required on the same calculation 34,125 men for their garrisons. The embarkation position remained as above described.

Expense of the Lines.—The disbursements on account of the lines, to the 6th July, 1810, were about £60,000; at the moment of the army occupying the ground the disbursements amounted to nearly £100,000: which sum was doubled before the conclusion of the war, by the outlay for the position of Almada, the repair and preservation of the various defences and communications, and by indemnities to some individuals for property wantonly destroyed or taken for the use of the troops during the occupation of the lines.

Public Mention made of the Lines.—"Having advanced from the positions in which I was enabled to bring the enemy to a stand, and oblige them to retire without venturing upon any attack, it is but justice to Lieut.-Colonel Fletcher and the officers of the Royal Engineers, to draw your Lordship's attention to the ability and diligence with which they have executed the works by which these positions have been strengthened to such a degree as to render any attack upon that line occupied by the allied army very doubtful, if not entirely hopeless. We are indebted for these advantages to Lieut.-Colonel Fletcher and the officers of the Royal Engineers, among whom I must particularly mention Captain Chapman, who has given me great assistance upon various occasions."[30]—*Dispatch from Viscount Wellington, dated Cartaxo, Nov. 21st, 1810.*

[30] Captain Chapman was next in seniority to Lieut.-Colonel Fletcher from the commencement of the lines, and was thus deservedly particularized for the great zeal and activity he displayed in aiding to carry into effect the plans of his commanding officer.

WORKS COMPOSING THE LINES,

AS NUMBERED ON THE GROUND AND ON THE PLAN.

District No. 1.

From the Tagus at Alhandra to No. 11, *above Arruda Road, inclusive.*

Nos. of the Works.	Infantry required.	Artillery mounted.				Names of Places where situated.
		12 Prs.	9 Prs.	6 Prs.	5½ How.	
1	1,000	4	3	6	..	Line across the low ground at Alhandra, resting on the Tagus.
2	800	2	..	..	..	Rising line to the left of do. do.
3	200	2	..	..	..	Redoubt, left extremity of rising line.
4	..	..	2	..	..	Right Flank to the scarped face of the position.
114	100	..	2	1	..	Flanking Redoubt to the scarped front of Alhandra.
115	100	..	2	..	..	do. do.
116	100	..	5	..	..	do. do.
117	150	..	..	..	..	Flèche do. do.
118	400	8	..	..	..	Redoubt on the most commanding point of the Alhandra position.
119	350	6	..	..	..	Redoubt closing the left of the position.
6	..	2	..	..	..	Barbette Battery retired on the extreme of the left.
120	130	2	..	..	..	Redoubt, extremity of left of front of the heights of Alhandra.
5	120	..	3	..	..	do. do.
121	250	..	3	1	..	Heights of Calhandrix, advanced redoubt.
122	300	3	..	..	..	do. right.
123	300	3	..	..	..	do. centre.
124	350	3	1	..	..	do. left.
125	250	4	..	..	..	Rear Work, to connect the Calhandrix position with the rear line.
7	200	3	..	..	..	Redoubt on the heights in rear of Alhandra, looking up the valley of Calhandrix.
			11	1	..	The valley of Calhandrix is closed at its mouth by a line of intrenchment and abattis, not numbered, thrown up whilst the army occupied the lines.
8	200	3	..	..	..	Heights in rear of Trancoso de Cima, to prevent Alhandra being turned with artillery.
9	280	..	3	..	..	St. Sebastian, right of pass of Matos.
10	400	2	1	..	..	Carvalhao, left of the pass of Matos.
11	300	4	..	..	..	Moinho do Ceo. Windmill above Arruda road.
	6,280	51	36	9	..	

District No. 2.

From No. 12, above Arruda Road, to the Left of Monte Agraça.

Nos. of the Works.	Infantry required.	Artillery mounted.				Names of Places where situated.
		12 Prs.	9 Prs.	6 Prs.	5½ How.	
12	120	..	3	..	..	Forte do Passo, rocky bluff above Arruda road.
13	120	2	..	..	..	Forte de Canara, paved road leading to Bucellas.
14	1,590	14	6	4	1	Main work Monte Agraça.
15	460	3	3	1	..	Advanced work on the same hill.
16	250	1	2	..	1	do. do.
17	300	..	..	7	1	do. do.
152	250	4	2	..	..	Advanced work right of road leading to Sobral.
	3,090	24	16	12	3	

District No. 3.

From Zibriera to the Caduceira Heights, inclusive.

Nos. of the Works.	Infantry required.	Artillery mounted.				Names of Places where situated.
		12 Prs.	9 Prs.	6 Prs.	5½ How.	
151	300	..	..	..	..	Patameira, redoubt for field artillery. Scarped plateau between the Quinta de Anoteira and Ribaldiera prepared for field guns.
128	500	6	..	..	..	Large work Serra de Caduceira.
129	350	6	..	..	..	Centre do. do.
130	200	..	5	..	..	Left do. do.
28	270	3	..	..	..	Enxara dos Cavalleiros, north redoubt.
29	280	..	4	..	..	do. do. south redoubt.
	1,900	15	9	..	..	

District No. 4.

From No. 144, *on the Left of the Pass of Runa, to the Sea.*

	Nos. of the Works.	Infantry required.	Artillery mounted.				Names of Places where situated.	
			12 Prs.	9 Prs.	6 Prs.	5½ How.		
	149	250	4	2	..	..	Height above Matacaes, to command the Runa road.	
	26	300	..	3	..	..	Advanced mill near do. to block the Runa road.	
Main work, Torres Vedras.	20	470	5	..	2	1	S. E. Bastion of the main work at Torres Vedras.	1,720 men.
	21	270	..	2	6	1	S. W. do. do.	
	22	380	5	..	3	1	N. W. do. do.	
		600	..	..	..	..	South Curtain 150 men, W. Curtain 90, N. E. Curtain 360.	
	23	180	..	4	3	..	West Redoubt, Torres Vedras.	
	24	300	..	7	..	..	East Redoubt, Torres Vedras.	
	25	200	..	2	..	..	Convent of St. Joa.	
	27	500	5	..	..	..	Castle of Torres Vedras in the town.	
	131	90	4	..	..	..	Enclosed Battery, left of Variatoja.	
	132	150	6	..	..	..	do. left of do.	
	133	120	..	4	..	..	do. behind White Quinta.	
	134	110	4	..	..	..	do. ridge of Casal de Serra, overlooking the village and heights of Bemfica.	
	135	160	..	4	..	..	do. do.	
	136	150	4	..	..	..	do. do.	
	137	100	4	..	..	..	do. do.	
	147	..	..	..	..	..	Open Battery upon Ponte de Rol.	
	148	..	..	..	..	..	do. do.	
	138	100	..	..	2	..	Enclosed Battery in rear of No. 30.	
	30	340	3	1	..	..	Redoubt above Ponte de Rol.	
	139	160	4	..	..	..	Enclosed Battery between Nos. 30 & 31.	
	140	120	4	..	..	..	do. do.	
	31	373	..	3	..	..	Redoubt at Algaterra.	
	141	180	4	..	..	..	Enclosed battery between 31 & St. Pedro.	
	142	150	4	..	..	..	do. do.	
	143	150	..	4	..	..	do. do.	
	144	130	4	..	..	..	do. do.	
	32	260	3	1	..	..	At St. Pedro de Cadeira.	
	145	250	..	4	..	..	Quinta de Belmonte.	
	111	250	5	..	..	..	Between St. Pedro and the sea, Quinta de Passo.	
	146	250	..	6	..	..	Quinta de Bessuaria.	
	112	220	4	..	..	..	Between Quinta de Bessuaria and the sea.	
	113	50	2	..	..	..	Enclosed Barbette Battery at the sea.	
		7,413	78	47	16	3		

District No. 5.

From the Tagus to the Pass of Bucellas, inclusive.

Nos. of the Works.	Infantry required.	Artillery mounted.				Names of Places where situated.
		12 Prs.	9 Prs.	6 Prs.	5½ How.	
33	300	4	..	..	..	Banks of the Tagus, right of position of Via Longa.
34	200	..	3	..	..	Advanced Redoubt to enfilade Calçada, do.
35	120	..	4	..	..	do. do.
36	370	9	..	..	..	do. summit of advanced hill, do.
37	50	..	3	..	..	Garden, right of paved road, do.
38	340	..	5	..	..	Building, left of road, do.
39	340	5	3	..	..	Summit of highest hill, do.
126	188	2	..	..	..	Right work to close the valley of Cabo.
127	154	..	..	..	..	Left do. do.
40	150	..	..	..	..	Caza de Portella, advanced redoubt. } These redoubts close the left of
41	240	5	..	..	..	do. right. } the position of
42	350	6	..	..	..	do. left. } Via Longa.
43	..	4	..	..	..	Right of Pass of Bucellas, open battery.
44	..	..	2	..	..	do. front emplacement.
45	..	3	..	..	..	do. rear do.
46	..	..	2	..	..	Left of Pass of Bucellas, front do.
47	..	3	..	..	..	do. rear do.
48	200	2	..	..	..	In rear of the Pass enfilading the Calçada.
18	300	4	..	..	..	Right work, Serra de Santa Ajuda.
19	200	..	3	..	..	Left do. do.
	3,502	47	25	..	..	

District No. 6.

From the Pass of Freixal to the Park of Mafra, including the Pass of Montachique.

Nos. of the Works.	Infantry required.	Artillery mounted.				Names of Places where situated.
		12 Prs.	9 Prs.	6 Prs.	5½ How.	
49	..	2	..	..	..	Pass of Freixal, emplacement right.
50	160	..	2	..	..	do. right redoubt.
51	300	4	..	..	..	do. left redoubt.
52	190	..	3	..	..	Right of the Pass of Montachique, entrance of Pass.
53	230	..	2	..	..	do. near the village of Prezenhiro.
54	210	..	..	..	..	do. mill on Enxara road.
55	150	3	..	..	..	do. rocky bluff.
56	150	2	..	..	..	do. pine wood.
57	270	3	..	..	..	do. rocky height covering the right.
58	310	..	3	..	..	Left of Pass of Montachique, entrance of Pass.
59	260	4	..	..	..	do. mill on Mafra road.
60	150	..	2	..	..	do. flèche covering the left flank.
61	190	..	2	..	..	do. covering the left flank.
62	390	3	..	..	..	In front of the road from Mafra to Montachique, covering the great road, Alto de Cheixa.
63	280	..	3	..	..	do. Casal de Serra.
64	210	..	3	..	..	do. corner of park wall.
65	270	3	..	..	..	Mafra road, Oiteira de Sta. Maria.
66	350	4	..	..	..	do. Malveira.
67	120	..	2	..	..	do. right of 66.
68	260	4	..	..	..	do. Monte de Zinho.
69	240	4	..	..	..	do. Pinhal de Fidalgo.
70	240	4	2	..	..	do. Quinta de Estrangeiro.
71	240	..	4	..	..	do. do.
72	130	..	2	..	..	do. Astadieros.
73	340	3	..	..	..	do. Casal de Conto.
	5,640	43	30	..		

District No. 7.

From the Park at Mafra, inclusive, to the Sea.

Nos. of the Works.	Infantry required.	Artillery mounted.				Names of Places where situated.
		12 Prs.	9 Prs.	6 Prs.	5½ How.	
74	190	..	2	..	..	Pass of Mafra, Casal de Pedra, right of Park, within the entrance. (Right of Pass of Mafra.)
75	70	..	2	..	..	Within walls of Park, advance Milharica. (Right of Pass of Mafra.)
76	390	4	..	..	..	Cabeça de Sincout. (Right of Pass of Mafra.)
77	380	4	..	..	..	Juncal. (Right of Pass of Mafra.)
78	110	2	1	..	..	Serra de Chypre, advanced work.
79	270	3	..	..	..	redoubt, advanced mill.
80	310	3	..	..	..	second mill.
81	280	..	3	..	..	lower work.
82	210	2	2	..	..	Left of the village of Morugueira, right.
83	240	..	3	..	..	do. centre.
84	290	3	..	..	..	do. left.
85	290	3	..	..	..	Ericeira road to Mafra, Alto de Arriero.
86	280	3	..	..	..	do. Alto de Paz.
87	340	3	..	..	..	Mill, south of Ericeira road, Pinheiro.
88	200	3	..	..	..	To command the road from Sobral des Alarves to Mafra.
89	310	3	..	..	..	Defence of Picanceira road.
90	230	3	..	..	..	Peneyaixo, to command the roads leading from Picanceira and Encarnaçoa.
91	200	3	..	..	..	Lagoa, do. three roads leading from Encarnaçoa.
92	180	3	..	..	..	Defence of the road to Morvao.
93	330	3	..	..	..	Ribamar, right.
94	320	2	..	..	..	do. left.
95	250	2	..	..	..	Rear line, right, Monte Gordo.
96	280	3	..	..	..	centre, Carvoiera.
97	350	2	..	..	..	left, St. Julian's.
	6,300	57	13	..	..	

District of Oeyras.

Nos. of the Works.	Infantry required.	Artillery mounted.					Names of Places where situated.
		24 Prs.	12 Prs.	9 Prs.	6 Prs.	5½ How.	
98	1,340	20	..	..	6	..	Main Work.
99	70	..	6	..	..	..	Right Battery to flank the valley and beach of Oeyras.
100	50	..	6	..	..	..	Left Battery to flank the valley of Oeyras.
101	250	..	10	..	..	..	Advanced to Great Work, right.
102	260	..	8	..	..	..	do. left.
103	130	..	..	3	..	..	Advanced in front of Oeyras, front.
104	100	..	..	2	..	..	do. south mill.
105	170	..	..	4	..	..	do. north mill.
106	320	..	6	..	..	..	Vineyard left of 98.
107	800	..	6	..	..	..	Quinta Nova, building and redoubt.
108	360	..	6	..	..	..	Left flank of position.
109	500	..	..	7	..	1	Advanced on a hill to the N. E. of Oeyras.
110	1,000	..	..	3	..	..	Line extending on the right from No. 104 to Fort das Mais.
	5,350	20	48	19	6	1	

May 1, 1812.

Detail of the Number of Works, Troops, and Ordnance, as proposed originally for the Occupation of the Position of Almada. This project was subsequently reduced, as described in page 23.

Works.	Guns.	Men.
Redoubt No. 1.	4	150
Redoubt No. 2.	4	150
Flèches and Outposts	2	100
Village of Morfacem	8	600
Redoubt No. 3.	4	200
Quinta de Geddos		50
Redoubt No. 4.	3	150
Redoubt No. 5.	5	250
Adjacent Village and Buildings		100
Redoubt No. 6.	12	600
Redoubt No. 7.	4	150
Adjacent Buildings		50
Redoubt No. 8.	5	150
Adjacent Village and Buildings		100
Redoubt No. 9.	5	200
Flèche and Village		100
Redoubt No. 10.	5	200
Adjacent Village		80
Redoubt No. 11.	5	250
Adjacent Roads and Buildings		100
Redoubt No. 12.	4	150
Flèche		50
Redoubt No. 13.	6	300
Adjacent Buildings		50
Redoubt No. 14.	4	150
Redoubt No. 15.	3	150
Flèche	2	50
Vill. N. Senora de Monte	6	400
Redoubt No. 16.	4	200
Redoubt No. 17.	5	200
Adjacent Buildings		60
Carried up	100	5,490

Works.	Guns.	Men.
Brought up	100	5,490
Redoubt No. 18.	5	200
Adjacent Buildings		60
Redoubt No. 19.	4	200
Flèche and Buildings	2	100
Redoubt No. 20.	6	300
Redoubt No. 21.	5	200
Adjacent Buildings		100
Redoubt No. 22.	3	150
Adjacent Buildings		40
Redoubt No. 23.	5	200
Flèche		40
Redoubt No. 24.	4	150
Adjacent Buildings		80
Redoubt No. 25.	4	150
Redoubt No. 26.	4	150
Flèche		40
Village of Pregal	4	300
Redoubt No. 27.	5	200
Redoubt No. 28.	4	150
Redoubt No. 29.	6	300
Redoubt No. 30.	5	200
Street and Buildings		150
Redoubt No. 31.	6	200
Redoubt No. 32.	4	150
Redoubt No. 33.	3	150
Redoubt No. 34.	3	200
Redoubt No. 35.	3	150
Village of Cazilhas		150
Town and Castle of Almada	12	800
TOTAL	197	10,750
RESERVE		4,000

NOTES.

Note 1.—Reference, page 2.

The following paper of memoranda or instructions, given to Lieutenant-Colonel Fletcher for his guidance in proposing the mode of strengthening the ground in front of Lisbon, is extremely interesting as showing the first conceptions of a system of defence subsequently perfected into the lines of Torres Vedras.

Memorandum. Lisbon, *October* 20, 1809.

In considering the relative state of the strength and efficiency of the allied and French armies in the Peninsula, it does not appear probable that the enemy have it in their power to make an immediate attack upon Portugal. They must wait for their reinforcements, and as the arrival of them may be expected, it remains to be considered, what plan of defence shall be adopted for this country.

The great object in Portugal is the possession of Lisbon and the Tagus, and all our measures must be directed to that object. There is another also connected with that first object, to which we must likewise attend, viz. the embarkation of the British troops in case of a reverse.

In whatever season the enemy may enter Portugal, he will probably make his attack by two distinct lines, the one north the other south of the Tagus, and the system of defence to be adopted must be founded upon this general basis.

In the winter season the river Tagus will be full, and will be a barrier to the enemy's enterprises with his left attack, not very difficult to be secured. In the summer season, however, the Tagus being fordable in many places between Abrantes and Salvatierra, and even lower than Salvatierra, care must be taken that the enemy does not, by his attack directed from the south of the Tagus and by the passage of that river, cut off from Lisbon the British army engaged in operations to the northward of the Tagus. The object of the Allies should be, to oblige the enemy, as much as possible, to make his attack with concentrated corps. They should stand in every position which the country could afford such a length of time as would enable the people of the country to evacuate the towns and villages, carrying with them or destroying all articles of provisions and carriages not necessary for the allied army; each corps taking care to preserve its communication with the others, and its relative distance from the point of junction.

In whatever season the enemy's attack may be made, the whole allied army, after providing for the garrisons of Elvas, Almeida, Abrantes and Valença, should be divided into three corps, to be posted as follows: one corps to be in the Beira; one to be in the Alemtejo; and the third,

consisting of the Lusitanean Legion, eight battalions of Chasseurs and one of Militia, in the mountains of Castello Branco.

In the winter the corps in the Beira should consist of two-thirds of the whole numbers of the operating army. In the summer the corps in the Beira and in Alemtejo should be nearly of equal numbers. I will point out in another memorandum the plan of operations to be adopted by the corps north and south of the Tagus in the winter months.

In the summer it is probable, as I have before stated, that he will make his attacks in two principal corps, and that he will also push on through the mountains between Castello Branco and Abrantes. His object will be by means of his corps south of the Tagus to turn the positions which might be taken in his front on the north of that river; to cut off from Lisbon the corps opposed to him; and to destroy it by an attack in front and rear at the same time. This can be avoided only by the retreat of the right, centre and left of the allies, and their junction at a point, at which, from the state of the river, they cannot be turned by the passage of the Tagus by the enemy's left.

The first point of defence which presents itself below that at which the Tagus ceases to be fordable, is the river of Castanheira, and here the army should be posted as follows:—

Ten thousand able men, including all the cavalry, in the plain between the Tagus and the hills; 5,000 infantry on the hill to the left of the plain; and the remainder of the army, with the exception of the following detachments, on the height in front and on the right of Cadafoes.

In order to prevent the enemy from turning by their left the positions which the allies may take up for the defence of the high road to Lisbon by the Tagus, Torres Vedras should be occupied by a corps of 5,000 men, the heights in the rear of Sobral de Monte Agraça by 4,000 men, and Arruda by 2,000.

There should be a small corps on the height east by south of the heights of Sobral, to prevent the enemy from marching from Sobral to Arruda; and there should be another small corps on the heights of Ajuda, between Sobral and Bucellas.

In case the enemy should succeed in forcing the corps at Torres Vedras, or Sobral de Monte Agraça, or Arruda. If at the first, it must fall back gradually to Cabeça-de-Montachique, occupying any defensible point on the road. If the second, it must fall back upon Bucellas, destroying the road over the height of . If the third, it must fall back upon Alhandra, disputing the road, particularly at a point one league in front of that town.

In case any one of these three positions should be forced, the army must fall back from its position as before pointed out, and must occupy one as follows:—

Five thousand men, principally light infantry, on the hill behind Alhandra; the main body of the army on the Serra of Serves, with its right on that part of the Serra which is near the Casal de Portella, and is immediately above the road which crosses the Serra from Bucellas to Alverca; and its left extending to the pass of Bucellas. The entrance of the pass of Bucellas to be occupied by the troops retired from Sobral de Monte Agraça, &c.; and the Cabeça-de-Montachique by the corps retired from Torres Vedras.

In order to strengthen the several positions, it is necessary that different works should be constructed immediately, and that arrangements and preparations should be made for the construction of others. Accordingly I beg Colonel Fletcher as soon as possible to review the several positions.

1. He will examine particularly the effect of damming up the mouth of the Castanheira river, how far it will render the river a barrier, and what extent it will fill.

2. He will calculate the labour required for that work, and the time it will take, as well as the means of destroying the bridge over the river, and of constructing such redoubts as might be necessary on the plain, and on the hill on the left of the road, effectually to defend the plain. He will state particularly what means should be prepared for these works. He will also consider of the means and time required, and the effect which might be produced by scarping the banks of the river.

3. He will make the same calculations for the works to be executed on the hill in front, and on the right of Cadafoes; particularly on the left of that hill, to shut the entry of the valley of Cadafoes.

4. He will examine and report upon the means of making a good road of communication from the plain across the hills with the valley of the Cadafoes and the left of the proposed position, and calculate the time and labour it will take.

5. He will examine the road from Otta Abringola, Labougeira to Merciana, and thence to Torres Vedras; and also from Merciana to Sobral de Monte Agraça. He will also examine and report upon the road from Alemquer to Sobral de Monte Agraça.

6. He will intrench a post at Torres Vedras for 5,000 men. He will examine the road from Torres Vedras to Cabeça-de-Montachique, and fix upon the spots at which to break it up might stop or delay the enemy; and if there should be advantageous ground at such spots, &c. will intrench a position for 4,000 men, to cover the retreat of the corps from Torres Vedras.

7. He will examine the position of Cabeça-de-Montachique, and determine upon its line of defence, and upon the works to be constructed for its defence by a corps of 5,000, of which he will estimate the time and labour.

8. He will intrench a position for 4,000 on the two heights which command the road from Sobral de Monte Agraça to Bucellas. He will intrench a position for 400 men on the height of St. Ajuda, between Sobral and Bucellas, to cover the retreat of the corps from Sobral to Bucellas; and he will calculate the means and the time it will take to destroy the road at that spot.

9. He will construct a redoubt for 200 men and three guns at the windmill on the height bearing east by south and east south-east from the height of Sobral de Monte Agraça; which guns will bear upon the road from Sobral to Arruda.

10. He will ascertain the points at which, and the means by which, the road from Sobral to Arruda can be destroyed.

11. He will ascertain the time and labour required to intrench a position which he will fix upon for 2,000 men, to defend the road coming out of Arruda towards Villa Franca and Alhandra.

12. He will fix upon the spots at which the road from Arruda to Alhandra can be destroyed with advantage.

13. He will construct a redoubt on the hill which commands the road from Arruda, about one league in front of Alhandra.

14. He will examine the little rivers at Alhandra, and see whether by damming them up at the mouths he could increase the difficulties of a passage by that place; and he will ascertain the time, labour, and means which this work will require.

15. He will fix upon the spots and ascertain the time and labour required to construct redoubts

upon the hill of Alhandra on the right, and prevent the passage of the enemy by the high road, and on the left, and in the rear, to prevent by their fire the occupation of the mountains towards Alverca.

16. He will determine upon the works to be constructed on the right of the position upon the Serra de Serves, as above pointed out, to prevent the enemy from forcing that point; and he will calculate the means and the time required to execute them. He will likewise examine the pass of Bucellas, and fix upon the works to be constructed for its defence, and calculate the means, time and labour required for their execution.

17. He will calculate the means, time and labour required to construct a work upon the hill on which a windmill stands, at the southern entrance of the pass of Bucellas.

18. He will fix upon the spots on which signal-posts can be erected upon these hills to communicate from one of these positions to the other.

19. It is very desirable that we should have an accurate plan of this ground.

20. Examine the island in the river opposite Alhandra, and fix upon the spot and calculate the means and time required to construct batteries upon it and play upon the approach to Alhandra.

21. Examine the effect of damming up the river which runs by Loures, and calculate the time and means required to break the bridge at Loures.

WELLINGTON.

Upon the letter of these instructions the position of Castanheira, thirty-two miles in front of Lisbon, was commenced to be retrenched on the 8th January, 1810; but Lord Wellington, on a second personal reconnoissance of the ground on the 10th February following, perceiving that it was a line open to be turned, ordered the works to be filled in.

NOTE 2.—Reference, page 9.

SIR, VISEU, *February* 18, 1810.

As the works carrying on under Lieutenant-Colonel Fletcher may require the employment of persons in the country, and the use of materials, without waiting for the employment of those persons or the purchase of those materials by an officer of the Commissariat, I have to request that all orders for workmanship, labour or materials, drawn by Colonel Fletcher upon the Deputy Commissary-General at Lisbon, may be paid; Colonel Fletcher being held accountable for the money.

I have also to request that the Deputy Commissary-General at Lisbon may be directed to supply Lieutenant-Colonel Fletcher with such numbers of fascines, palisades and picquets as he may require at such stations as he may point out, without waiting for further orders from me.

(Signed) WELLINGTON.

The Commissary-General, &c. &c. &c.

Note 3.—Reference, page 16.

Memorandum *sent to Lisbon during the Retreat of the Army.*

With a view to occupation of the works in the lines in the front of Lisbon, they must be divided into certain districts, and an officer must be appointed to command or regulate the troops in each. The troops (that is to say, the Militia, the British and Portuguese Artillery, and the Ordenanza Artillery) must be assembled in the district; and the officer commanding, or the regulating officer, must make the arrangement and distribution of them, to be carried into execution when it will be necessary by the advance of the enemy.

The Commissary-General of the British army must supply all the troops in these positions under the arrangement of June, 1809; and there must be a Commissary in each district.

No. 1. . . Tents for 2,500 men.	No. 4. . . Tents for 5,000 men.
No. 2. . . Tents for 2,000 men.	No. 5. . . Tents for 10,000 men.
No. 3. . . Tents for 5,000 men.	No. 6. . . Tents for 10,000 men.

No. 1 District.—Troops to be assembled at the head-quarters forthwith.

2,470 Militia Infantry.	140 Regular Portuguese Artillery.
250 Ordenanza Artillery.	70 British Artillery.

No. 2 District.—Troops to be assembled at the head-quarters forthwith.

1,300 Militia Infantry.	140 Portuguese Artillery of the Line.
300 Artillery of Ordenanzas.	40 British Artillery.

No. 3 District.—Troops to be assembled at the head-quarters forthwith.

400 Militia Infantry.	60 British Artillery.
60 Artillery of Ordenanzas.	

No. 4 District.—Troops to be assembled at the head-quarters forthwith.

1,100 Militia Infantry.	80 Portuguese Artillery of the Line.
500 Ordenanza Artillery.	

No. 5 District.—To be assembled immediately.

2,400 Militia Infantry.	120 Portuguese Artillery.
480 Ordenanza Artillery.	50 British Artillery.

No. 6 District.—Troops to be assembled at the head-quarters immediately.

700 Militia Infantry.	230 Artillery of the Line.
350 Ordenanza Artillery.	40 British Artillery.

The Districts are to be as follows:—

No. 1. From Torres Vedras to the sea. Head-quarters, Torres Vedras.

No. 2. From Sobral de Monte Agraça to the valley of Calhandrix. Head-quarters, Sobral de Monte Agraça.

No. 3. From Alhandra to the valley of Calhandrix. Head-quarters, Alhandra.

No. 4. From the banks of the Tagus, near Alverca, to the Pass of Bucellas inclusive. Head-quarters, Bucellas.

No. 5. From the Pass of Freixal, inclusive, to the right of the Pass of Mafra. Head-quarters, Montachique.

No. 6. From the Pass of Mafra to the sea. Head-quarters, Mafra.

W.

Note 4.—Reference, page 16.

The following is a copy of the letter of instructions under which the officers of Engineers acted as regulating officers in the several districts.

Head-Quarters, Rio-Major,
6th October, 1810.

Sir,

I enclose a memorandum, by which you will see the manner in which I have divided into districts the country which has been fortified between the Tagus and the sea, the objects for which this division has been made, and that you are appointed regulating officer of the district No. —.

I likewise enclose a list of the redoubts and works in that district, stating the number with which each is marked, the number of guns it contains, and the number of infantry deemed necessary for the defence of each.

The business of your situation as regulating officer of district No. —, is to arrange the troops in their several stations when they will be sent into the district to occupy the redoubts; to take charge of the mines intended to blow up the roads and bridges; and to carry my orders in the district into execution till an officer to command the troops within it will be appointed; you are then to assist him in making his arrangements as one of his staff, and in the defence of his post, with your professional abilities.

(Signed) Wellington.

Captain ————, Royal Engineers.

Note 5.—Reference, page 17.

In appreciating this distance of seven miles, it should be recollected that the number of men required to guard a position depends less on the extent of its front than on the facility of access to the several portions of it. Large armies with their numerous trains of artillery cannot engage across a country, particularly when the defensive force is strongly posted or retrenched; but their principal columns of attack must march by the great roads or open spaces. To ensure a victory over good troops, it is not sufficient to push up their position bodies of light and unsupported troops, or even strong columns with bayonets only, as Marshal Massena did at

Busaco; but a superiority of force of all arms must be brought to act conjointly on the point destined to be overwhelmed.

Being so, it is evident that the nature and number of the lateral communications within, and of the direct and lateral communications without a position, are main points on which the force necessary for its occupation depend. In front of the range of heights extending from Monte Agraça to Torres Vedras, the only exterior road parallel to its front (that of Runa) was blocked to an offensive force till after the capture of several strong redoubts; and only two direct roads, and those little distant from each other, lead over the range. This ground consequently possessed defensive capabilities which far more than counterbalanced its extent of front.

APPENDIX.

(Private.)

August, 1810.

Of Alhandra I hope we shall form a very strong position. I consider it now a strong position for 10,000 men, a fortnight hence I hope it will be thought the same for 7,000 men, and in a month I doubt whether more than 5,000 will be required for its defence.

Alhandra, however, does not altogether satisfy me as a position; I should fear that an enemy acting with a very superior force would penetrate by the hills on the left and get possession of the Serra in the rear of it—a movement which would not only turn all our defences, but might perhaps lead to the capture of the whole force in the position, as it would then find itself surrounded and its retreat cut off.

On riding over the ground above A dos Matos, it appeared to me, that a post for 1,500 men might be established there, which would effectually prevent such an enterprise. I feel diffident, however, in making the proposal; but, although no advocate for multiplying works, the necessity for creating some obstruction to the march of an enemy along the heights on the other side of the valley which bounds the left of the Alhandra position, is so thoroughly impressed on my mind, that I believe I shall suppress all other feelings and write to you officially on the subject; perhaps a strong work for a battalion on the rear Serra itself might answer every end. When the mind is deeply engaged on any object, various thoughts and ideas occur which appear reasonable to the person forming them, and yet are in themselves absurd and will not bear investigation. Such, perhaps, is my case now, but I cannot avoid thinking that Alhandra should not be left an isolated position, but be joined to the Ajuda works, and that 2,000 men strongly intrenched on its left would serve to connect the country into one defensive line from the Tagus to the Ajuda valley.

Lisbon, 29th August, 1810.

Sir,

In consequence of your wishes I have now the honour to enter into some detail respecting the position at Alhandra and of the means to prevent its being turned. I enclose a paper of memoranda which I drew up yesterday when on the spot—it must

be read as relating to the state of work on Saturday next, and will, I hope, prove a satisfactory account of that strong position.

The ground on the opposite side of the valley on the left is a range of strong hills of a much superior elevation to any other ground near them, and connected by a regular descent with the hills in rear of the position.

At a point about a mile retired from the front of the Alhandra position this ridge terminates to its left with a bluff point, which overlooks all the country to the Ajuda works, at the distance perhaps in a straight line between them of less than three miles; at this spot it appears to me that a post might be formed for 1,500 men, extending completely across the ridge, one flank of which shall appui on the bluff point, and consequently overlook the country in that direction, and the other flank rest on the valley which forms the left of the Alhandra position, and its fire co-operate with the Alhandra redoubts in preventing the passage of an enemy through the valley.

This post would so thoroughly occupy these hills as to prevent the march of infantry to the rear otherwise than by the space of two or three miles between it and the Ajuda works, and it would leave the whole army at liberty to act in that difficult country, whilst the enemy would have the garrisons of Sobral and Alhandra in their rear, and I should conceive it too hazardous an enterprise for them to attempt. If that be admitted, it follows, that it would secure Alhandra from being turned by an enemy with or without artillery. I have one feeling of doubt on my mind, which it is my duty to state, and that is, the possibility of an enemy forcing the valley between the two works. I will here state what has been done to secure it, and if not judged sufficient, orders may be sent for further obstacles being created: at its entrance, eight 12-pounders, in inattackable situations, can shower down grape shot upon the enemy, and during a passage of half a mile they will always be under the fire of at least six pieces of that nature of ordnance, and for some part of the way under ten; the work now proposed will give an additional cross fire, and will prevent an entry into the valley by a collateral branch which exists about midway, and which is a most serious disadvantage: it is, however, to be recollected, that the fire of the artillery is from a very great height, and that much cover is created in the valley by hollow ways and steep rising grounds, and that in the night the fire of artillery will of course be uncertain; when an attack is expected, it will be proper to cut down the trees and place them as an additional obstacle across the valley, and also to level the houses, walls, &c. The works I propose to construct are three redoubts for 400 men each, mutually flanking each other, with a smaller work in advance to look down the valley in front, which the three forming the position cannot do: it is proposed to make them to resist cannon, and they being nearly a mile retired from the front of the Alhandra position, I do not think any enemy dare to bring up artillery for their reduction without having first forced Alhandra, for as the rear of that post will be open to our army and hid from him, he can never tell whether there be 4,000 or 14,000 men in it.

I have sent a hasty sketch from memory of the ground, but which I trust will be sufficient to point out the situation of the proposed works. The soil is very unfavourable for their construction; it will therefore require nearly two months to complete them from the day of their commencement.

(MEMORANDA REFERRED TO IN THE FOREGOING LETTER.)

The position of Alhandra, as now taken up, is formed of an isolated range of heights; its right bounded by the Tagus, its front, left, and part of the rear by a deep and difficult valley.

It may be viewed under the divisions of its front, left flank, and rear.

The front naturally subdivides into two parts: 1st. An extent of upwards of 2,000 yards on the left, which has been so cut and blasted along its summit, as to give it a continued scarp every where exceeding 10 feet in height, flanked in its whole length by musketry and cannon, and the approach to the scarp lying under a fire of grape shot: large general flanks have been established for that purpose, and redoubts have been erected on the summit for the security of the guns and troops, should any part of the position be forced. The second division of the front is an extent of 700 yards, more than half of it the low flat ground bounding the Tagus; the remainder is the slope of a hill of easy ascent, gradually rising from the low ground till it meets the artificial scarp. This whole length has been retrenched by a continued flanked line of a strong profile; across the low ground an advanced ditch has been added, flanked from the line ascending the hill, and which has likewise been made to answer as a powerful flank to the low ground generally. At the left extremity of this line, and at the point where the nearly inaccessible part of the front ceases, a redoubt has been thrown up.

The left of the position may be considered as having a front of half a mile. The ground is very high and steep, but not inaccessible. Two redoubts have been established there, the one on the most commanding point of the whole position, for 400 men and eight 12-pounders, the other on the left, for 350 men and six 12-pounders. A species of redoubt or flèche has been thrown up where the nearly inaccessible part of the front finishes on the left, for which perhaps 150 men should be apportioned, as in case of necessity they can support the front or flank as either may be pressed. Scarping and other impediments of that nature have also been attempted with success, so that the left flank may be considered only less strong than the front.

The rear of the position is above two and a half miles in extent. It is very open and of easy ascent, and one part of it is commanded by a range of hills, the occupation of which by an enemy would turn all our defences, and most probably cut off the retreat of the troops.

There are but three ways by which an enemy can get in the rear, or obtain possession

of the above-mentioned range of hills. 1st. By forcing his way through the valley on the left. 2d. By marching a column along the opposite heights of Calhandrix parallel to the left flank. 3d. By making a detour to his right of several miles. To guard against the first, a height detached in advance of the position on the left has been occupied by a work for 250 men and five 12-pounders, and which, from its situation and construction, is so strong, that it ought never to be forced: the fire from this work and from the redoubts, with an abattis, may, perhaps, be deemed sufficient to prevent an enemy from passing along the valley. The second passage might be impeded by the construction of a post for 1,500 men upon the hills parallel to the left flank: at present, to carry artillery by that route, it would be only requisite for the enemy to force the redoubt above Trancoso. The third method can only be properly opposed by the manœuvres of the general commanding the army; but its bad effects might probably be counteracted by the erection of a strong work on the rear range of hills, where it would be the object of an enemy to establish himself.

J. T. J.

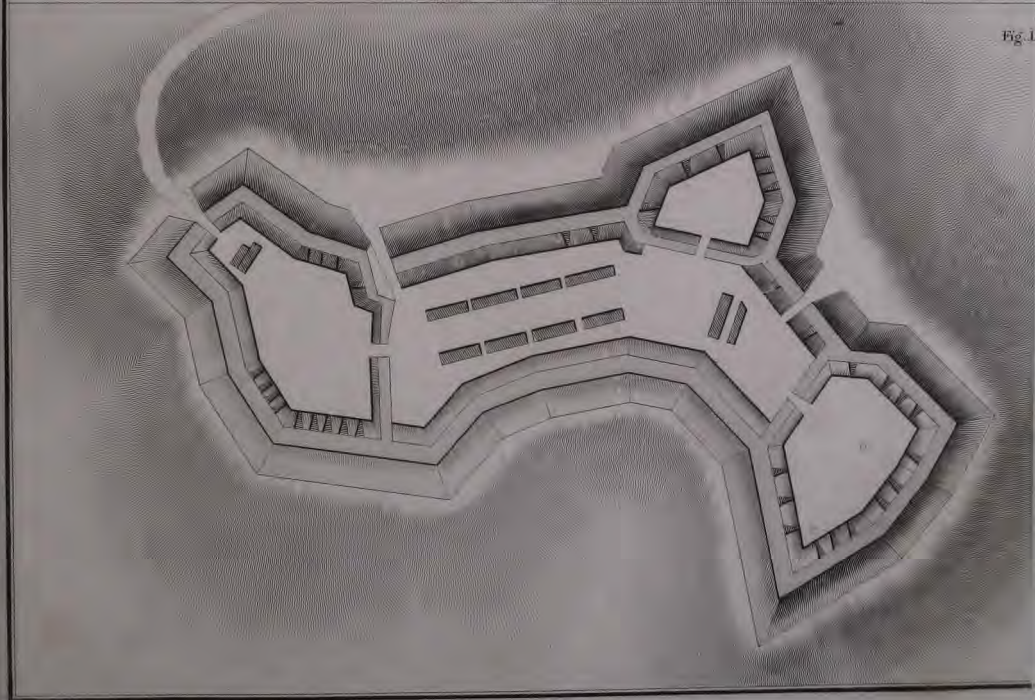


Fig. 2

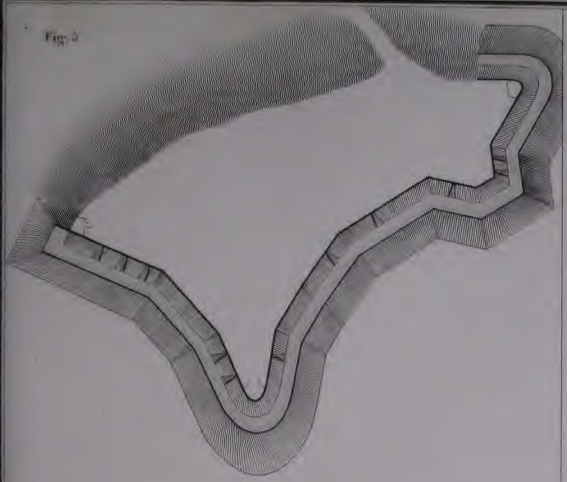
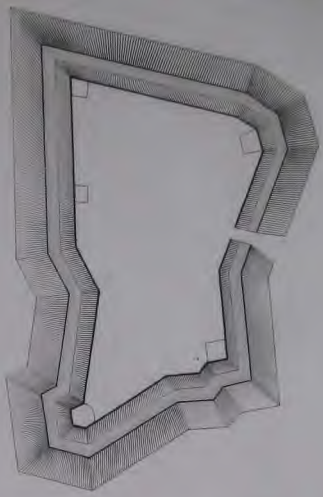


Fig. 10



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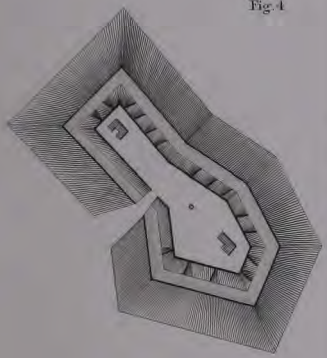

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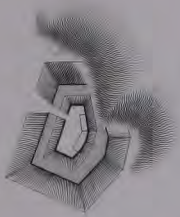

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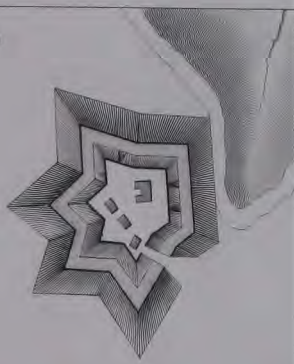

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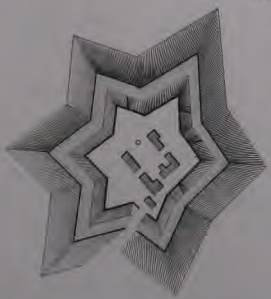
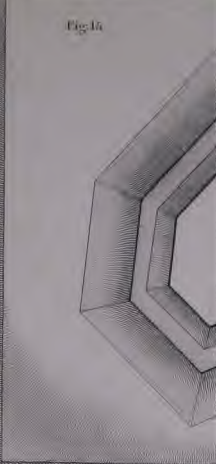
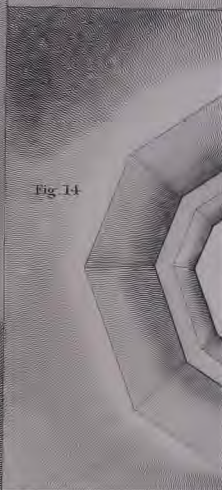
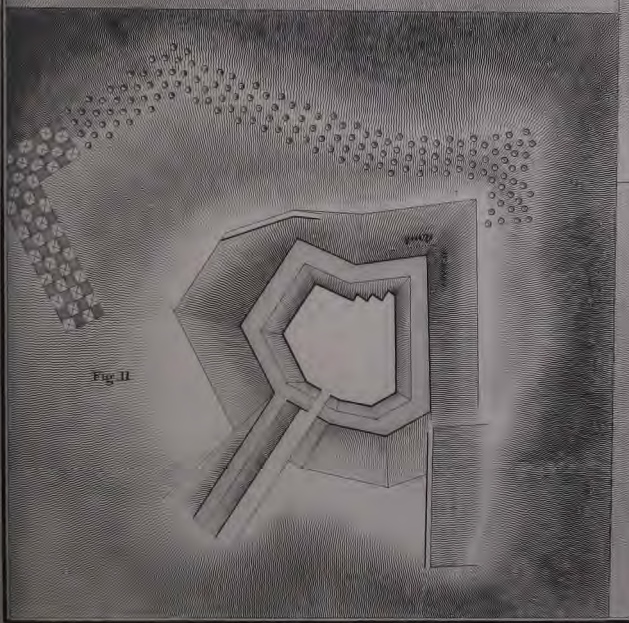


Fig. 6

Fig. 8







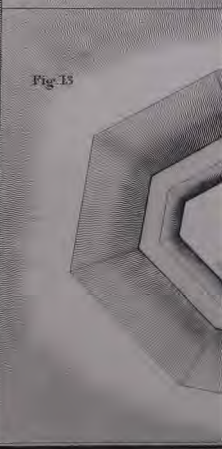


Fig. 18

Fig. 21

Fig. 25

Fig. 17

Fig. 20

Fig. 22

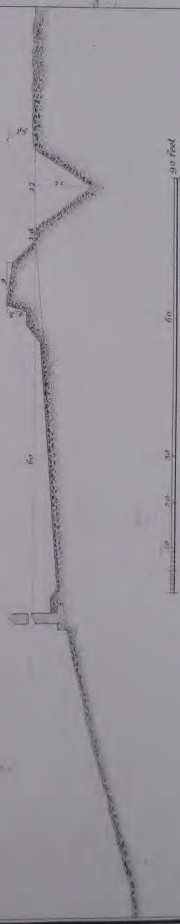


Fig. 16

Fig. 19

Fig. 25

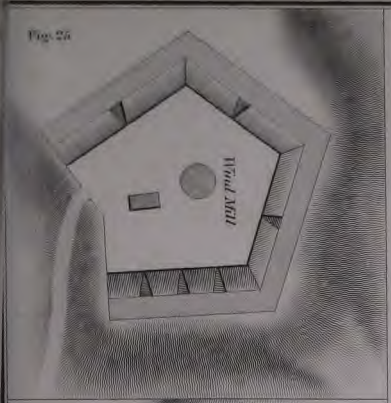


Fig. 26

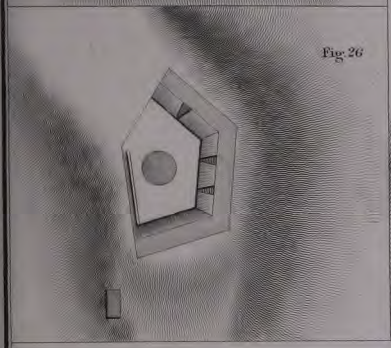
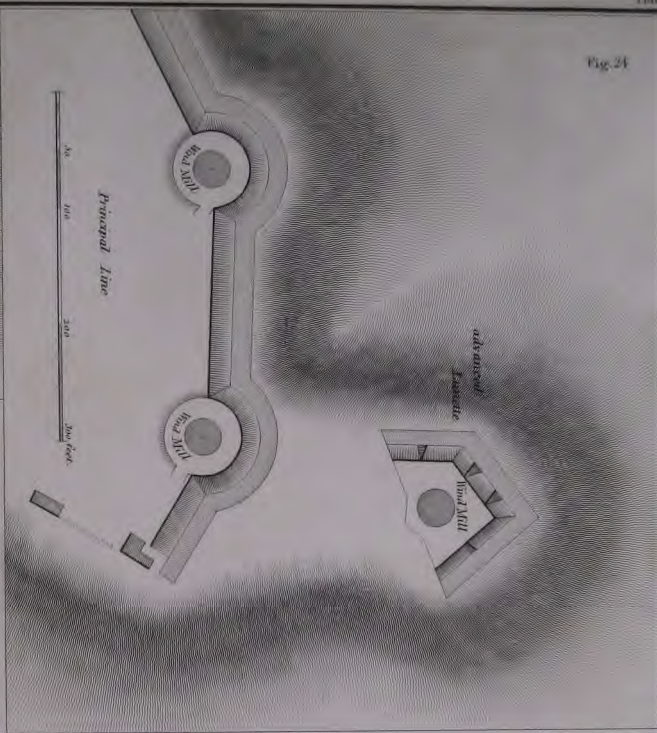
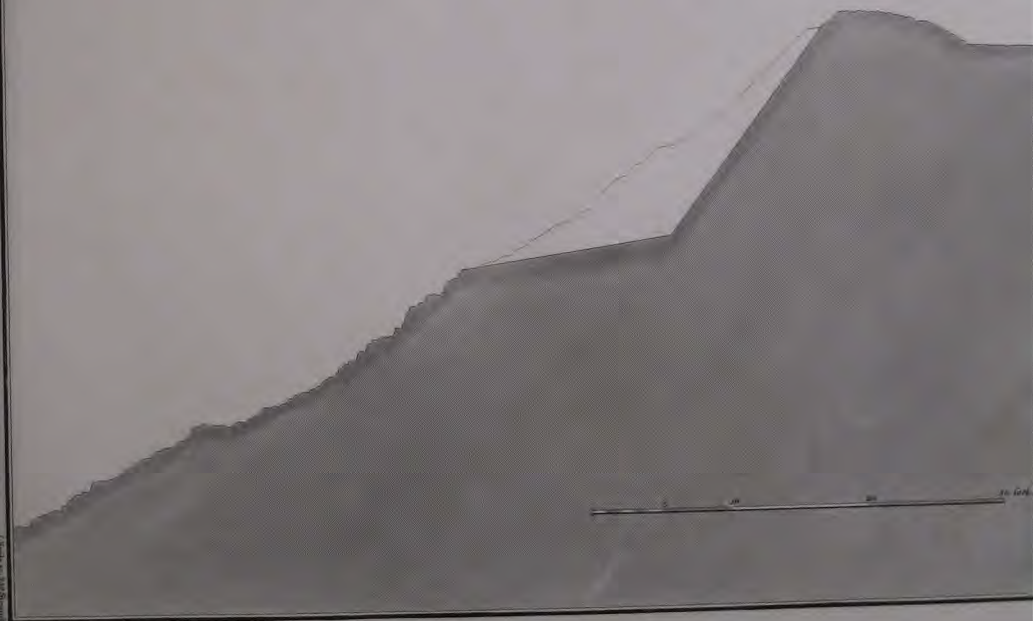


Fig. 24





II.—*Memoranda relating to the Defence of Cadiz, and explanatory details of the Position intrenched by the British troops under Lieutenant-General* Graham, *in* 1810.

The intrenched position of the Isla de Leon has been but little noticed by military writers upon the Peninsular War, although Cadiz was always considered a point of great importance, being a first-rate fortress with a noble harbour, and the only one which the French were unable to obtain; and as its preservation may in a great measure be attributed to the skill of the British general, aided by the labour of the British soldier, some account of the earlier operations and details of the works forming the intrenched position may not be uninteresting.

With this view the following Memoranda, relating to that position, have been drawn up; the details of the execution are the results of personal observation. The works were planned with great professional talent and ability by Captain Birch, who succeeded to the command of the Engineers upon the lamented death of Major Lefebure.

The following extracts from Lord Wellington's dispatches are given to show his opinions with respect to the system of defence which ought to be adopted whenever Cadiz should be threatened with an attack; and, in general terms, it may be said that all the measures adopted were based upon the principles suggested by his Lordship. The only point which might admit of a question, is that where his Lordship lays so much stress upon the necessity of disarming the forts along the shores of the bay. These works, having been constructed originally as sea defences, were not calculated to resist a serious attack from the land, and their capture by the enemy would have put them in possession of a great number of pieces of heavy artillery; but the gallant defence of Matagorda, and the long period it was held by the British, would lead to the inference that it would have been judicious, in

a military point of view, to have retained possession of Forts Santa Catalina, Matagorda, and St. Louis, and to have strengthened their land fronts.

LIEUTENANT-GENERAL VISCOUNT WELLINGTON, K.B. TO MAJOR-GENERAL WHITTINGHAM.

Badajoz, Dec. 22, 1809.

I have every confidence, not only in the patriotism and honour, but in the military abilities of General Vanegas, and I am convinced he will adopt every measure which prudence and skill can suggest for the defence of the place (Cadiz) entrusted to his charge. It occurs to me, however, that it would be most important to Cadiz to finish the work which has been commenced on the isthmus between Cadiz and the Isla de Leon, (the Cortadura or Fort St. Fernando,) and I would even go further, and would recommend the construction of another strong work at the Torre de Ercole, (Torre Gorda,) which would secure the communication with the Isla de Leon, and much impede the advance of the enemy towards the main body of the place. The defence of, and communication with, the Isla de Leon is a most important consideration for any body who is to conduct the defence of Cadiz itself; and the works constructed, and the troops employed in the defence of the Isla and the approaches to it, would be materially aided, and their retreat to Cadiz covered and secured, in case of accident, by the construction of the proposed work at Torre de Ercole. These are the points to which I would in particular draw the attention of General Vanegas if I were likely to see him.

TO LORD LIVERPOOL.

Jan. 30, 1810.

I also beg to draw the attention of His Majesty's government to a fact respecting the harbour of Cadiz, which has been stated to me, and which deserves their attention, and further inquiry from the officers of the navy, as being likely to influence their measures respecting Cadiz, even supposing that place should hold out till after the time at which the British army should evacuate Portugal. I understand that the channel by which large ships are obliged to enter and go out of the port of Cadiz lies to the northward, and is protected and commanded by the fire of the batteries on that side of the harbour, and not at all by that of the fort of Cadiz itself. These batteries had not been destroyed, or even disarmed, when I was at Cadiz in November, and I have not heard that they have yet been disarmed, although I have suggested, through a third person, to General Vanegas, the expediency of disarming them if he expected from the British navy any assistance in the defence of the place. Whether these batteries are destroyed or disarmed or not, it is obvious that if the only channel which can be used by large

ships is on the north side of the entrance, the enemy will have the command of it during any operations which may be carried on at Cadiz.

TO MAJOR-GENERAL THE HONOURABLE W. STEWART.

Viseu, Feb. 27, 1810.

I know that, however important to our interests that Cadiz should be defended and maintained, we can effect our object only by convincing the Spaniards that it is essentially their interest (as it really is) to maintain the place, and that we operate in its defence with a view to the importance of the preservation of the place, for their cause particularly, as well as for the general and British interests. They appear to me to hold the Isla de Leon more as the intrenched camp (and hardly as deserving of that name) of an army than as a fortified post, upon the possession of which every thing is to turn in future. I entirely agree with O'Farrell that if the Isla de Leon is lost, the town of Cadiz will not, and probably cannot, hold out a week. The Spaniards and we should deceive ourselves if we could suppose that a most serious attack will not sooner or later be made upon the Isla, or upon the communication between the Isla and Cadiz, which it would be in vain to expect to resist without having recourse to all the measures for the defence of these points which art can suggest. It is impossible to say whether the enemy will begin by making their great attack upon Cadiz, or will turn their attention to our situation in Portugal, but sooner or later all that force or art can do to obtain possession of the Isla de Leon will be done, and those efforts can be successfully resisted only by the adoption of similar measures. I would therefore suggest to you to get Captain Landmann[1] to examine particularly the Isla de Leon, and the communication between the Isla and Cadiz, without loss of time, and to consider of the general principles and plan upon which these important possessions ought to be defended. Let him then suggest the construction of the works which appear to him to be most necessary, working always upon the principle and plan which he would first have laid down for the defence of the Isla, and supposing always, which he may be sure will be the case, that there will be a sufficient number of men to occupy and defend the works, the construction of which he shall recommend.

TO LORD LIVERPOOL.

Viseu, March 6, 1810.

Although the Isla de Leon (the possession of which I consider essentially necessary to the possession of Cadiz) is naturally a very strong position, and the number of troops

[1] Captain Landmann was a British engineer, but had the rank of Colonel in the Spanish service. After the fall of Matagorda he was attached to, and employed solely with, the Spanish troops.

now at Cadiz are sufficient to defend it against any body which might attempt to carry it by assault, I do not consider the Isla to be in a state of defence against a serious attack, which will certainly be made upon it sooner or later, directed and assisted by all the resources which art can furnish, and made by all the French troops which can be assembled there from all parts of the Peninsula.

TO LIEUTENANT-GENERAL GRAHAM.

Viseu, April 8, 1810.

I am convinced the enemy cannot at present make a serious attack upon Cadiz. I have no doubt that they will take secure possession of the peninsula of the Trocadero, by which they will cut off the communication between the outer and inner harbour, and will probably affect, to a certain degree, the anchorage in the outer harbour, and a part of the town. I fear this cannot be avoided, and the only measure to be adopted is to place at once in the inner harbour the boats and vessels which may be deemed necessary for the naval operations to be eventually carried on there, and to secure, as far as possible, the landing places between Puntales and the town, and to form a communication with the Isla from the right of the Cortadura, and along the right of the existing road.

In February, 1810, after the fall of Seville, a French corps under Marshal Victor was ordered to march upon Cadiz. The Duke of Albuquerque threw himself, with his division of 8,000 men, into the Isla de Leon just in time to barricade the bridge of Zuazo, and to repulse an attack made upon it by the French. Upon the resignation of the Supreme Central Junta, a Regency was formed, who immediately ordered that the French and Spanish ships of war should be removed from the inner to the outer harbour, and caused the forts and batteries on the northern shore of the bay to be dismantled and destroyed. Lord Wellington, in pursuance of his instructions, immediately detached from his army a brigade consisting of the 79th, 94th, and 2nd battalion of the 89th regiments, with two companies of artillery, under the command of Major-General the Honourable Sir William Stewart, to assist in the defence of Cadiz. This force was soon after reinforced by the 20th Portuguese regiment, which the Regency of Portugal had offered for this particular service. The British general, upon his arrival at Cadiz, immediately perceived the great importance of occupying the fort of *Matagorda*,[2] and finding that the French had not

[2] This fort commanded the passage between the inner and outer harbours, and by its fire would

yet established themselves there, determined to take possession of it, and for that purpose he ordered a detachment of the 94th regiment, under the command of Captain Maclaine, and a detachment of the royal artillery, under Lieutenant Brereton,[3] to land, and to establish themselves upon the ruins of the fort; this was executed, and parapets of sand-bags were built during the night. Two 12-pounders were mounted, and by daylight the post was in a state of defence. A party of seamen from the ships of war, and additional pieces of ordnance of heavy calibre, were subsequently landed and mounted. A Spanish 74 gun ship, the St. Josef, and a flotilla of gun-boats were anchored above the fort, so as to bring as much fire as possible upon the village of the Trocadero, in which it was evident that the enemy would intrench himself, and erect batteries against Matagorda. Sand-bags were filled at Puntales, and sent across the bay in Spanish boats, the parapets were thickened, embrasures opened, but these necessarily were very oblique to the line of the parapet, in order to enable the guns to fire upon the village of the Trocadero. Traverses were erected, and 4 shafts were sunk at the back of the revetment of the face opposite Puntales, which were intended to be loaded with large charges of powder, to be exploded whenever it should be considered necessary to evacuate the fort: it was expected that the effect of these mines would be such as utterly to destroy the fort, and prevent the enemy from erecting batteries within it. As an additional security, and to prevent surprise, during the night an attempt was made, when the tide permitted, to cut a ditch across the narrow neck by which the fort was connected with the main land at low water. From the frequent interruptions[4]

prevent the erection of batteries on the only point from whence shot and shells could be thrown into the city of Cadiz. So long as it continued in possession of the garrison, the communication by water with the Isla de Leon would be preserved.

[3] At present Lieutenant-Colonel Brereton, C. B., K. H.

[4] The interruptions were occasioned by the following ludicrous circumstance:—Before the working party commenced, a corporal's picquet was sent in advance, in order to give notice, should the enemy approach. The workmen (Spaniards) were desired, whenever that should take place, to retire instantly, with their tools, to the foot of the escarp of the sea face, and there to remain quiet. After the work had commenced, some of the men struck their steel and flint, in order to light their cigars. The sparks startled the picquet, who immediately discharged their muskets and retired. The working party scampered off: the artillery fired a round or two of grape over their heads, and after waiting some time, and no enemy appearing, the picquet advanced, and the Spaniards resumed their work, to be again interrupted, after a short interval, from the same cause.

which were experienced, and being tide work, but little progress had been made at the period the enemy opened his fire upon the fort. Matagorda is 1,330 yards from Fort Puntales in the Isla de Leon, and 3,888 yards from the left bastion of the land front of the town of Cadiz. This fort was built of good masonry, and surrounded by the sea at high water; it was a square of 150 feet interior side, having a scarp 15 feet high, and without flanking defences; under the rampart of the land front was a magazine and a few store-rooms. This fort was erected for the defence of the inner harbour: its fire crossing with that from Puntales rendered it nearly impossible for any vessel to pass between them.

In the beginning of March, a reinforcement of British troops, consisting of the 88th regiment and a detachment of artillery, with some Spanish troops, were sent from Gibraltar to Cadiz, under the command of Major-General Bowes; and on the 24th of March, General Graham arrived from England with a division of British troops, about 5,000 men, composed of artillery, engineers, a brigade of guards, one battalion of the 95th rifles, and a company of the Royal Staff Corps.

In the beginning of April, the enemy were to be seen daily carrying fascines and gabions into the village of the Trocadero, by which it was evident that preparations were making for an attack; in order to retard his operations, a heavy cannonade was frequently directed against the points where it was supposed the works were constructing; and so riddled were the walls of the houses, that it was considered almost impossible for any batteries to have been thrown up behind them.

Notwithstanding, however, on the morning of the 25th of April, 1810, the enemy exploded several mines in the village, and threw down the walls, behind which he had erected batteries, containing 25 guns in embrasures, and a mortar battery in rear of them. The fire from all these batteries was, in the first instance, directed upon the Spanish 74 gun ship and gun-boats: they soon slipped their cables and ran to the outer bay. Having thus driven one opponent away, the whole of the enemy's fire was concentrated upon the small fort of Matagorda. After a few hours' firing, the parapets were destroyed; but by the gallant and persevering exertions of Lieutenant Brereton, of the Royal Artillery, and the garrison, a fire from seven guns was kept up as long as possible. The heavy and well-directed salvos from the enemy's batteries soon reduced the fort to ruins. The cannonading ceased with day-

light, only occasional rounds of grape being fired during the night. An attempt was made, during the cessation of the fire, to clear the batteries and restore the parapets, but little could be effected in this respect. A great error had been committed, which caused considerable trouble and inconvenience, as well as proving a serious impediment to the defence. As before stated, the embrasures were oblique to the line of the parapet, and from a desire to mount as many guns as possible on the faces of the two land fronts, the merlons terminated in a point on the face of the revetment of the scarp, and consequently had not sufficient thickness to resist cannon-shot; moreover, being built with sand-bags, when a shot struck the merlon, it either fell, or the greater part of the sand ran down and choked the embrasure, so as to prevent the gun from being fired. The platforms were too near each other, and the artillery-men were consequently very much impeded in working their guns. The following morning, the 26th, the enemy again opened his batteries; and as it was evident, from the body of fire which was incessantly directed against the fort, that it could not hold out, Major Lefebure, the commanding officer of British engineers, was sent by General Graham to examine the state of the fort, with discretionary authority to order its evacuation. That officer having ascertained that every exertion possible had been made and further defence impracticable, gave the necessary orders, and the garrison embarked in the boats of the men of war without interruption; but Major Lefebure, when about to descend the ladders,[5] had his head carried off by a cannon-shot, and thus the corps of engineers lost one of its most distinguished members. The garrison was carried off by the boats of the fleet in a gallant style, under a heavy fire; and Matagorda was abandoned to the French, who, although they held it for two years, were never able to fire a shot from it, so accurate and well-directed was the fire of the artillery from Fort Puntales, under Lieutenant Brett. The mines which, from a deficiency of powder, had been loaded with too small charges, necessarily failed in the effect intended. The enemy's fire produced a curious effect upon the masonry of that face of the fort opposite to the Trocadero; it was on this side, as being farthest removed from an attack by sea, that the store-rooms and magazine had been placed; the continued fire of the enemy breached the revetment, and laid open the

[5] The only means of communicating with the terre-pleine of the fort from the boats was by ladders.

interior of the casemates, while the rampart and parapet above, resting upon the arch, remained firm, and the artillery were able to continue firing. The detachment of the royal artillery was commanded by Lieutenant Brereton,[6] who, upon being wounded, was succeeded by Lieutenant Henry Wright.

The following letter from Lord Wellington shows the importance attached to the preservation of Matagorda.

TO VICE-ADMIRAL THE HONOURABLE G. BERKELEY.

May 2, 1810.

The loss of Matagorda is certainly a misfortune in a variety of ways. If, however, care has been taken to assemble within the inner harbour a sufficient quantity of craft to establish and secure the naval superiority there, it will not be of so much importance. If that has not been done, the Isla de Leon may be attacked in the rear as well as the front, and the whole line of communication will be open to attack; and I am afraid they will not be able to hold it.

Immediately Matagorda had fallen into the hands of the enemy, and put him in possession of the nearest land to the city, from whence, upon the erection of batteries, shot and shells might be easily thrown into it, and the shipping of every description obliged to move beyond the range of artillery, to a more exposed anchorage, every exertion was used to strengthen Puntales. This fort is situated in the Isla de Leon, opposite Matagorda,—was erected to act in conjunction with it, and, by the united fire of the two forts, to prevent vessels passing to the inner harbour, the distance between them being only 1,330 yards. Puntales is of a square figure, about 160 feet of a

[6] The case of Lieutenant Brereton may be adduced as an example of the great injustice entailed upon the subalterns of artillery and engineers by the present organization of their respective corps. For the gallant defence of Matagorda, every officer, as well as the hospital mate, received promotion, save and except the officer of artillery, who was the only officer wounded, and whose duties required him to be constantly in the most exposed situations, the defence being confined entirely to the artillery service. Lieutenant Brereton never received the slightest reward for his gallant conduct on this occasion, although acknowledged to be entitled to it. The reason assigned was, that "the rules of this branch of the service did not permit of his being promoted;" and from the same cause, not a single subaltern of engineers who was employed at either of the assaults of Ciudad Rodrigo, Badajoz, and St. Sebastian, received promotion; nearly all of whom are still captains in the corps, having held that rank from *twenty-three to twenty-five years and upwards.*

side. The rear or land front consists of two demi-bastions, with very long faces, connected by a short curtain: the two sides had very bad and short flanks, and in the centre of the sea face was a small *Redan*. The interior of the fort was divided into two parts, forming an upper and a lower battery: the communication to the upper was by a ramp from the lower, and from this to the country by a gallery running under the upper battery, with a drawbridge across the ditch of the land front;[7] heavy artillery was mounted upon all the ramparts of the fort, and a few hundred yards in rear of it two mortar batteries were constructed, from all of which a heavy fire was for some time directed upon Matagorda, and on those points in rear of it where the enemy had begun to throw up intrenchments and establish batteries. The upper and lower batteries had been armed with mortars, 24-pounders, and heavy howitzers, firing through embrasures. The concussion of the guns soon began to shake the masonry: the materials which best resisted the concussions caused by the firing of the guns were green hides, fastened with thongs on the superior slope in the middle of the merlons, and also on the exterior face of the parapet; but the sun, which at this season began to be very powerful, had such an effect upon the hides, that the effluvia caused thereby made them so offensive that they were necessarily discontinued; and after various attempts to preserve the cheeks of the embrasures with fascines and gabions, the embrasures were filled in, and the guns mounted upon traversing platforms. The interior of the fort was perfectly open without a single traverse, which was the cause of a great many casualties taking place. A good deal of inconvenience was occasioned by the space required for the recoil of the 8-inch howitzers when fired with the great charges necessary for long ranges; several plans were tried to check the recoil, by raising the tail of the platform with a much greater slope than the front, and at the back of this fascines were placed; but the most effectual mode was by a block of wood formed in the shape of a double wedge, one side rising much more rapidly than the other: these blocks were

[7] The only casemated cover was a small magazine, guard-room, and chapel, near the entrance gate. A large building, which had been erected on the terre-pleine of the lower battery, was soon riddled by the enemy's shot, and rendered uninhabitable.

The Escarp, land front, was 28 feet high,
Counterscarp . . . 10 ... ...
Escarp, sea front . 18 ... ...
above high water mark; and all built with good substantial masonry.

placed at 4 or 5 feet distance from the wheels before the howitzer was fired.[8] Sand-bags answered remarkably well for the moment, but in a short time they became rotten, burst, and a great deal of labour and time was required to clear the interior of the fort and restore the traverses with materials of a more lasting nature. Fascines[9] were found very troublesome to use as a revetment for the mortar batteries, which were thrown up in the sandy ground in the rear of the fort—there was a difficulty in getting the pickets to hold the fascines, and the concussion from the 13-inch mortars, when fired with heavy charges, had the effect of shaking the parapet so much that a few rounds soon brought the interior down: in order to guard against a recurrence of this evil, the platforms were laid at double the usual distance from the parapet.

Plate 7. The island of Leon is of a triangular figure, the base of which, formed by the river *Sancti Petri*, is nine miles in length (following the course of the river). The two faces, which unite at Torre Gorda, are washed, one, ($5\frac{1}{2}$ miles long) by the Atlantic Ocean; the other, ($4\frac{1}{2}$ miles long) by the waters of the bay or inner harbour. From the apex of the triangle at Torre Gorda a narrow isthmus projects into the sea a distance of five miles, at the extremity of which stands the city of Cadiz: at 4,800 yards from Torre Gorda the isthmus is intersected by the fort of St. Fernando (Cortadura), from whence it increases considerably in breadth. The city of Cadiz is strongly fortified, and presents but one front of fortification across the isthmus, with counterguards, ravelin, ditch, covert-way, and glacis countermined. Of the remaining fronts of the town, the scarps are washed by the sea. In the centre of the isthmus runs the Calzada, or high road to Cadiz, bounded on each side with substantial walls about ten feet high. The intervening space between the road and high water mark is a deep sand; but at half ebb the sands were firm, and made an excellent road both for carriages and horses. The eastern side

[8] The following circumstance will show one of the disadvantages of brass ordnance, where a heavy fire is required to be kept up. Two 13-inch and two 10-inch brass mortars were placed in the bastions of the land front: one day a shell was brought up to one of the 13-inch mortars; when the gunners attempted to put it into the muzzle, it would not enter; and, after repeated vain attempts, it was discovered that the mortar had dropped at the muzzle, and was thereby rendered useless. From the same cause, several 24-pounders were rendered useless.

[9] The fascines, after they were dried by the sun, became useless, and were replaced by wine barrels, as soon as a sufficient quantity could be procured from the commissariat; but these were difficult to use, owing to the difference in their size.

was used as the communication between the Isla and Cadiz, winding round the left bastion of the Cortadura, which was built across the Calzada. The Cortadura was intended for a square fort, but at this period, only the Isla front with the demi-bastion of the east and west fronts had been erected.[10] When the British troops under General Graham arrived, the Spaniards were occupying the line of the *Sancti Petri* river, and the Caraccas or royal dock-yard on the left, in advance of the river; also a fortified post at the Portazgo, or turnpike, where the high road from Chiclana unites with the Camino Reale from Seville, and Puerto Reale. This position was occupied by Spanish, English, and Portuguese troops as follows :—

4,068 Spaniards encamped at Sancti Petri.
4,000 — Caraccas and Puenta Suazo.
868 Town of La Isla. 79th British regiment.
1,249 Town of St. Carlos. 20th Portuguese ditto.
113 Town of La Isla. British artillery.
1,266 Spanish artillery, stationed in the different batteries.
1,272 { Sierra de los Martires. / Towns of La Isla and St. Carlos. } Spanish cavalry.
Total,—Infantry, 10,185: Cavalry, 1,272: Artillery, 1,379.

The river Sancti Petri,[11] which separates the island of Leon from the main land, and forms a deep water communication between the Atlantic Ocean and the inner harbour, varies in breadth from 200 to 300 yards. This river runs through an extensive marsh, intersected with several large creeks or rivers, all running into it from the enemy's side. In the marsh are salt-pans innumerable, separated from each other by narrow footpaths. At low water spring tides certain parts of the river are fordable. The marsh itself formed a very strong feature of defence, impassable for large bodies of men; and although troops in Indian file might move across it by the paths formed between the salt-pans, still it required an intimate acquaintance with them to be enabled to do so, as numerous trenches and ditches were made to cut off

[10] On each flank, down to low water mark, a strong barrier was formed by the iron railings taken from the balconies of houses.

[11] The Spanish flotilla in the river Sancti Petri consisted of forty gun and howitzer launches, divided into four divisions, and stationed at the Caraccas, Bridge of Suazo, Gallineros, and Sancti Petri.

the communications. The salt collected from the pans, and formed into large mounds from 10 to 15 feet high, afforded excellent cover for picquets; from the tops of them great command was obtained over the surrounding marsh. Several were prepared as batteries, and armed with field-pieces. Along the advanced or exterior line occupied by the Spaniards, batteries for heavy guns had been thrown up on all the principal points, to fire upon the different branches of the river as well as upon the approaches to it from the enemy's lines.[12]

The Caraccas, or royal dock-yard, surrounded by a deep creek, had numerous batteries constructed for its defence, on which were mounted 150 pieces of heavy artillery. Being situated at the extreme left of the line, it was a post of great importance, and might be considered almost impregnable with common vigilance on the part of the defenders. Great danger was to be apprehended from the quantities of combustible material in store-houses, which, if once set on fire, it would have been beyond the power of the garrison to extinguish. The line-of-battle ship Pluton, of 74 guns, by great neglect on the part of the Spaniards, had been allowed to remain in the river; advantage was taken of this circumstance to convert her into a floating battery to flank the front of the Caraccas facing the bay; she was hauled into the proper position, and her broadside presented a very formidable flanking fire. The Portazgo battery, one mile in advance of the Puente quays, was merely a mud work with 3 or 4 guns in embrasures to enfilade the causeway, across which a cut had been made, and the excavation from it assisted to form the parapet, leaving an imperfect and bad ditch, without palisades or other obstacles to arrest the advance of the assailants.

Plate 7. From the above description of the advanced line, and of the works constructed for its defence, it will appear to have been an excellent position for the Spanish force allotted for its defence; to this sort of warfare of fortified posts and intrenchments, they were better suited than if placed in a position where manœuvring would have been required. The interior position was so varied in character, and in the nature of the ground, that it requires to be divided into four parts, viz., right, right centre, left centre, and left. The right, from the sea to the foot of the Sierra de los Martires, was a flat

[12] All these batteries were open in the rear, and consequently were not regarded as defensible posts against an enemy who should have crossed the river.

sandy plain; the right centre, to the town of La Isla, running along the crest of the limestone ridge above Gallineras, was bold and open, having a fine command over the marshes in front; the left centre was low, skirting the marshes in front of the town of La Isla; and the left along the more elevated ground on which the new town of St. Carlos had been commenced, having a tolerable command over the intervening marshy land between it and the river in rear of the Caraccas. All this part of the position was very much intersected with high walls, hedges, and small enclosures, which rendered the communication from the right to the left extremely difficult, except by the principal street of the town of La Isla, which was upwards of a mile in length. Upon this line 15 redoubts and several advanced flèches were constructed, all armed with heavy artillery. The redoubts were placed upon the most commanding points, so as to bring every part of the ground in front under their fire, and as far as was practicable to cross with the fire from the collateral works, which were seldom more than 400 yards distant. They were not connected by lines of intrenchments; the intervals between them were intended for the movements of field-batteries and columns of infantry. And for field-guns to act in advance of the redoubts, the ground was, in the most favourable situations, levelled, and epaulements thrown up to protect them from a flank fire.

Before entering upon the details of the execution of the works, it will be proper to insert the General Order issued to the troops by General Graham, by which it will be apparent how much alive that distinguished officer was to the importance of the soldier wielding well the pick-axe and shovel: and it is gratifying to state that the greatest cordiality and good will existed between the troops and engineers; great zeal was shown by the soldiers, and, under the daily inspection of the Commander of the Forces, the works advanced rapidly, and soon assumed an imposing appearance.

GENERAL ORDERS.—46.

Isla, May 1, 1810.

The immense importance of keeping possession of the Isla, as a position covering Cadiz, is obvious; and though nature has done much to make it strong, nothing that art can do to render it still more so should be neglected.

The Spanish troops have been and are busily employed in the construction of the batteries of the first line. It remains to form a great intrenched camp, as it were, of

the whole ridge of the island, so as to effectually check the progress of the enemy, should he succeed in penetrating at any point of the first line.

The plan of the necessary works for this purpose being now agreed on, it is the Lieutenant-General's determination to give the most active assistance in the execution of them.

It is needless to remind the troops under his command, that this kind of service is one of the most essential duties of soldiers; and, like every other, ought to be cheerfully and diligently performed. Though the men will work under the immediate direction of the officers of engineers, it is nevertheless the bounden duty of every officer and non-commissioned officer present, to be vigilant during the whole time, and to prevent any negligent or improper conduct in the men.

It was considered so entirely in this light by that most distinguished officer, the late General Sir Charles Stuart, in circumstances of a similar nature, that his orders were, "That every *officer, non-commissioned officer, and soldier, not on duty*, should *every day* be *employed* on the works of Fort St. Phillip, in Minorca, till the line was completed."

The Lieutenant-General well recollects that in consequence, he, in command of the 90th regiment, as well as all the other commanding-officers of battalions, and every field-officer, did for several months give constant attendance with their respective regiments so employed.

The Lieutenant-General, wishing to render this service as easy to the officers as possible, will at first only call for a proportion of them, in the hope that, by their attention, no greater number will be required.

It is his intention, however, gradually to increase the working parties to as great a number as possible; and for the convenience of the execution of those works at a considerable distance, a camp will be formed, where the same detachments will remain at least a week before being relieved.

It is as much a soldier's duty on service before an enemy to work as to fight, without any additional pay. No man has any right to any additional allowance of any kind on account of this service; but the Lieutenant-General, following the practice established in Minorca, where General Sir Charles Stuart directed that all those men who were not marked down idle or disorderly should receive, as an indemnification for the wear and tear of necessaries, sixpence per day (the day to be reckoned eight working hours), will order that the proper department should pay the men employed on the works at that rate, upon the certificate of the commanding-officer of engineers.

In order to give effect to the above-mentioned system, the following regulations will be observed:—

1. All officers and men warned for working duty will consider themselves as attached to it for one week, until further orders.

2. That the works may be performed with as little inconvenience as possible, the

commanding-officers of working parties, in concert with the officers of engineers, will regulate the working hours, beginning very early in the morning, intermitting during the heat of the day, and completing the day's work of eight hours, in the evening.

3. The men not employed within reach of their quarters will have the benefit of some tents to shelter them from the sun during the intervals of work, and their dinners will be sent out by their respective battalions at stated hours.

4. Rolls will be called, and all men absent will be marked off as idle, and not to be included in the additional pay-list, besides being liable to such other punishment as the case may require.

5. Though it may not be possible to give separate work to the men of each battalion, yet, in a distribution of squads, the men of the same regiments will be kept as distinct, under charge of their own officers and non-commissioned officers, as possible.

6. It will be the duty of the officers of the engineer department to report any idle or disorderly conduct to the officers of the respective regiments, and, if necessary, to the commanding-officer of the department.

7. Notwithstanding the second article, fixing the day's work at eight hours, it is left to the commanding-officer of engineers to commute, according to his judgment, a day's work into the execution of a certain task, to those men and squads willing to undertake the same; and the men having finished this work are to be considered as free from further labour on that day.

8. With the approbation of the commanding-officer of the working party, who is especially enjoined not to allow any men to work during the interval, which the heat of the sun in this climate renders necessary, the officer of engineers may, if he choose, employ such squads as have finished their task early, and are willing to go on in the afternoon, in such further task-work as may amount to a quarter or half day's work more.

9. Where the case requires night-work, it will be done in the same proportion of eight hours' work, with such interval for rest as may be expedient.

The Portuguese regiment will not be included in the detail of the working parties, as it is the Lieutenant-General's intention to employ them in a separate work, near their own quarters.

The guards of the St. Juda's and St. Angelo's batteries will be taken off until further orders.

The in-lying picquet will consist of 3 captains, 4 subalterns, 9 serjeants, 4 drummers, and 300 rank and file, until further orders.

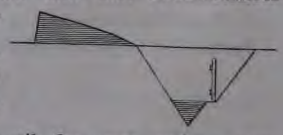
The same working party will parade, at the same hour and place, to-morrow morning, and will consider themselves on this duty for a week.

For the duty of general officer for the day to-morrow,—*Colonel Wheatley.*

(Signed) JOHN MACDONALD, A. A. G.

The working parties were visited twice a day by the field-officer on duty, once at least by the general-officer for the day, and generally twice a day by General Graham.

From the foregoing description of the features of the position to be intrenched, will be understood the difficulties which the executive engineers had to encounter in the construction of field-works; for it must be borne in mind that scarcely materials of any description could be obtained for revetting the parapets, excepting a few sods for three or four of the redoubts on the Sierra de los Martires, and this resource soon failed. Not a stick of any kind, available for fascines or gabions, could be procured on the island. The troops were unaccustomed to the use of the pick-axe and shovel, and the difficulty of making the men extend themselves properly to work with advantage was very great. They did there, what I have experienced with military working parties within the last few years,—crowd together, and thus hinder each other from working with proper effect. The weather was extremely unfavourable when the works were commenced, which added very considerably to the difficulties. All was hurry and haste to get the position intrenched, as the enemy was strong, and evidently making great preparations for an attack. 1,300 British and Portuguese soldiers were employed daily, commencing at 4 o'clock in the morning, until 8 A. M., and from 4 P. M. until 8 P. M. All the carpenters and sawyers from the regiments, about 80 in number, under an assistant engineer, were detached to the Caraccas, to convert the timbers, from such buildings as the Spanish authorities pointed out to them, into platforms and splinter-proofs, and for which the British government were obliged to pay; and although paying for the timber used on the works thrown up solely for their own defence, it was with great difficulty that an adequate supply could be obtained, and what was furnished was of a very bad description. The figure of the redoubts generally was that of a square from 130 to 150 feet of a side (interior), with a ditch 20 feet wide at top, and 10 feet deep, with a row of palisades running along the foot of the counterscarp. The works were armed with eight or ten pieces of heavy artillery, 18-pounders, firing en barbette. When time and circumstances permitted, the works were strengthened by raising the parapets and forming embrasures, which was effected without a single shovelful of earth of the original work requiring to be moved: the ditch was sunk six feet deeper, until the scarp and counter-



scarp nearly met in a point, leaving the palisades undisturbed on a step which still kept them under the musketry fire of the parapets: the escarps were increased in height by it, and no footing could be obtained in the bottom of the ditch for a body of men. This description applies more particularly to the works on the right centre, and in other parts of the position where the soil permitted such a construction. In throwing up the works in the marsh, it was found necessary to excavate the ditches from 70 to 100 feet in advance of the parapets. Until this plan was adopted, the weight of the parapets constantly forced in the sides of the ditches before they were excavated sufficiently deep to admit of their being filled with water at high water spring tides. When once this was accomplished, they became some of the strongest works in the position. Great difficulty was experienced in keeping clear the old road between Nos. 14 and 15, across the sandy plain, intended as the ditch of an intrenchment, and which was several times filled with water. A sirocco would set in, driving the sand before it from Sancti Petri, and in one night fill it up, not leaving a sign that any ditch had ever been made.

Figs. 1 to 6, Plate 8.

Figs. 7 to 11, Plate 8.

Near No. 13 redoubt there were several bomb-proof magazines; these were intrenched, a ditch excavated 10 or 12 feet distant from their enclosure wall, banquettes formed of earth inside, the walls pierced with loop-holes, and the interior fitted up as a barrack.

In the hurry of commencing the works, and without levels or other instruments of any kind, every distance was marked by pacing, which, owing to the fall of the ground, caused great errors; and great difficulties were experienced in consequence when the ditches were deepened, and the slopes and parapets trimmed and neatly finished.

Although the works were commenced in very bad weather, the dry season set in before the necessity of a good system of drainage was made apparent; the consequence was, when the heavy rains fell in the autumn, many of the half-sunken redoubts had 3 or 4 feet water standing in the interior, from which they were relieved either by the water forcing itself through the entrance, or carrying away large portions of the parapets; washing down the scarp, and injuring the foot-bridges; in every case causing great damage, and making a puddle of the interior of the work. This lesson was not lost upon me; for afterwards, when intrenching a position, I never allowed the working party to commence until drains had been made, in the best manner that the ground

Drainage.

and time permitted, either by stones, brushwood, or sods; and during the winter of 1813 and 1814, as well as in the positions intrenched by me in front of Salamanca and Tordesillas, in presence of the enemy, on the retreat from Burgos, not the slightest damage befel any of the works, although the greater number were constructed in very wet weather. The redoubts on the Sierra de los Martires were revetted with sods; the men were employed to cut a certain number as a task, 300 in each relief: this was easily performed, and great economy in this most important material was obtained. The ground was marked out for each man's task, each sod being 14 inches long, 9 inches broad, and not less than 3 inches thick. This prevented the men from ranging about to seek for ground most easily worked. From the experience gained here in building with sods afterwards, I invariably revetted my parapets from the natural ground, and not upon the new-raised earth, the level of the top of the banquette;—the consequence was, great solidity; and by paying particular attention to fill up settlements whenever they appeared at the back of the sod work, I never had a fall or a slip of any kind. After the wet season set in, and the parapets began to settle, I caused the superior slopes to be examined every morning, before the working party was told off; and whenever any cracks were discovered, two or three men were employed in filling and ramming them with great care. Another description of revetment was introduced by Lieutenant Roberts, who had been employed at Gibraltar, in imitation of the material of which the Moorish castle had been built: it was called Tapia, and was composed of fine gravel, earth, and lime, mixed together, and which being thrown into wooden boxes or frames, in layers of 3 inches thick, was well beaten by wooden rammers wedge-shaped. The boxes were 2 feet 6 inches wide, and 3 feet high, secured by iron bars passed through and keyed. This description of revetment answered very well when made only one box in height, and the upper surface secured from wet; a great deal of earth, as well as time and labour, were consumed in its construction; when finished it presented a very neat appearance.[13] In No. 3 redoubt this description of work was employed to support the rampart, and to gain space for splinter-proofs to be laid against it: after having been built 3 tier of boxes high, and the earth backed in, the weight was found too great, the pressure threw down

Sod revetments.

Tapia revetments.

[13] This work differs from the description employed in England, Ireland, and France, where a considerable quantity of straw is mixed with the earth.

the tapia, which filled the interior of the work, requiring much time and labour to clear it out. This description of revetment should only be adopted in a dry climate, and where other materials cannot be procured. Great attention is required to prevent rain from soaking into the body of the tapia; the upper surface should be covered with good mortar or other material to throw off water. The cheeks of the embrasures were usually revetted throughout their entire length; subsequent experience made me reject this mode, whether in masonry, sods, gabions, or fascines; the effects of the explosion when a gun is fired in an embrasure is to shake and bring down that part immediately adjoining the muzzle: in order to avoid this inconvenience, the better plan appears to be not to carry the revetting material quite so far into the embrasure, as the muzzle of the gun, when run home, projects beyond the interior line of the parapet. The platforms were laid of the usual size at that time adopted in the British service, 10 feet in front, 12 to 14 in the rear, and 18 feet in length, 5 sleepers and the planks spiked down to them; another plan was with a ribband laid over the ends of the planks, and screwed down to the outside sleepers: this is an excellent mode, quickly and easily executed, and the platform is firm, and stands remarkably well. Guns upon traversing platforms should traverse from the front, centre, or rear, according to their situation; and one great advantage possessed by the old wooden traversing platform is now lost, by the impossibility of altering the situation for the pivot in the field, it being absolutely necessary to state, when demanding the new pattern (iron) platform, where the pivot is to be placed, in order that, by the assistance of machinery at Woolwich, the pivot may be fixed in the position required. The evil of such an arrangement needs no comment. At No. 1 redoubt curves were directed to be prepared for 3 guns to traverse from the front; the platforms were sent by water from Cadiz; after running the gauntlet at Puntales, and delivered at the work, the pivot was found to be in the rear, but being made of wood, the carpenters soon remedied the defect: had these platforms been made of iron, they could not have been altered, and it would have been necessary to send them back to Cadiz to be exchanged. Thus great labour, expense, and inconvenience would have been incurred, and the consequences of the redoubt not being speedily armed might have been attended with great danger to the position.

Embrasures.

Platforms.

Traversing platform.

In throwing up earth-works it is of the utmost importance that the foundations should be as nearly horizontal as possible throughout the length of the

Foundations on hilly ground.

faces, and in the depth perpendicular to the slope to be formed, or otherwise great slips may be apprehended. By observing this rule I never had an accident; and in many situations on the side of steep hills, I have had slopes from 20 to 25 feet in height, which stood perfectly. In the annexed figure the shaded parts represent those portions of the ground which were cut away before the parapet or embankment was commenced; great attention was always paid to fill up any cracks which might have been made by the consolidation of the earth. The magazines in the different redoubts were generally made with splinter-proof timbers, laid against the reverse side of a traverse, and, when time permitted, covered with 2 feet of earth.

Magazines.

When the preparations made by the enemy gave reason to suppose that he meditated an attack in rear of the Cortadura, a large redoubt was thrown up on the sand-hills between Fort Puntales and the city of Cadiz; from the moving nature of the sand it was impossible to keep any thing like a ditch, which should present an impediment to the advance of an enemy. Advantage was taken of several hedges formed of aloes; these were carefully transplanted in the ditch, and, placing them 5 or 6 rows deep, they took root, and soon presented such a formidable obstacle that it was almost impossible to pass them; and thus, from being a very weak work, it became one of a very respectable character. The working parties were employed by task, and it is only those who have adopted that system who can fully appreciate its advantages: and after a little experience there was not any description of work of which a fair quantity could not be assigned as a task, whether in cutting sods, carrying sods, building with the same material, excavating, &c. Sometimes, in commencing upon a new work, the first day's task might either be too heavy or too light; but this soon corrected itself; the men worked with spirit, the tasks were always performed, and every thing left clear for the relieving party. Another great advantage arose from the greater ease with which 300 or 400 men could be set to work. The tasks having been measured and prepared beforehand, as soon as the party arrived on the ground, they were told off into the number of squads required, and the N. C. O. of sappers showed them their respective portions.

Task-work.

After adopting the system of task-work, when the soldier felt confidence in the engineer, and assured from experience that the quantity marked off was

fair, he would set to work cheerfully; all grumbling on his part, and complaints on that of the engineer, were avoided; and if different regiments were working near each other, a spirit of emulation was created that kept every body in good humour. On the retreat from Burgos in the year 1812, I was employed in intrenching the left of the army covering Salamanca; a midnight relief of the Guards arrived, and the men were told off to their work in the best manner the darkness of the night permitted, by extending them along the line marked for the ditch. Going round to ascertain that the men were distributed properly, a soldier addressed me, and said, "Mr. Jones, I wish you would give us a task, as you used to do at La Isla." There are certain descriptions of work that soldiers never execute willingly unless they have a task, as in wet soils, or rock, particularly; or any labour to which they have not been accustomed.[14]

As soon as the position of La Isla had been placed in a defensible state, Torre Gorda, a small circular tower, was intrenched and made as strong as possible: it was a very important point to hold, not only to cover the retreat of the troops from the position in front of La Isla, but also to arrest the progress of the enemy, it being impossible for him to advance upon Cadiz without being in possession of this post. The roads from the Isla and St. Petri

[14] The following anecdote will show what may be effected by task-work. In 1812 I was employed in repairing the great breach at Badajoz, and improving the defences of the front attacked: in the cunette at the foot of the counterscarp, where the light and 4th divisions descended into the ditch during the night of the assault, the greater part of those men who had been killed on the breaches were buried; it became necessary in the course of the progress of the repairs to remove their bodies; a company of Portuguese grenadiers were told off for this duty. After having shown them what to do, my attention was directed to parties employed on other parts of the works; in about one hour's time a report was made to me that the Portuguese grenadiers were all sick. I immediately ran to see what was the matter: the powerful effects of the sun in the narrow ditch, and the state of decomposition of the bodies, had turned all their stomachs; the whole company were lying down apparently in a state of great suffering: the effect at the moment was alarming; of course I sent the men away immediately; the next thing was to consider how such an immense mass of corruption could be removed; to do so was absolutely necessary, not only to prevent the probability of pestilence being engendered among the workmen and inhabitants, but also to enable me to proceed with the works. When the next relief came, I gave them a certain number of bodies to remove; after some hesitation, and reconnoitring their task, they proceeded to undertake it, but before commencing the work of removal, they stuffed their mouths and noses with grass, and this disagreeable and painful duty, which required several days, was executed without further difficulty, or any of the men suffering in their health.

unite here, and the breadth across from the Atlantic to the inner harbour is only 600 yards. As the enemy's preparations in the Trocadero gave reason to expect an attack in the neighbourhood of Puntales, the left bastion of the Cortadura, having an escarp of 34 feet, was cut off from the curtain by a ditch, and otherwise intrenched so as to form a strong post, being well situated to enfilade the high road from La Isla, and also by its fire to prevent the enemy's flotilla from disembarking troops on the sands between it and Fort Puntales. Redoubts in the rear of Puntales, and batteries to defend the landing places, were also thrown up, thus following the instructions of Lord Wellington of the 8th April, 1810.[15] There were 175 pieces of artillery mounted on the works of the interior position, and distributed as follows :

ENGLISH LINES.

Redoubt.		
No. 1	3 Guns	Traversing.
2	11 —	Embrasures.
3	6 —	En barbette.
4	2 —	Embrasures.
5	4 —	Barbette.
6	8 —	Do.
7	8 —	Embrasures.
8	2 —	Traversing.
	8 —	Embrasures.
9	10 —	Do.
	2 —	Traversing.
10	7 —	Embrasures.
11	8 —	En barbette.
12	6 —	Do.
13	3 —	Do.
	3 —	Traversing.
14	4 —	Do.
15	4 —	Embrasures.
Flèche	6 —	Do.
Do.	6 —	Do.

[15] The communication along the right of the Cortadura and existing road to La Isla, as suggested in Lord Wellington's dispatch to General Graham, was never adopted as the general line, partly from the circumstance that the left side had been heretofore used, and at high water there was no free passage on the right of the Cortadura.

Redoubt.			
St. Petri	16 Guns	. . . . .	Embrasures.
Contera	15 —	. . . . .	Do.
Contera	6 —	. . . . .	Traversing.
Torre Gorda	7 —	. . . . .	Do.
Sand Hill	11 —	. . . . .	Embrasures.
Do.	3 —	. . . . .	Do.
Do.	6 —	. . . . .	Do.
	Total 175		

The defence of Matagorda cannot fail to be a subject of interest and reflection to all military men: from it we may judge what would have been the effect upon the war in Andalusia if all the forts along the shores of the bay had been retained until the garrisons were driven out of them by the fire from the enemy's batteries. Matagorda was taken possession of by the British in the middle of February, and it was only on the 26th of April following that the garrison retired from it, having held it two months, and the enemy, before he could obtain possession of it, was obliged to construct batteries, and to bring heavy guns and ammunition from Seville. If he had been compelled to carry on a similar operation against Forts Santa Catalina and St. Louis, it is probable that the summer of 1810 would have been consumed in their reduction. To have blockaded them would have required a large force, well intrenched, in order to guard against sorties, which could easily have been made from any one of these points; the spirits of the inhabitants of Cadiz would have been greatly elated; the Guerillas in the mountains of Andalusia would have been more free to act and annoy the enemy; and the anchorage in the bay would have been available, instead of the ships of war and merchant vessels being obliged to anchor near the town in a very confined space, to be as far as possible from the reach of the enemy's shells, by which they were often annoyed from Santa Catalina.

A very sensible change was perceived in the feelings and actions of the Spaniards at Cadiz immediately Matagorda[16] had fallen into the hands of

[16] When the British arrived at Cadiz, detachments of monks from the principal convents used to go daily and exercise the 24-pounder guns on the sea batteries. Such conduct produced an excellent effect upon the crowded population within the walls of the town. It was certainly a very novel and interesting sight to witness a battery of twelve or fourteen guns thus manned; but this praiseworthy conduct soon ceased after the fall of Matagorda.

the French, who were thereby enabled, notwithstanding the long range, to throw shells into the town. The distance from the principal battery on the Trocadero to the market-place was 5,700 yards. The great importance of the possession of the Trocadero for the security of Cadiz became every day more apparent, and great anxiety was caused by the visible preparations made by the French for an attack, by collecting boats, &c. in the creek of the Trocadero, numbers of which were seen carried across the isthmus on waggons, and at one period it was expected an attempt would be made from the Trocadero to push across the inner harbour at night, and effect a landing somewhere in the neighbourhood of Puntales: to assist in this operation a battalion of seamen joined the blockading army. There can be little doubt, had Lord Wellington, during his visit to Cadiz in November, 1809, been enabled to have visited the Trocadero, and made himself acquainted with the locality, that he would have urged upon General Vanegas the importance of strongly fortifying it, and holding it equally with the Isla de Leon; more fears were entertained of an attack from the Trocadero than from any other point in the line occupied by the French, and several great advantages would have been gained by retaining it. 1st. The enemy would have been removed to such a distance from the city of Cadiz as to have relieved the inhabitants from all fears of a bombardment. 2ndly. As a position on the main land, it would have obliged the enemy always to have left a large force in that immediate neighbourhood, to repel the attacks which the garrison could at any time have made upon their position. 3rdly. The entire anchorage of the outer, and the safe communication with the inner, harbour would have been preserved; an object of great importance, as the watering place for the Spanish ships of war was at the Cantera Point in the Isla de Leon, the benefits of which were in a great degree lost to the fleet after the fall of Matagorda, as any vessel which attempted to pass from one harbour to the other was certain of being fired at as soon as she arrived in a line between the enemy's batteries and Fort Puntales; and the little communication that took place by water was generally effected at night. The loss of this easy and cheap mode of conveying provisions, stores, &c. to the Isla was severely felt;—to transport them by land was a work of great labour and expense, arising from the badness of the road, which was a deep sand nearly the entire distance between Cadiz and Torre Gorda.

It appears by a work styled "Comentarios de la Guerra de Espana, e

Historia del Rey Philipe," that the English attacked Fort Matagorda in 1702, and lost 600 men in an attack by assault. Trenches were opened and the fort cannonaded. The Spanish and French gun-boats gave much annoyance to the batteries, which were constructed of sand. Sorties were constantly made, and great injury done to the trenches, which could not be repaired during the day, while exposed to such heavy fire.

Here we have an instance where Matagorda saved Cadiz; and a perusal of the operations of the expedition under the Duke of Ormond, contained in the work above mentioned, will be found amusing as well as instructive to the military reader: and the promoters of the Joint Stock Company for raising treasure in Vigo Bay might also have derived some useful information from the same work, as the treasure is there stated to have been landed before the English destroyed the galleons.

On the peninsula of the Trocadero the French constructed numerous batteries for heavy artillery, and along the line of their position strong redoubts were thrown up on the commanding points, and encampments formed in their immediate neighbourhood, as well as near the towns of Santa Maria, Puerta Reale, and Chiclana, and opposite the entrance of the river Sancti Petri. Great labour was bestowed on these works, which were all enclosed, and heavy artillery mounted on them.

FRENCH LINES.

At Sancti Petri	14 Guns.	
Works in front of Chiclana	31 Guns.	
Redoubt between Chiclana and Puerta Reale	20 Guns.	
Do. in front of the Portazgo	9 Guns.	
Opposite the Caraccas	29 Guns,	2 Mortars.
Puerta Reale	33 Guns.	
Trocadero	104 Guns,	23 Mortars.
Santa Maria and Catalina	32 Guns,	5 Mortars.
Total	272 Guns,	30 Mortars.

Upon an inspection of the plan, it will be seen that the position occupied by the British was of great extent for the number of troops (5,000 men) allotted for its defence. From the right to the left of the Isla position was $5\frac{1}{2}$ miles, without the possibility of forming good communications from one part of the line to the other; the right was the best suited for the manœuvring

Plate 7.

of troops; large gaps in the aloe hedges were opened, so that bodies of infantry and artillery might move rapidly to the points attacked; and so far this might be considered a position in itself, for the only communication to the Suazo Bridge (the centre of the line) or to St. Carlos, the extreme left, was either by the principal street of La Isla, above a mile in length, or a narrow and bad road skirting the town and marshes; nor was it possible from any point to command a view of what was passing at either extremity of the line; so that in case of an attack, the General commanding would have been placed in a situation of great difficulty, as it may be supposed that the enemy would at the same time threaten all the principal points, and thus prevent any particular part of the position from being reinforced; and it might be expected that an attempt to land troops in the neighbourhood of Puntales would be made at the same time, which, if successful, would cut off the communication between the town of Cadiz and the position of La Isla; and his embarrassment would have been considerably increased by having the defence of the front line intrusted to the Spanish troops, in whom, whether justly or not, the British placed but little confidence. The retreat from this position would have been a very difficult operation, there being only one road from the town of Isla de Leon to Cadiz, which was from its western extremity, and ran in a straight line across the marshes to Torre Gorda; so that in the event of an enemy pushing in by the centre of the position, the troops on the left would most undoubtedly have been cut off, and those on the right and right centre also, who must have retired by the sea side through a deep sand, unless they could succeed in retiring from the Sierra de los Martires and Gallineros before the enemy could extend to his left sufficiently to prevent them. It might naturally be supposed that the Spaniards would have defended the town La Isla, and certainly it ought to have been done in the event of an attack, but we could not calculate upon it; no preparations for defence had been made, nor did the feelings or dispositions of the inhabitants lead us to expect that they would be inclined to offer resistance.

The capture of Cadiz was an object of so much importance to the success of the French cause in Spain, that there cannot be a doubt that if circumstances had permitted, the attempt would have been made; their daily preparations gave evidence of the intention; its capture would have deprived the Spaniards and British of a first-rate fortress, which was the seat of government, and have compelled the Regency and Cortes to have sought an asylum


Arsenal Puente
4 Guns
PUERTO DE STA MARIA
Puente y Terraza
4 Guns
Molino de Marino
4 Guns
2 Guns
6 Guns
4 Guns
RIVER SAN PEDRO
5 Guns
PUERTO REAL
6 Guns
30 Guns
2 Guns
7 Guns
la Maquilla
Fra de Capillos
Fra de Cruz
Canal de Troca dero
Fuerte de Encamp.
Molino de Guerra
17 Guns
Sta Catalina
14 Guns 5 Mortars
3 Guns
12 Guns
2 Guns 7 Mortars
4 Guns
2 Guns
4 Guns
3 Guns
5 Guns
7 Guns 4 Mortars
4 Guns
Batt.a Napoleon
2 Guns
6 Guns
3 Guns
Trocadro
3 Guns
la Cabezuela
Matagorda
Fort Louis
Pontales
la Corrales
Batt.a
Batt.a
Mole
Aguada Batt.a
Sandhill Redt
Fort San Fernando
CADIZ
Fort St Sebastian
Scale

59 High Holborn

Fig. 1.

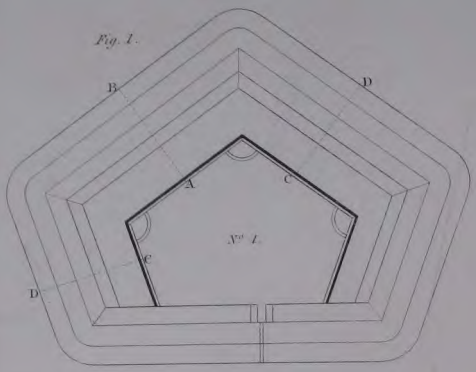


Fig. 2.

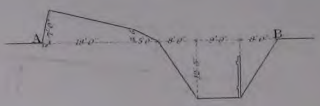


Fig. 3.

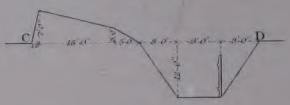


Fig. 4.

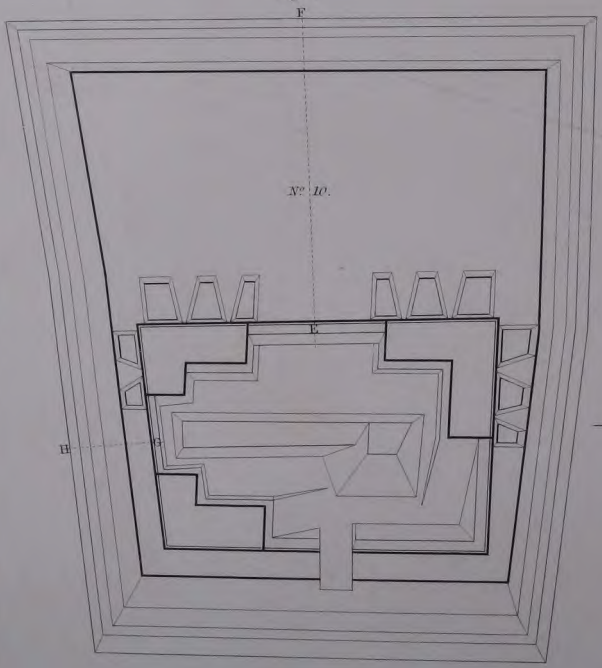
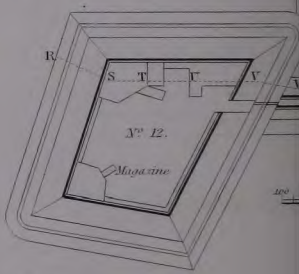


Fig. 12.



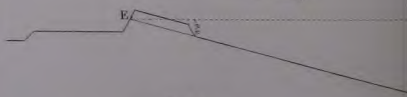
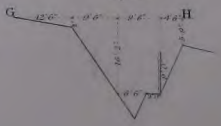
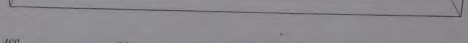
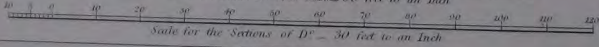


Fig. 6.

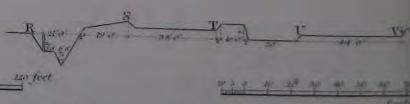




Scale for Plans N°s 1, 10 & 11. — 60 feet to an Inch.

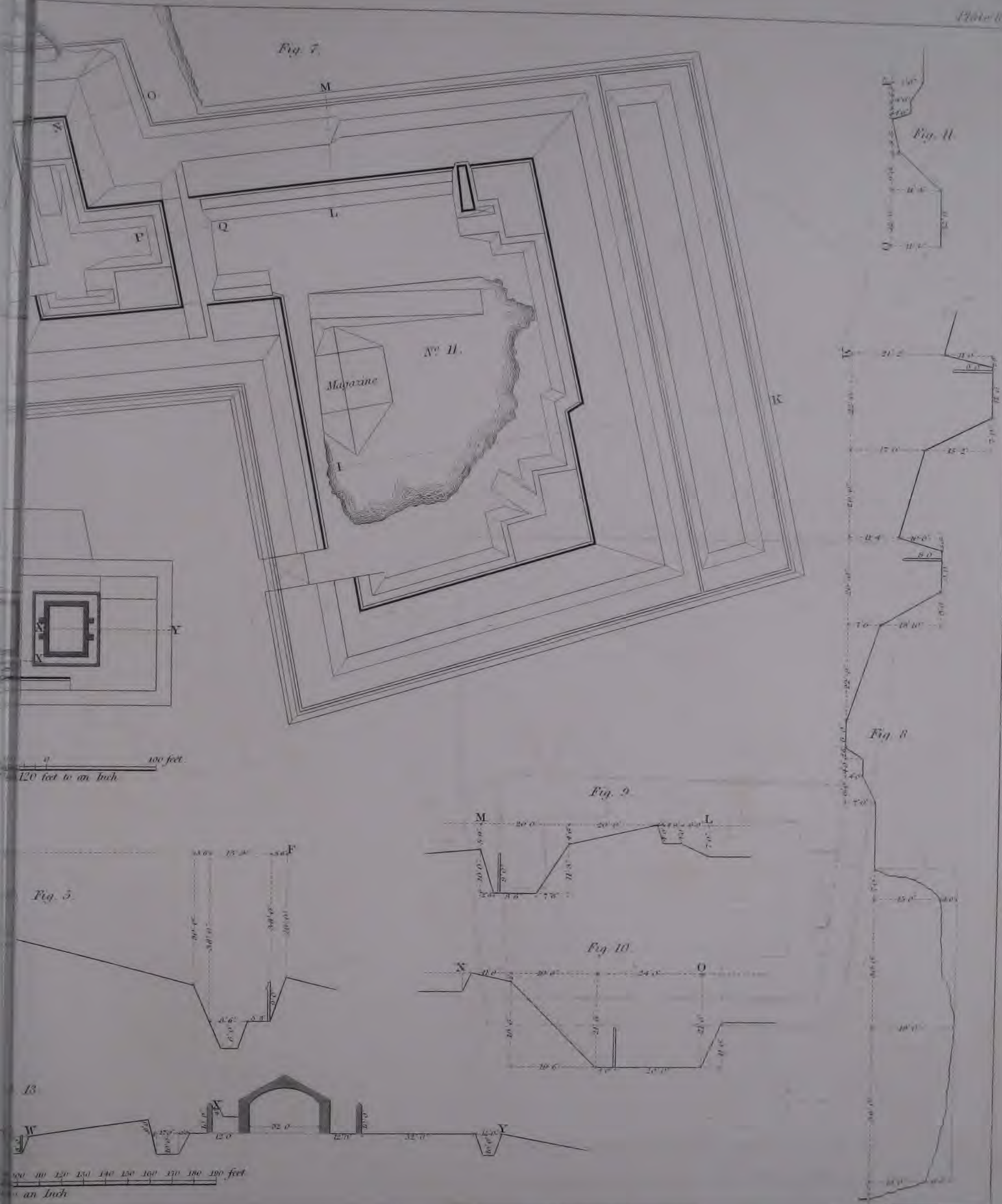


Scale for the Sections of D° — 30 feet to an Inch.



T OF CADIZ.

Plate 8.



J. R. Greig sculp.

High Holborn.

in the Balearic Islands: that such a disaster was prevented is to be attributed to the zeal and exertions of the British General and troops, who enabled the Spaniards to retain possession of their beautiful city for upwards of two years against a powerful enemy, commanded by Napoleon's best General.

HARRY D. JONES,
Major Royal Engineers.

Dublin, 27th December, 1838.

III.—*Instructions of the Minister of War concerning the Model-towers approved of by Napoleon. Translated by Lieut.* Laffan, *Royal Engineers.*

The Emperor has given orders that the guard-houses, powder magazines, and other buildings usually constructed for the service of coast batteries, and other small works of fortification, should in future be united, and arranged in the manner best adapted to the defence, in bomb-proof loop-holed towers, capable of serving as keeps in the interior, or at the gorge of these works. Several plans of towers were accordingly drawn up by the central committee of fortifications, from among which the Emperor selected, as the best adapted to the purposes for which they were intended, the model-towers Nos. 1, 2, and 3, of which plans, sections, and elevations are annexed. The table at the end gives a summary of the estimates of the expense. These details and estimates must, however, be considered merely as examples, susceptible of such modifications as may be necessary to adapt them to the nature of the ground to which they are to be applied, and the materials to be procured.

Plate 9.

The object of these orders is to give, as a supplement to the detailed plans and table of estimates,—

1st, A brief description of the model-towers ;

2nd, Some remarks on the different purposes to which they may be applied, and on the relations between them and the works of which they form the keeps.

1. *Description of the Model-towers.*

The arrangement of these towers is a combination of that of the towers planned by Vauban, and of those erected in Egypt, at the time of the last expedition.

They are covered by a bomb-proof arch, and are surrounded by a ditch with a bridge, part of which forms a draw-bridge.

The total height of these towers, from the bottom of the ditch to the top of the parapet, is twenty-seven feet, and from the floor of the vaults to that of the platform twenty feet. Their height above the natural level of the ground is eighteen feet.

The vaults contain magazines for powder, provisions, and military stores, and a cistern.

The ground-floor is to be inhabited by the garrison, and will contain, in No. 1, sixty men; in No. 2, thirty men; and in No. 3, twelve men and a keeper, or eighteen men without a keeper. The walls are loop-holed, and in No. 1 two guns are placed to defend the entrance.

The platform is armed with cannon: that of No. 1 with four 24 or 16-pounders, mounted on coast carriages; that of No. 2 with a field-piece, and two carronades mounted on traversing platforms; and that of No. 3 with two brass carronades, mounted in the same manner. The foot of the tower is defended by four machicoulis, projecting from the platform, with loop-holes at the sides to defend the angles.

The staircases to the vaults, to the platform, and to the machicoulis, are constructed in No. 1 in the thickness of the walls, and in Nos. 2 and 3 in the interior of the towers. The opening on the platform is closed by a trap-door.

2. *Remarks on the different purposes to which these towers may be applied, and on the relations between them and the works of which they form the keeps.*

The chief purposes to which these towers may be applied is to form the keeps of coast batteries, of lunettes, of redoubts, or small forts, of works thrown up to cover the head of a bridge, or the entrance of a defile, and of many other small works which cannot be revetted, either for want of time, or because the object which they are intended to answer will not allow it.

When the nature of the ground is favourable, the works which cover the towers should be raised fifteen feet above the natural level of the ground: the towers, being raised above it eighteen feet, will then have a command of three feet. They cannot be touched by artillery from sea or land, they possess all the properties of a keep, and, in order to destroy them, the enemy

must establish breaching batteries on the outer works, exposed, during their formation, to the fire of the platform and of the interior of the tower.

When the covering works can only be raised twelve feet above the level of the ground, the towers will have a command of six feet, which will enable the garrison to fire at the same time from the outer works and from the platform of the tower. The parapet of the latter can, however, be breached from a distance. The tower still preserves the fire of its casemates, but loses many of the advantages of a keep.

When the covering works cannot be raised to the height of twelve feet, the towers must, if possible, be sunk to such a depth as to have a command of from three to six feet.

When the nature of the ground will not allow this to be done, the towers can be breached from a distance. They will still be formidable against musketry, but will be useless when opposed to cannon.

The relative sizes of the towers and their covering works should be so calculated that the tower might receive the whole of the gunners, if the covering work be a battery, and contain one-third of the garrison, if it be a small work of fortification. The remainder might live in huts.

When the covering work is a battery, or a work of which the garrison is very weak, the latter should live in the tower, and place sentinels on the outer works, and on the platform. They should not leave the tower except when required to man the guns, or annoy an enemy by musketry when landing. They should never allow their retreat to be cut off, but shut themselves up in the tower and defend it till relieved, or until the enemy has formed a breach.

When the garrison is sufficiently numerous, the outer works should be obstinately defended; great support will be derived from the tower which serves as a point d'appui in the interior, and directs its fire upon the enemy as soon as the progress of the attack exposes him to it.

The next purpose to which these towers may be applied is to occupy the top of a mountain, the crest of a ridge, the isthmus connecting a peninsula with the main land, the extremity of a promontory, the summit of a rock, or the top of a sand-hill, whenever there is not sufficient space for a greater work, or when such could only be constructed with great labour, and at an expense disproportioned to the object.

When the point occupied by the tower commands all the neighbouring ground, and there is no point within range from which the enemy's artillery can be directed on it at the angle necessary to form a breach, the tower may be raised above its counterscarp, the object of which is then merely to oppose an obstacle to an attack by escalade, by the mine, or by a petard. The height of the tower above the ground should be such as to enable the defenders to see all the slopes and hollow ways in the neighbourhood, and the covert-way should be traced in such a manner as to occupy with its crests the summit of the slopes, and enable the defenders to direct their fire upon such parts of the neighbouring ground as could not be seen from the tower, or on which the fire of that work would be too plunging.

When the tower is commanded from points on which the enemy can establish breaching batteries, it must be defiladed from them, and hidden by the parapet of its covert-way; for which purpose the tower must be sunk in the rock, or the covering mass raised to a sufficient height by earth brought from a distance. The tower, however, is now nothing more than the keep of a fortified post; it has no influence beyond its covert-way, and its only object is to prevent an enemy from occupying a point, of which it is of importance to prevent his gaining possession. Under these circumstances the covert-way alone exercises any exterior influence, and should therefore be strengthened by multiplying in its front the obstacles usually made use of in field-fortification.

When the tower occupies the summit of a sand-hill, it is necessary, in addition to the above precautions—

1st. That the bottom of the ditch should if possible be paved, in order to render it easier to remove the sand, except when the tower and its counterscarp are built on a common foundation of masonry.

2nd. That the bottom of the ditch, (when it cannot be paved,) the terre-pleine of the covert-way, the slopes, banquettes, parapets and glacis should be covered with earth, and sown with grass, and that trees and shrubs should be planted on the glacis.

3rd. That the slopes of the glacis should be continued, protected in this manner, till they intersect the slopes of the neighbouring sand-hills, in order that they may be disturbed as little as possible by the action of winds carrying away the sands from beneath them.

4th. That stakes should be driven at the crests and extremities of the glacis, and wattles worked between them: these will prevent the sand accumulating on the glacis, allow the shrubs time to take root, and protect them from injury.

Instructions of the Minister of War concerning two models of towers, arched at top, but not bomb-proof, intended to form defensive guard-houses in coast batteries.

His Majesty has ordered bomb-proof towers to be constructed, to ensure the defence of the most important coast batteries, to form keeps in islands, and to occupy the summits of a mountainous country.

In consequence of these orders, plans and descriptions of the towers Nos. 1, 2, and 3 were sent to the director of fortifications.

Bomb-proof towers can only be applied to very few cases. For—

1st. The great expense of these towers prevents their being proposed for all the points where it is necessary that towers should be constructed; in many cases the expense of even the tower No. 3 would be out of proportion with the object it is intended to answer.

2nd. There are very few cases in which a tower is exposed to a bombardment, and to the fire of a stationary squadron.

3rd. Several coast batteries, though important to defend, are situated in marshy ground, or on escarpments, far from any point favourable for a landing, and cannot be the object of an immediate attack.

4th. There are a great many batteries of less importance, accessible to infantry, but against which an enemy cannot bring artillery; these only require cover against musketry.

In these several circumstances it is sufficient that the defenders should have a point of security from which they can direct a musketry fire against the enemy, and prevent him from spiking the guns.

A loop-holed guard-house, formed like the tower No. 3, but without the bomb-proof arch or platform, seems sufficient for this purpose.

Plate 10. The towers Nos. 4 and 5 show two simplifications of the tower No. 3, proportioned to the importance or remoteness of the battery.

Each of these towers contains a guard-room, with camp beds for 10 or 12 men, a room for the keeper, and a powder magazine. It is surrounded by a

ditch, with a bridge, part of which forms a draw-bridge. A glacis, formed of the earth from the ditch, covers part of the masonry, and leaves to the loop-holes the necessary command.

The tower No. 4 is intended to form the keeps of isolated batteries. In this tower the guard-room and keeper's quarters are on the first-floor; the ground-floor contains a powder magazine, a magazine for provisions, and a cistern.

The tower No. 5 has only the ground-floor, which contains the quarters for the men and keeper, and a powder magazine; it supplies the place of the ordinary guard-houses of coast batteries. It has no cistern or magazine for provisions: as the garrison consists of very few men, their provisions occupy but a small space, and the water can be kept in a cask.

The defenders are secured from accidents by fire of every kind by a light arch, over which is constructed an ordinary roof.

This roof will be especially useful in northern countries, where the continual rain and snow renders the preservation of the platforms very expensive. It might perhaps be advantageous, in those climates, to cover even the platforms of the bomb-proof towers by roofs constructed in such a manner as not to interfere with the fire.[1]

The estimates of the towers 4 and 5 show the expense of the first to be £480, and that of the second £320, allowing a surplus of a sixth for contingencies. This expense does not exceed that of the isolated guard-rooms, powder magazines, and cisterns of ordinary batteries; and it has the additional advantages—

1st. Of securing these works from surprise.

2nd. Of ensuring the defence of the battery.

This average expense will be exceeded—

1st. Whenever it is necessary to obtain a foundation in unfavourable soil by means of piles, or to excavate in a rock, circumstances which equally increase the expense of the ordinary works.

2nd. When it becomes necessary to join the tower to the battery by a palisade, a loop-holed wall, or a ditch, or to make alterations in the battery itself.

[1] The material (asphalte) lately introduced into this country will probably be found of great service in covering the platforms of bomb-proof towers and the arches of powder magazines. It is perfectly water-proof, and its elasticity will enable it to resist the shock of a shell, which the best cement can hardly be expected to do.—Ed.

These works, being regulated by the nature of the site, cannot be comprised in a general description, and must vary with each battery.

These loop-holed guard-houses should, with the exception of the use of artillery and resistance to shells, be defended in the same manner as the tower No. 3; for which see the instructions for the defence of bomb-proof towers.

Summary of the estimates of the Model-towers.

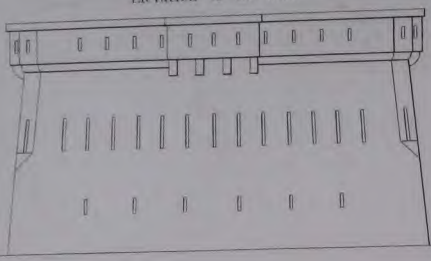
Conditions.	No. 1. For 60 men.		No. 2. For 30 men.		No. 3. For 12 men and a keeper, or 18 men without a keeper.	
	Without Counterscarp.	With Counterscarp.	Without Counterscarp.	With Counterscarp.	Without Counterscarp.	With Counterscarp.
	£. s.	£. s.	£. s.	£. s.	£. s.	£. s.
1st. The tower alone	1520 0	1520 0	720 0	720 0	529 $12\frac{1}{2}$	529 $12\frac{1}{2}$
2nd. The bridge	40 0	40 0	36 0	36 0	30 $8\frac{1}{3}$	30 $8\frac{1}{3}$
1st. The glacis without counterscarp	1560 0	1560 0	756 0	756 0	560 1	560 1
2nd. The glacis with counterscarp revetted	200 0	840 0	40 0	484 0	40 0	440 0
	1760 0	2400 0	796 0	1240 0	600 1	1000 1

Summary of the estimates of the towers arched at top, but not bomb-proof.

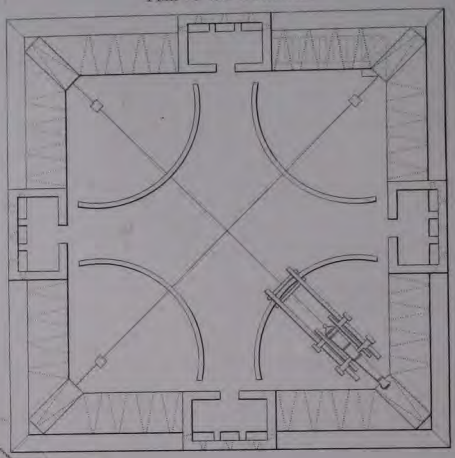
Conditions.	No. 4. Two stories.	No. 5. With only a ground-floor.
	£. s.	£. s.
1. The tower alone	361 0	232 0
2. The bridge	28 0	28 0
3. The glacis without a revetted counterscarp	17 0	11 0
	406 0	271 0
Contingencies one-sixth	74 0	49 0
Expense of each tower	480 0	320 0

N° 1.

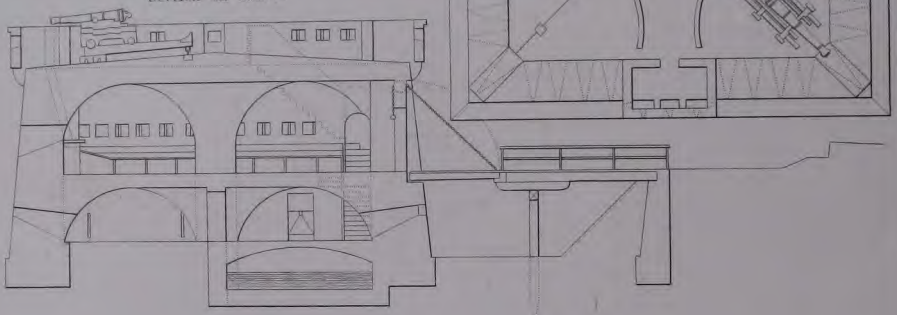
Elevation of the Tower.



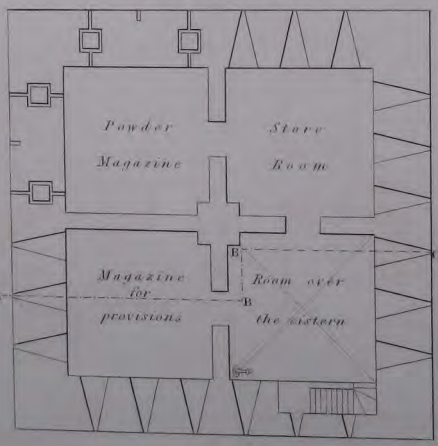
Plan of the Platform.



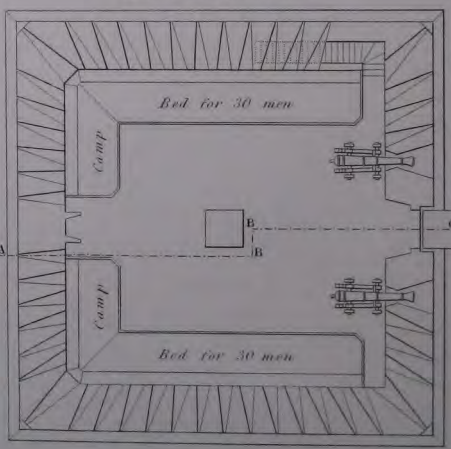
Section on A.B.C.



Plan of the Vaults



Plan of the ground floor.



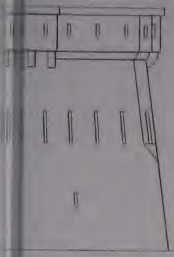
Lieut Dutton R.E. del.

John Weale Architectural

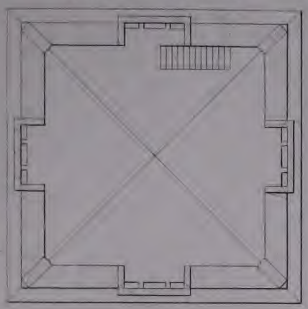
ED BY NAPOLEON.

N° 2

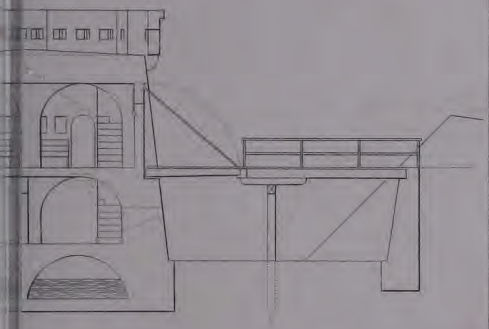
the Tower



Plan of the Platform.

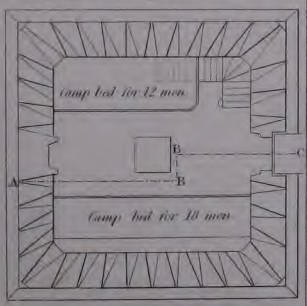


n A.B.C



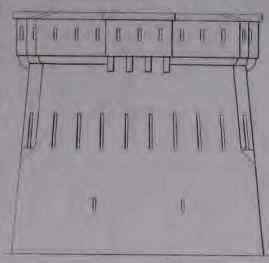
he vaults

Plan of the ground floor

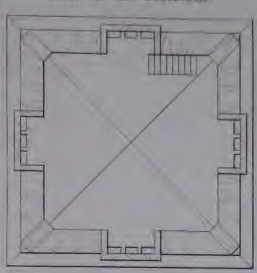


N° 3

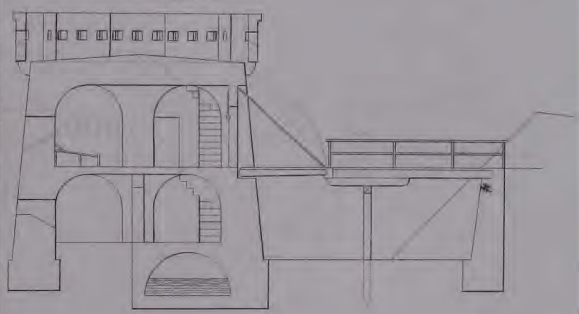
Elevation of the Tower



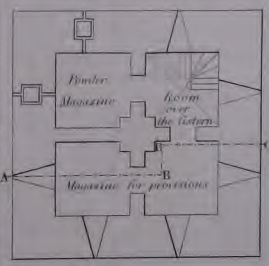
Plan of the Platform



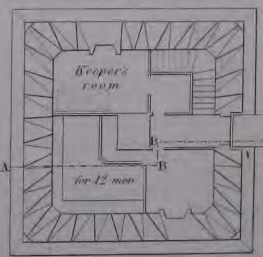
Section on A.B.C



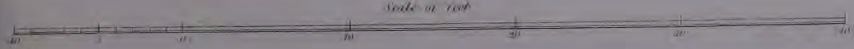
Plan of the vaults



Plan of the ground floor



Scale of feet



NAPOLEON.

N^o 4 Tower.

N^o 5 Tower.

Fig. 2.
Section on the line D.E Fig. 3 & 4.

Fig. 1.
Elevation.

Fig. 6.
Elevation.

Fig. 7.
Section on the line A.B. Fig. 8.

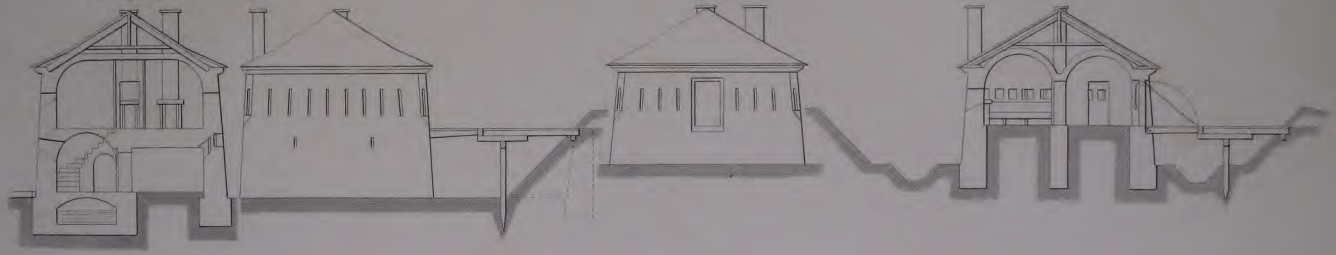


Fig. 3.
Plan of Ground Floor.

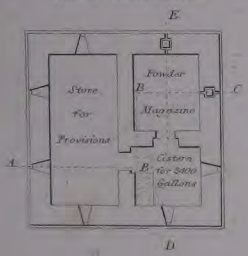


Fig. 4.
Plan of First Floor.

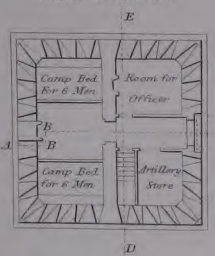


Fig. 5.
Section on the line A.B.C. Fig 3 & 4.

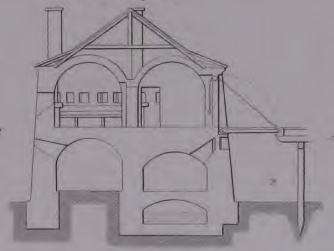


Fig. 8.
Plan of Ground Floor.

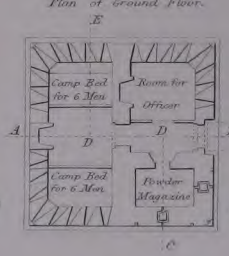
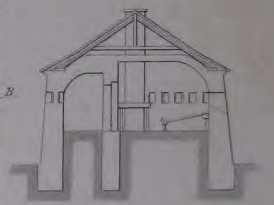
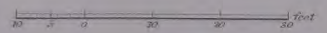


Fig. 9.
Section on the line C.D.E. Fig 8.





IV.—*Report on the Demolition of the Revetments of some of the Old Works at Sheerness, on Saturday the 14th July*, 1837.

GENERAL DESCRIPTION.

THE revetments to be destroyed consisted of 266 feet in the face, flank, and curtain of a front of fortification in the old defences towards the land side, and of 260 feet of the revetment of the ravelin in front. The revetment in the body of the place was 16 feet 6 inches high, 3 feet thick at top, and 5 feet at bottom, supported by counterforts 3 feet wide, and 4 feet long, placed at unequal central distances of from 15 to 17 feet. The revetment of the ravelin was 10 feet high, 3 feet thick at top, and 4 feet 3 inches at bottom, supported by counterforts 3 feet wide, by 2 feet 4 inches long, placed at regular central distances of 20 feet. Those works were originally surrounded by water, and at the time they were ordered to be destroyed were found to be covered up 6 feet from the foundation. The masonry was for the most part good, the bricks frequently breaking before the mortar; but from the settlement of the foundation several of the counterforts were cracked.

Plate 11. Figs. 9, 10, 11.

PROJECT OF DEMOLITION.

A trench was ordered to be cut along the face of the revetment of both works, 6 feet wide, and as deep as the foundations. In the body of the place, shafts were ordered to be sunk at the back of the revetment by the side of each counterfort, and returns to be made into them 1 foot above the foundation, and at such a distance from the back of the revetment that the centre of the barrel which contained the charge should be in the centre of the counterfort, and 7 feet 6 inches from the face of the revetment.

In the ravelin, shafts were also ordered to be sunk at the back of the revetment by the side of each counterfort, as well as one midway between

each ; returns were ordered to be made into the counterforts so as to lodge the charge in the centre, and 5 feet from the face of the revetment ; the other charges were also laid 5 feet from the front.

The charges were calculated exactly according to Lieut.-Colonel Pasley's rules. In the body of the place the lines of least resistance were taken 7 feet 6 inches, the calculated charge for which, for two-lined intervals ($\frac{1}{5}$th of its cube), is 84 pounds ; but as some of the counterforts were more than 15 feet from centre to centre, a barrel or 90 pounds was used. In the ravelin the mines were exactly 10 feet asunder ; the line of least resistance was 5 feet, the charge for which was exactly 25 pounds, (being also $\frac{1}{5}$th of its cube.)

In the large mines the barrel was lowered down and placed on its end in the return, the copper hoops having been previously taken off, and a hole drilled in the top to receive the hose : the top was off at this period. That part of one of the staves nearest the hole, which projects above the top, was knocked off to prevent the hose from being cut whilst laying it ; the hose was pushed into the barrel about 9 inches.

In the smaller mines large bags were used, and the hose sewn into them, and, where there was any symptom of moisture, laid in straw.

Three-quarter-inch hose was used, but it was thought that half-inch would have been quite sufficient.

The mines in the ravelin were fired in succession, first along one face, and then the other. For this purpose the hose was laid straight along the top of the revetment, communicating in succession with the short pieces coming from the charges, and fired from one extremity. In the body of the place the mines were fired by twos or threes, for simultaneous explosions.

EFFECT.

The most complete demolition was produced. The whole revetment from one extremity to the other was laid in ruins, and yet so nicely were the charges calculated, not a brick was thrown 50 yards, and people at that distance might have looked on in security.

It was observed that the mines in the body of the place produced a greater effect on the ground to the rear than might have been anticipated : the shock on the adjacent mines prepared for explosion was such as to lay the hose, which was previously covered with 3 or 4 inches of earth, quite bare.

Fig. 1
FORT SCHULEMBOURG
AT VIDO.

Fig. 3.
Section on a.b.

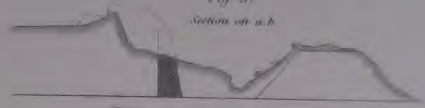


Fig. 4
Section on c.d.

Fig. 5.
Section on e.f.

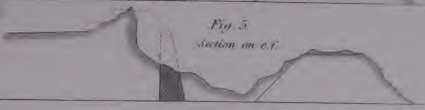


Fig. 6
Section on g.h.

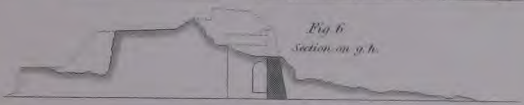


Fig. 7.
Section on k.l.

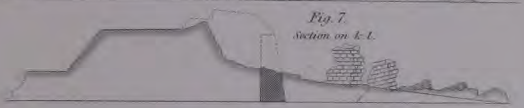


Fig. 8
Section on m.n.

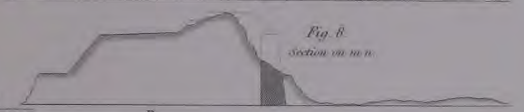
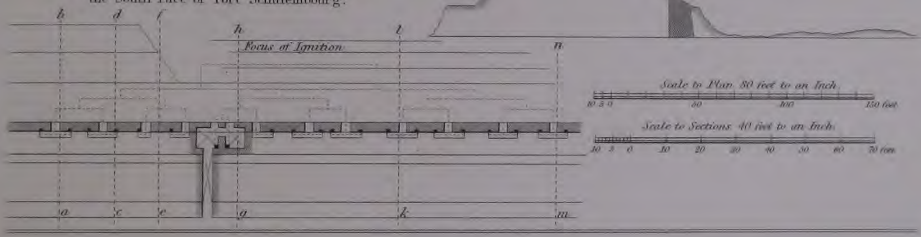


Fig. 2
Plan of the distribution of the Mines to destroy the South Face of Fort Schulembourg.



Plan of the Revetments
destroyed at Sheerness on the 14th July 1827.

Fig. 10.
Section through the body of the plan.

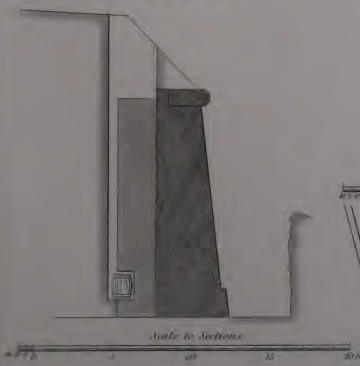


Fig. 9

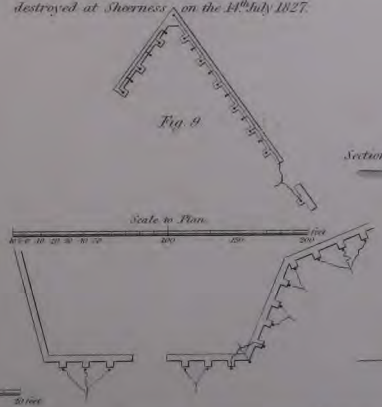
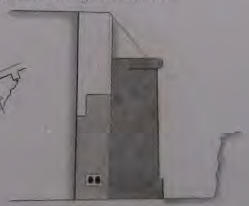


Fig. 11
Section through the Ravelin



In firing the mines, commencing at No. 1 in the left face of the ravelin, Nos. 1 and 2 failed. This was owing to the hose which was laid along the top of the revetment having been displaced by people getting over the work at this corner. Had the precaution of taking a half hitch with the hose coming from the mine, around that which ran along the revetment, been taken, this accident would not have occurred.

In firing the mines in the right face, commencing between Nos. 18 and 19, Nos. 19 and 6, at the two extremities, failed; the hose in this case burnt to the edge of the shaft and there stopped. I attribute this to the hose being choked at the angle, and the powder settling down a little in the shaft, so as to cut off the communication.

In the body of the place we commenced with Nos. 1, 2, and 3 simultaneously; then 4 and 5; then 6, 7, and 8; then 9 and 10; then 11 and 12; and then 13, 14, and 15. All these succeeded, but the shock from Nos. 11 and 12 deranged the hose of No. 13 so much, that Lieut.-Colonel Pasley ordered it to be cut; after Nos. 14 and 15 were fired, the hose of No. 13 was completely buried, but we succeeded in finding it by digging, and fired it also, but owing to the quantity of rubbish that had closed in around it from the right and left, its line of least resistance was changed, and became vertical; the crater produced was very large.

HENRY JAMES,
2nd Lieutenant Royal Engineers.

V.—*Letter from Lieut.-Colonel* ROBERT THOMSON *to Lieutenant* DENISON.

Dover, January 4, 1838.

SIR,

Having been requested to contribute something to the Corps Publication, of which you are the Editor, I beg to transmit herewith two drawings of a furnace for heating shot.

Plates 12 & 13.

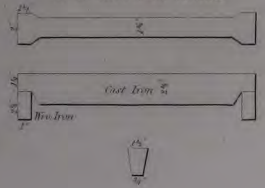
With respect to these I would submit a few observations.

In the event of war, steam armed vessels will force a special attention to our sea batteries, and more particularly to the subject of hot shot. My attention was drawn to this question in 1826, when I designed a furnace upon the reverberatory principle, a copy of which I send you now. The drawings are but very indifferent, but I have no means at my disposal by which I can have them better executed at the present time.

Unless a shot be placed in the gun at a white heat it will have no chance of causing combustion when it reaches the object against which it is fired; the wet wad, the cold gun, the passage through the air, all tending to lower the degree of heat. Now the grates which have been usually supplied by the Ordnance for heating shot could never, by any expenditure of fuel, raise shot to a white heat. The thing is impossible, and therefore they are useless.

A furnace of some sort must be used, either of the blast or reverberatory kind. The latter is the most simple, and therefore best adapted to military purposes. I think I sent home drawings from the Cape of Good Hope in 1831 or 1832 of a furnace of this description, to be attached to a sea battery in Simon's Bay, which possibly may be more explanatory than the enclosed. A furnace on this construction will heat shot in the shortest possible time (without the necessity of using bellows) to a white heat, with a facility of preserving the shot at that heat for any length of time which the service may require.

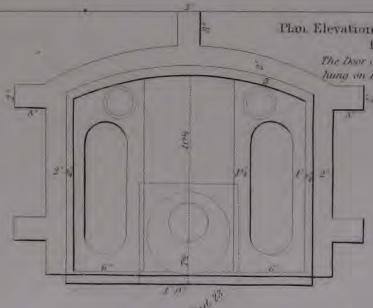
Plan Elevation & Section of the Bars of the Furnace.



Plan Elevation and Section of Cast Iron Frame of Door for extracting Hot Shot.

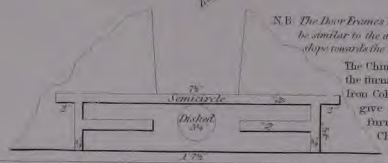
The Door sides to be wrought Iron with Rebate for Tile to be hung on Brass Pullies with Chains and Counter weights.

Scale 2" to 1 Foot



N.B. *The Door Frames for feeding with Cold Shot will be similar to the above, excepting that the Sill will slope towards the Furnace with a fall of .5 in 1.8½"*

The Chimney will be independent of the furnace & supported on the Cast Iron Columns b b b b in order to give a facility of repairing the Furnace without disturbing the Chimney Shaft.

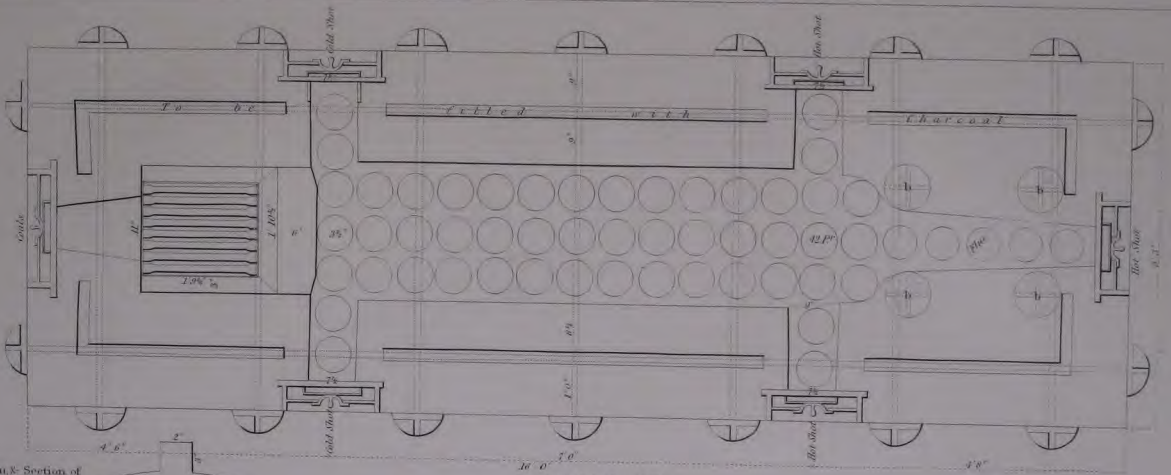


Scale ½ Inch.

SECTION OF A REVERBERATORY FURNACE FOR HEATING SHOT.

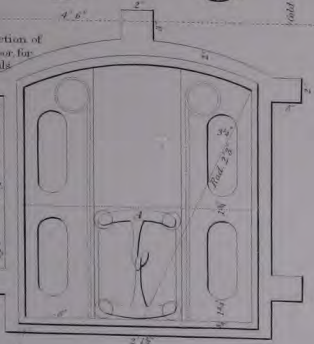
Damper to be on the Top of Flue

London. John Weale. Architectural Library. 59. High Holborn

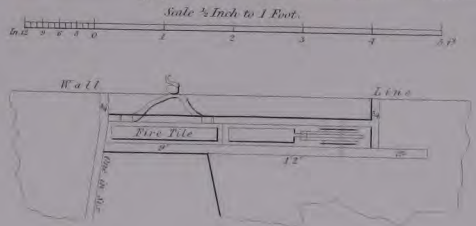


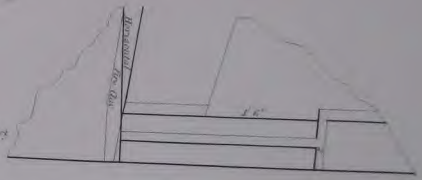
Plan, Elevation & Section of cast Iron Frame of Door for feeding Furnace with Coals.
The door to be hung on Brass Pullies with Chains & Counter Weights.
The Door Case to be wrought Iron with Rebate for Tile.

The upper pair of Rollers will be sufficient to guide the door, the lower pair may therefore be dispensed with, in which case the hook for lifting and shutting the door may be at A

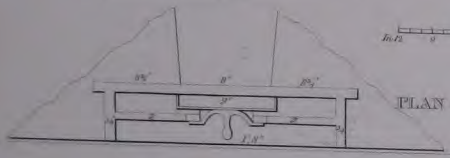


Scale ½ Inch to 1 Foot.





Scale 1 Inch to One Foot.



PLAN OF A REVERBERATORY FURNACE FOR HEATING SHOT.

(see Section.)

By construction the furnace will admit of being fed with cold shot from time to time to supply the consumption, and of withdrawing the hot shot with ease, and without danger either of scorching the men, bursting the furnace, or running the shot. It appears to me that this subject has not received the attention which its importance merits.

I would suggest that working drawings of all tools, more particularly brick-makers' tools, would prove of great use in the colonies, and I would also propose a Treatise on Brick-making for insertion in the Corps Transactions.

I am, Sir,
Your most obedient humble servant,

ROBERT THOMSON,
Lieut.-Colonel Royal Engineers.

VI.—*Memoir on Posen, by* T. R. Stavely, Esq., *late Captain Royal Engineers.*

Posen is a well-built town, the capital of the Prussian province of Posnania, containing 30,000 inhabitants. It is situated on the river Wartha, which runs through the town, and is about 100 yards wide, and is navigable for country boats, so that there is a water communication with Berlin and Stettin.

Posen is in the direct road from the capital to Warsaw, and is only 40 English miles from the frontier of Russian Poland. As Coblenz may be considered the bulwark of Prussia to the west, so Posen will eventually be the rallying point and centre of all military operations to the east; and for this purpose extensive fortifications have been constructing for the last fifteen years. The system employed is attributed to Colonel Breze, of the Prussian engineers, sanctioned by General Von Rauch, now minister at war; Lieutenant-General Von Reiche, and Major-General Von Liebenrothe. Major Von Prittwitz is the resident directing officer.

GENERAL IDEA OF THE SITUATION OF THE TOWN AND WORKS.

The country in the neighbourhood of Posen is an undulating plain, about 150 feet above the level of the river. The town is situated on a gentle declivity, a great part being low: it is on the comparatively high ground that the citadel or Fort Viniari is placed, and the site has been chosen with much judgment. On the approach from Berlin it has a very imposing appearance, and its towers and redoubt are here seen to most advantage in a picturesque point of view, which in most of the modern Prussian fortresses is worthy of some remark.

It will be seen that the citadel, the Schwartz Thurm, and redoubt covering sluice C, the oval tower and flèche covering sluice A, the Schrodka sluice B, and the two advanced flèches, are the only works completed, or in a state of forwardness. The other works commenced are principally to the west of the Schwartz Thurm, and near the seminary, where ramparts are being thrown up, and ditches excavated.

The general idea is, that the commanding points round the town are to be occupied by redoubts and towers à la Montalembert, and, where necessary, to be connected by lines or curtains. The system is well adapted to the ground, as in many instances the intervening spaces could be covered by inundations. The most eligible sites for these redoubts and towers would be the seminary, Vorstadt St. Roch, near the Evangelische Kirkhof, and Windmill Hill. The latter is calculated for a work similar to Viniari in many respects, but without its advantages of the river and inundation to protect the flanks; at the same time it has few disadvantages, the ground being very favourable. The two roads from Berlin and Breslau will point out the probable form.

The sluices deserve particular attention. The principal sluice and bridge A, is across the river Wartha, which has here been cut straight. This sluice and bridge is extremely well constructed; it has 12 arches; in the piers between each are simply three sets of grooves 6 feet apart, into which thick planks can be slipped, as occasion requires: this is a better plan than gates, as any damage can be easily repaired. The waste water is made to escape by the old course, over which a bridge has been built, to keep up a communication with the works on the east side of the river.

The Schrodka sluice B, is not so strong, and has only two sets of grooves; it is at present unfinished. By means of these sluices A and B, the waters of the Wartha can be raised 15 or 16 feet above their usual level, and in the course of two hours the inundation would extend over the lower part of the town, beyond the Schutzen Hans, and Carmelite convent; and on the opposite side of the river in the direction of the Comanderia.

The Schwartz Thurm sluice C, is only sufficient to dam up a small stream so as to flood the flat ground and meadows to the west.

The roads communicating with Berlin and Breslau are excellent; that towards Thorn is only macadamized for a short distance: the Warsaw road is left in its original state, like all the roads of the country, through a deep sand.

Plate 14.

FORT VINIARI AND ITS IMMEDIATE DEPENDENCIES.

This fort occupies the hill on which the village of Viniari stood, to the north of the town, and on the western bank of the river Wartha. It consists of a large pentagonal redoubt, covered by two fronts of fortification, and two demi-fronts; these are connected with the redoubt by two long lines, thus forming a species of crown-work. Its immediate dependencies are the Schwartz Thurm and redoubt, and the oval tower and flèche, both of which are joined to the body of the place by defensive vaulted ways, which are bomb-proof, so that the sluices A and C may be considered as closely connected with the citadel, to which they afford powerful protection. As the redoubt is so prominent a feature it will be first mentioned.

It is an irregular pentagon, having a large casemated tower at the angle towards the town, now used as a state prison, and bomb-proof store-houses on the faces on either side. The other three sides are occupied by casemated barracks, capable of containing, in conjunction with the other casemates, a considerable garrison. The whole is surrounded by a ditch from 20 to 25 feet deep.

The two fronts of fortification, and two demi-fronts, have a good command over the country, which is open, arable, and slightly undulating; these may be considered as of a perfectly regular trace as to the polygonal angles, and the length of the fronts, faces, and flanks, as any slight irregularity does not affect the work in a general point of view. High cavaliers in the two ravelins Nos. 2 and 3 will look into all the hollows, with one exception, which is 600 yards in front of ravelin No. 2, and this hollow is capable of sheltering a battalion; but as the range from the salient would be well ascertained, it would not much advantage an enemy.

The whole of these fronts are countermined, commencing from redoubt No. 2 to redoubt No. 3, and there are communications from all the salients under the ditch to small block-houses at the entrances of the countermines. The two long lines connecting these fronts with the redoubt are each divided into three parts, so that the lines of defence shall not exceed 250 yards. At the angles are square redoubts, having casemates 80 yards in length, of

which all but 20 yards for the defence of the ditch is necessarily concealed behind the counterscarp and body of the place. (Vide plan, redoubts Nos. 1, 2, 3, and 4.) These casemates would afford good accommodation for troops. The glacis of the long lines is steep, terminating at the river on the east, and the low ground on the west.

SCHWARTZ THURM AND REDOUBT.

This is a large tower covering sluice C, and is now used as a military prison. It has a ditch towards the redoubt, 60 feet wide and 25 feet deep. This redoubt has little that is peculiar, except that the escarp of the two faces is loop-holed near the top, so as to command a closer fire on the glacis. This tower and redoubt have the defect of not commanding the Cannonen Plaz in their front, from whence the main sluice might be injured, but at a long range, and under the fire of the citadel. But, as a remedy, the site of the old church near the Garrison Kirche will be occupied, as reported, by a tower or other work; and for this purpose the government has purchased all the buildings as far as the Magasin Strasse.

THE OVAL TOWER AND FLECHE.

This tower covers and protects the main sluice and bridge; it has only one tier of embrasures, and the flèche in front is in earth, and has a wet ditch. This bridge has a casemated battery for its whole length, looking down the river, serving also as barracks for the men in charge of the sluices.

PLATE 15.

A FRONT OF FORTIFICATION, SHOWING THE SYSTEM EMPLOYED ON THE NORTH SIDE OF FORT VINIARI.

It cannot be expected, under the circumstances, that this front of fortification can be quite correct in all its dimensions; but wherever numbers are given, there have been actual admeasurements by pacing. It is to these fronts that every attention has been paid by the Prussian engineers, as they must necessarily be the point of attack; and it is here that the system of Colonel Breze is put in practice as a new system of fortification, but of which the outlines or foundation will be found in Choumara. The front chosen is the left centre.

The ravelin has the revetments counter-arched for the length of half the front from the salient, which has a mortar battery and guard-room, and an arched communication with the rear. The faces and flanks of the bastions have also counter-arched revetments, and the whole of them would form good and dry quarters for troops. As before remarked, the two ravelins have cavaliers, but as these at present are only raised in earth, the precise nature could not be ascertained. The caponnières also are only pointed out by their foundations to the floor, but it may be presumed that of the main ditch will have two tiers of guns, as at Coblenz. The curtain deserves particular attention; the escarp here is only 20 feet high, and the thin parapet of masonry enables the occupants to see into the ditch; but an escalade under any circumstances would be hazardous, the guns in the flank being so disposed as to sweep the top of the wall, the bottom, the rear of the parapet, and the face of the rampart. The bastions 1, 2, and 3 must now be noticed, and it will be seen that they are very peculiar. The faces are 70 yards, the flanks are casemated for 3 guns on the upper tier, and one on the lower, as will be seen by reference to the section. These flanks are continued inwards, and separated from the rampart of the curtain by a road of communication to the *fausse braie* or *chemin des rondes*, thus insulating in some degree the bastions, the rear of which is enclosed by a loop-holed wall and powder magazine, the latter serving also as a block-house. The space in the bastions is much diminished by the cutting off the angle of the shoulder: the only reason for this would appear to be to procure a more direct fire on the glacis in front of the ravelins.

GENERAL REMARKS.

Few or no sections are given, as these, to be useful, should be quite correct. It may be stated, as a general rule, that the scarps are from 30 to 35 feet high, and the ditches of the ravelins, and of the body of the place, are of the same depth. When there are casemates, reference may be made to Colonel Blanshard's details, in his plans of the fortresses of Western Germany. All the towers may be considered to be taken from Montalembert. The length of lines of defence, of course, are shown by reference to the plan and scale, which, as far as possible, has been rigidly adhered to.

The Prussian custom of planting the glacis is here followed, and this is done soon after the work is traced out; no particular trees are chosen, but such as suit the soil, and would be useful in case of a siege. These plantations effectually mask the works from a reconnoissance, and the roots would prove a serious impediment to sappers.

The whole of these redoubts and forts are built of well-burnt brick, of a rather larger size than those used by us, and the foundations are generally of rough stone; they do credit to the superintendence of Major Von Prittwitz, the directing engineer officer, whose talents are fully appreciated by his government, and by the corps to which he belongs.

These works, with the greatest economy, must necessarily be expensive, on account of the great quantity of masonry employed in caponnières, counter-arched revetments, towers, redoubts, casemates, countermines, and communications of every description, which are very complete. All the casemates are very dry; this may be owing much to the soil and climate, but it may be here remarked that every care has been taken in their construction, a coat of pitch or tar being applied to the rear of the walls, as well as the revetments, to secure them from moisture.

The fortifications are as yet far from being complete. Masons are employed on the counterscarps of the north fronts of the citadel, and on the escarps of the ravelins; the remaining lines near the Schwartz Thurm redoubt, and towards the seminary, are thrown up in earth, the ditches not being yet excavated, and ample time will yet remain for remarks and observation, which will become more difficult as the works approach completion. It must be borne in mind that the accompanying sketches are not given as correct working plans, but only such as any military man might construct from personal observation, and some actual admeasurements, but still sufficiently true to enable experienced officers to decide on the system employed, which is the chief object of this memoir.

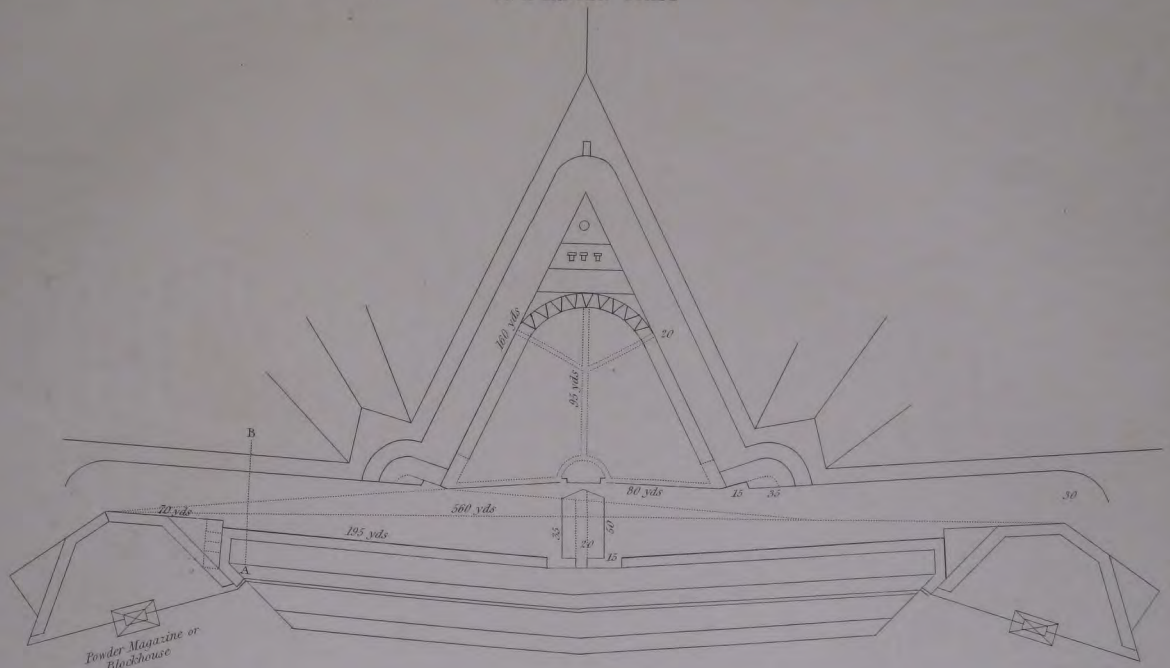
Whatever advantages the system at present employed by the Prussians may have over those of Vauban, &c. has to be determined by experience. One thing is very evident, that both Posen and Coblenz are constructed for a close, vigorous, and protracted defence; and provided there is a sufficient garrison, well found in stores and provisions, no officer would be justified in surrendering, until he was driven, inch by inch, to his last redoubt.

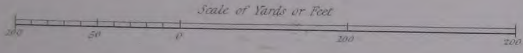
The Russians have of late years erected many new fortifications, chiefly at Warsaw, Modlin, Zamoitz, &c. They have in all instances taken as models those of the Prussians, particularly Fort Alexander at Coblenz, and Viniari at Posen. These have lately been visited by General Grolman, commanding the 5th corps of the Prussian army, and Major Von Prittwitz and other officers, at the express invitation of the Emperor; and plans of all these fortresses are in possession of the Prussian engineers at Berlin. It may not be uninteresting to state, that the Emperor of Russia himself is considered a good engineer officer, and takes a great personal interest in all that concerns this department.

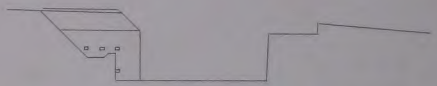
GENERAL PLAN OF THE CITADEL OF POSEN.

PLAN OF A FRONT OF FORT VINIARI.

ON A LARGER SCALE







Section on A.B. shewing the Flank & escarp of the Curtain

E. Mansell sc.

VII.—*Report on Beaufort Bridge. By* R. J. Nelson, *Lieutenant Royal Engineers.*

Devonport, Feb. 21, 1839.

During my rambles in the Rhenish provinces in 1834, I sketched a prettily contrived adaptation of the Prussian beams to a light foot-bridge of nearly 100 feet span, with a central rise of about 6 feet.

Having shown this to Lieutenant H. Butler, 27th Regiment, (our valued assistant engineer, then in charge of the sub-district of the Kat, on the eastern frontier of South Africa,) he immediately suggested its applicability as an economical communication across our rivers. I so far adopted and enlarged on the idea, as to submit to Colonel Lewis, R. E., through (the then Captain, now) Major Selwyn, R. E., a project of building the large permanent bridge intended for Fort Beaufort on this principle. The design and working drawings obtained his approbation,—contingent, however, on the amount of the estimate. This—though by no means a heavy sum—eventually, and unluckily for me, so far exceeded the amount *authorized* for the above-mentioned military communication, that the project was abandoned.

I have, nevertheless, offered it in this Paper, with the hope that, in whole or part, it may in some way or other be of use to my brother officers; under happier circumstances of improved construction in the mechanical, and greater prosperity in the financial, departments.

TO CAPTAIN SELWYN, COMMANDING R.E., EASTERN FRONTIER.

Royal Engineers' Office,
Graham's Town, March 8, 1838.

The military communication between the right and left banks of the Kat River at Beaufort, to consist of a bridge, and so much road at either end as is necessary to make this bridge available, by access so convenient that in the event of the hurry attendant on alarms no obstruction may take place.

Bridge.—The bridge to be in three 60-feet arches; stone piers and abutments, with a wooden superstructure, on the Prussian principle. The piers to be 2 feet higher than the highest known floods. The roadway to be horizontal, and 25 feet wide in the clear, so that two waggons drawn by wild country oxen may pass one another, and allow room for foot passengers, especially in case of alarm.

Road.—The road on the right bank cannot be well less, I apprehend, than 300 yards in length, before the steep rocky hill-side can be easily ascended from the bridge. As this last joins the road nearly at right angles, and as a sufficient sweep for long spans of oxen cannot well be given without curving the road, and thus throwing it deeper into the hill, a turning space, 40 feet × 25 feet, is allowed for at this end of the bridge.

The road on the left, or Beaufort bank, need not exceed 50 yards in length; the work required on this part will be trifling.

I have estimated for 25 *effective* feet of width, as the least that I can propose for these roads.

SPECIFICATION OF WORKS FOR THE BRIDGE IN THE ORDER OF THEIR EXECUTION.

Excavators' work.—To give effect to the approved design of September 27, 1837, the bridge is considered as lying in a trench, the section along the bottom of which is shown, in the annexed Plate, by the full line. The mean transverse section will be about 52 ft. × 9 ft., as given in the "detail," so as to relieve the bridge from the rough bank, and do justice to the appearance of the whole by giving it general symmetry and decision of character.

Plate 16. Fig. 1.

The left bank is the edge of the diluvial deposit of loam and gravel on which Beaufort stands.

The right bank, rising considerably above the left, is a firm sandstone, the beds of which form the bottom of the river, and shelve under the left bank at a dip of perhaps 10°. There is a slight covering of stony soil and loam on the slope of this bank.

As no foundations on the left bank can be considered as secure from the violent and irregular action of high floods on its sandy and gravelly clay, unless they stand on the rock beneath, a serious part of the expense of this bridge, *on whatever principle it may be built*, will lie in the deep masonry foundations and their excavations necessary to reach rock on this side.

Plate 16. Fig. 3.

The foundations on the right bank will occasion no unusual expense.

The rubbish from trench and foundations to be for the most part wheeled to convenient lengths along the banks. The floods that will take this down will have been already so loaded with mud from the higher districts, as not to be sensibly affected by this slight addition; though it *may* produce some slight change in the course of the river below.

If very clean and properly sized gravel can be had, I propose to lay not more than 3 inches of it over the flooring: the plank will thus receive some protection, and the hollow sound, which may frighten oxen, will be reduced, without any sufficient body of material to retain moisture.

Masonry.—Laying, in Foundations, Piers, and Abutments.

Foundations.—Ordinary rubble grouted; the stones to be as massive as possible, for the sake of stability, and of economy in mortar.

Should it be found practicable to use the rubbish from the trench on the right bank, so much will be saved; but as no good or certain communication can be relied on, I have omitted this in the prices, leaving it for the good of the heavy contingencies to which works situated like this bridge are liable during construction.

Piers.—The starlings to be laid in rough massive courses, and at the upper ends, to be shaped like a boat, inverted.

The ends of the piers to have a semicircular horizontal section: the parabolic would have been better, but so expensive that the difference of cost would not be repaid by the benefit obtained.

These ends to be faced in plain ashlar in equal courses, toothed into the body of the pier. Rustic ashlar with droved margin would be cheaper, but it would not be in keeping with the simple Egyptian style of the pier elevation, and, from its rough surface holding the mud from the water, would soon be unsightly.

The body of the pier to be of best rubble masonry, in courses corresponding to those of the ashlar, so as to avoid settlements. For this reason also, as well as for the sake of stability, common backing has not been estimated for in the piers, as rather choice material must be employed, and great attention paid to *bond* in the interior.

The capitals of the piers to be in plain ashlar in mouldings.

The whole to be grouted.

Abutments.—Intended to resist any tendency of the main beams to fly upwards, as well as their slight lateral thrust.

Plate 16. Figs. 2 & 3.

They are short and hollow; and, not requiring to be deeper than usual, take far less masonry than if intended to oppose the pressure of stone arches.

Only the common arrangements of parapets have been followed in this project.

Carpentry.—The general principle followed is that of kerfed beams, so extensively adopted in the Prussian Royal Engineer departments at Berlin and Cologne.

The points to which I have attended are,

1. Strength required to support the greatest probable load with steadiness.
2. Lateral thrust on the abutments.
3. Tendency of the river to lift the bridge from the piers in extraordinary floods.
4. Forward thrust in this case in the direction of the stream.
5. Settlement.
6. Drainage.

With reference to these points,

1. I suppose that the severest trial to which the bridge can be subjected is when crowded with soldiers in close column, keeping step as they march; and when two heavily loaded waggons pass one another. This pressure, varying from 150 to 200 lbs. per foot, will, it is to be hoped, be satisfactorily met by the main beams, without having recourse to my original and more expensive project of an upper tier of small kerfed beams, that would be only in part dependent on the main ones. As it now is, the framing, though indispensable in either case, is rather a burthen than a relief to these last, in point of weight: all that I could do in dispensing with the upper and relieving beams was to make the lower ones *strong enough* for any thing. Thus economy has compelled me to propose a system which in some respects I know to be defective. The superstructure of a bridge should be, if possible, an accession to its strength, without being an additional burthen.

Having had no assistance from experiments, I have been guided only by my general idea of the strength of the wood employed.

2. The little thrust there is, will be met by the hollow masonry abutments.

Plate 17. Figs. 1 & 2.

3. To prevent the lifting of the bridge, I have loaded the *outer ends* of the

outside beams with much of the weight of the masonry abutments, and have also endeavoured so to pin down the central and inner ends to the piers, by means of pier ties, that I apprehend no danger can be expected. Plate 17. Figs. 9 & 11.

4. The framed girders FA*a*, GB*b*, &c., being bolted to the main beams, and being connected together diagonally and horizontally by the braces above and by the wale-pieces below,—all that would be likely to be swept away in case of unusual floods will be the joists and planking; and as it is perhaps desirable for the bridge that these *should* go in such a case, the joists are only slightly nailed down, so that the bridge may be relieved as soon as possible.

5. Settlement I could only oppose by the struts BFCG, &c.

Should the above be deemed insufficient as a compactly trussed framing, diagonal iron bars *b*H, *c*G, &c. can be added. I have, however, omitted them, and *many other lines* necessary to complete a *symmetrical* scheme, for the sake of economy.

6. Had I raised the bridge towards the centre to effect this, the execution would have been more complicated, and no adequate benefit obtained. As it would be impossible at a moderate expense to prevent openings between the edges of the flooring boards, the rain water *will* drip through upon the framing beneath. Hence I have deemed it at once the cheapest and simplest plan to suppose the drainage provided for by the openings between the flooring boards, and have therefore even avoided a herring-bone arrangement for these planks, in two courses, which would have added to the stiffness of the bridge.

Materials.—I propose to use three kinds of wood,—sneeze-wood, right yellow-wood, and els, white or red.

Sneeze-wood to be used wherever the carpentry comes in contact with masonry; and great attention to be paid to ventilation in such cases, as well as to sufficient seasoning.

Large pieces will generally be required; and as this wood is rarely sound in trees of any size, the required pieces will have to be built by scarfing sound short portions.

Right yellow-wood to be used in every part of the framing, except where it touches masonry.

Els, white or red, for plank in the flooring.

No sap to be on any account permitted; and all shakes and splits to be filled with a mixture of tallow and lime, as practised in the English dock-yards with Roman oak.

REMARKS ON THE PRINCIPAL PIECES AND THEIR CONNEXIONS WITH EACH OTHER, FOLLOWING THE ORDER OF THE LIST GIVEN IN THE 'DETAILS' AT THE END OF THE PAPER.

In the following, the more received proportions from breadth to depth have been often disregarded; *i. e.*, where lateral stability, or additional thickness to afford mortising, is concerned.

I have avoided crippling the main pieces by mortises, indents, &c., as much as possible, preferring bolting and bedding on cleats.

Yellow-wood *framed*, in lengths exceeding 15 feet, has been estimated for as sawn down the middle, reversed, coupled and bolted. There is no reason to suppose that *strength* is gained by this process, but it is a particularly advisable arrangement *in wooden structures in hot climates*, where warping and twisting are so sure to occur, from the injudicious disposition of timbers of different textures, descriptions, and densities, even though they bear the same name.

A.[1] *End pier plates.*—To give an even bearing and lateral steadiness to the main beams which lie in them on cleats. I have not supposed it necessary to bolt the beams to these plates.

B. *Cradle plates.*—Same intention as the above, but much broader, having the ends of two sets of beams to bear.

C. *Pier ties.*—To fix the framing of the bridge to the piers by tying the beams down by the saddles C riding over them.

D. *Main beams.*—Kerfed, bent and hooped on the Prussian principle. Steaming, as suggested by Captain Selwyn, will render the bending easier, and greatly forward the seasoning of such large and important pieces.

E*a*. *Scarfed ends.*—It will be difficult to get timber long enough to dispense with these: they are scarfed to the beams, and bound down by strong iron bands.

E*b*. *Cross beams.*—The upper one buts against the ends of the scarfed additions to the main beams; its ends are buried in the side walls of the abutment; the lower one is buried in the circular back. These cross

[1] The same letters refer to the same pieces in all the plates.

beams with their plates E*c* below, and their iron bands, so connect the ends of the beams as to generalize any lateral thrust over the abutment, and at the same time prevent any part of the end portion of the framing from flying up, without raising the mass of masonry above it. Plate 17. Fig. 1.

F. *Framed girders.*—These are of different heights to allow the joisting to be laid level. The two centre pier girders have a heavier scantling than the rest. The lower beams F*b* are bolted to the main beams, the bolt going through the latter, and fixed by screw and nut. The remainder of the framing is by mortise and tenon, the latter spiked through. Plate 17. Figs. 3, 4, 5, & 6.

The upper beams F*a* to be protected from drippings by zinc.

G. *Struts.*—To resist settlement.

H. *Cleats.*—As abutments to the struts, spiked down.

I. *Wale-pieces.*—These give a diagonal bracing to the main beams, and are thin enough to admit of being bent and spiked down to their upper surfaces.

J. *Braces.*—Here I have put both diagonals to render the trussing as complete as possible; as, with the side-guards and the upper beams of the framed girders, it is the upper surface of the framed part of the bridge. The lower braces J*b* are deeper than the upper ones J*a*, to allow the former to be let into the latter. Any thing above this, as before stated, will be kept down by little more than its own weight. Plate 16. Fig. 2.

L. *Joisting.*—Perhaps the scantling of this is an excess compared with the best fir timber; but I am not as yet sufficiently acquainted with all the habits and properties of yellow-wood to risk experiments on such a scale.

M. *Flooring plank.*—The thickness of this is what is allowed in the decks of the smaller men of war.

N to S. *Railing.*—This will be a long feeble line in a wood so given to warp as yellow-wood; it has been supported as much as possible by the cleats and struts, and stiffened by both the side-guards and rail being sawn, reversed, and bolted. Plate 17. Figs. 1 & 2.

The side-guards N are firmly strapped down to the upper beams of the framed girders.

Iron work.—Chiefly used to render the beams, framed girders, braces, wale-pieces, and side-guards, one hollow, but stiff, mass of trussing.

The whole of the iron work to be hot varnished.

Pitching.—Pitch tempered with grease and whale oil, or coal tar; to be laid on twice, hot, after the shakes, &c. have been filled with tallow and lime.

Painting.—Lead colour, twice, only on the railing.

GENERAL OBSERVATIONS ON THE MODE OF CARRYING ON THE WORK, &c.

Labour.—Military labour has been estimated for in excavation and pitching; in bending the beams, and fixing them on the bridge, half the *labourers* are military. I have in all other cases supposed civilians employed. Unless this arrangement be observed in practice, the estimates cannot stand out.

There should be as large a party employed as possible on the excavation, and such masonry as lies below the level of the pier heads; if floods come down during this stage the expense will be endless.

Task or piece-work to be employed, if practicable; but I have not reckoned on it in my prices.

Materials.—All to be assembled well in advance of the work in hand.

The wood to be ordered at once, now being the best time of the year. Large scantlings to be squared immediately, and all timber to be kept under proper sheds to season.

Transport, &c.—Much will, I apprehend, be saved by a small temporary establishment being formed near the bridge; consisting of timber shed, carpenters' shop, saw-pit, and a hut for a person in charge.

SPECIFICATION OF CLASSES OF CARPENTRY.

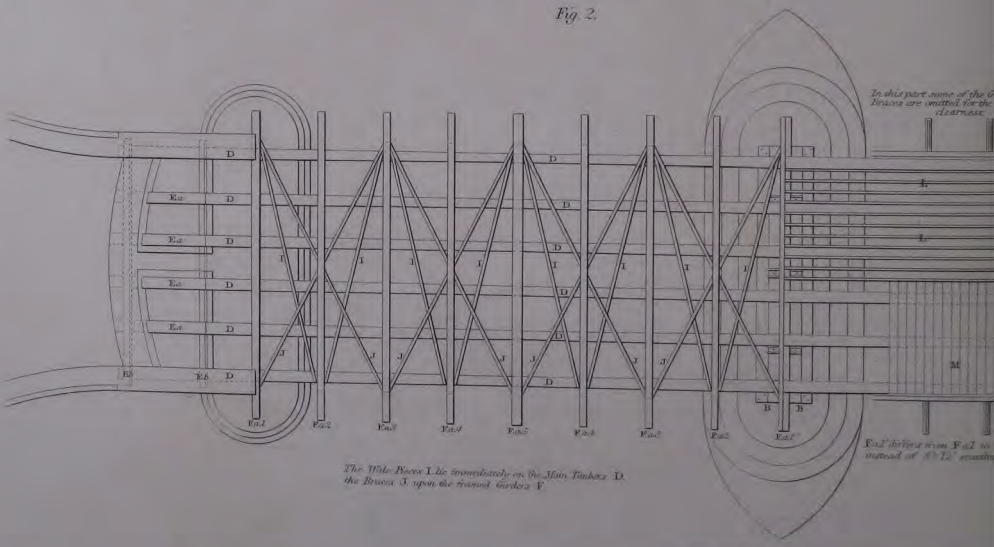
	Class.		
Sneeze-wood	S. W.	1	Sneeze-wood in plates and ties,—sawn, scarfed, bolted, and fixed.
Yellow-wood	Y. W.	1	Right yellow-wood in main beams,—sawn, kerfed, mortised, hooped, and fixed.
Do.	Y. W.	2	Do. . . . in extra lengths,—sawn, reversed, coupled and bolted, framed, wrought and fixed.
Do.	Y. W.	3	Do. . . . wrought, framed and fixed.
Do.	Y. W.	4	Do. . . . sawn and fixed in joisting and cleats.
Els	E.	1	Els, white or red, sawn and fixed in flooring plank.

PROJECT OF A BRIDGE

IN 3

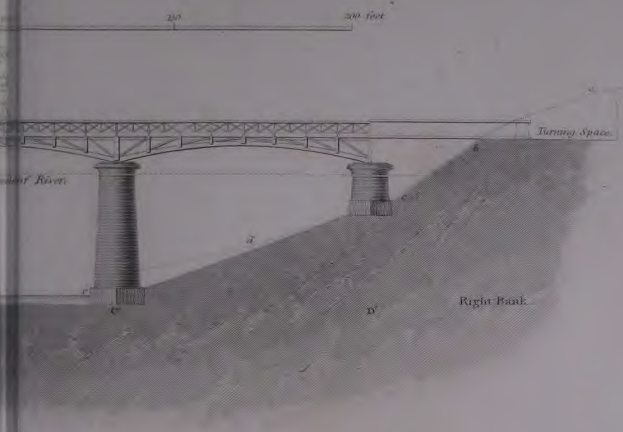
The Dotted section is the N

Fig. 2.



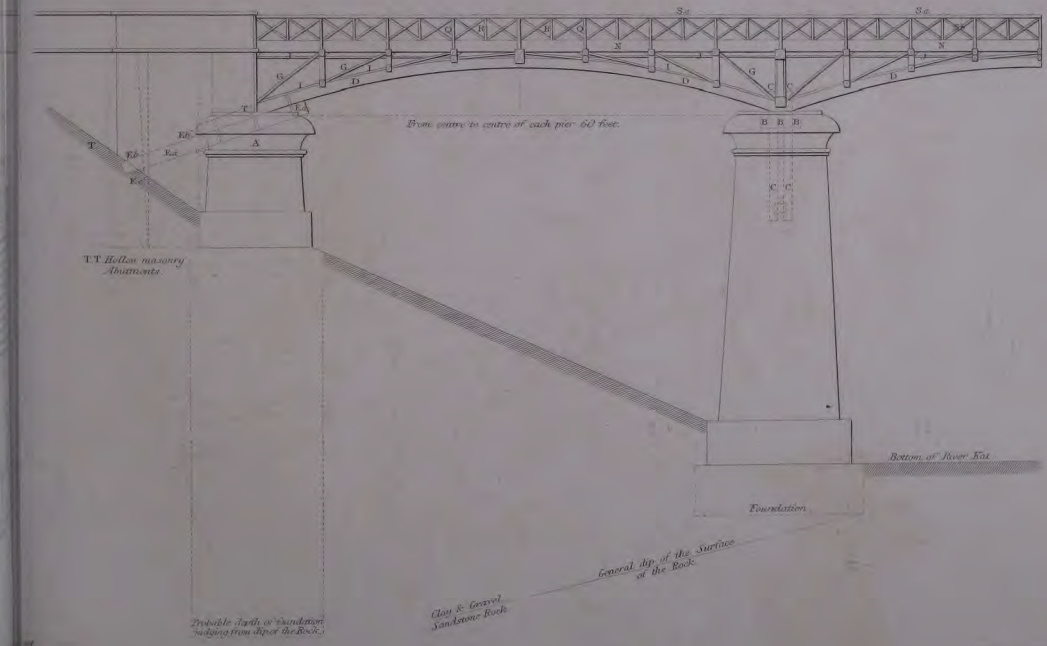
Scale for Figs. 2 and 3.

E KAT RIVER AT BEAUFORT,
T ARCHES



Full line is the Proposed one.

Fig. 3.



59 High Holborn.

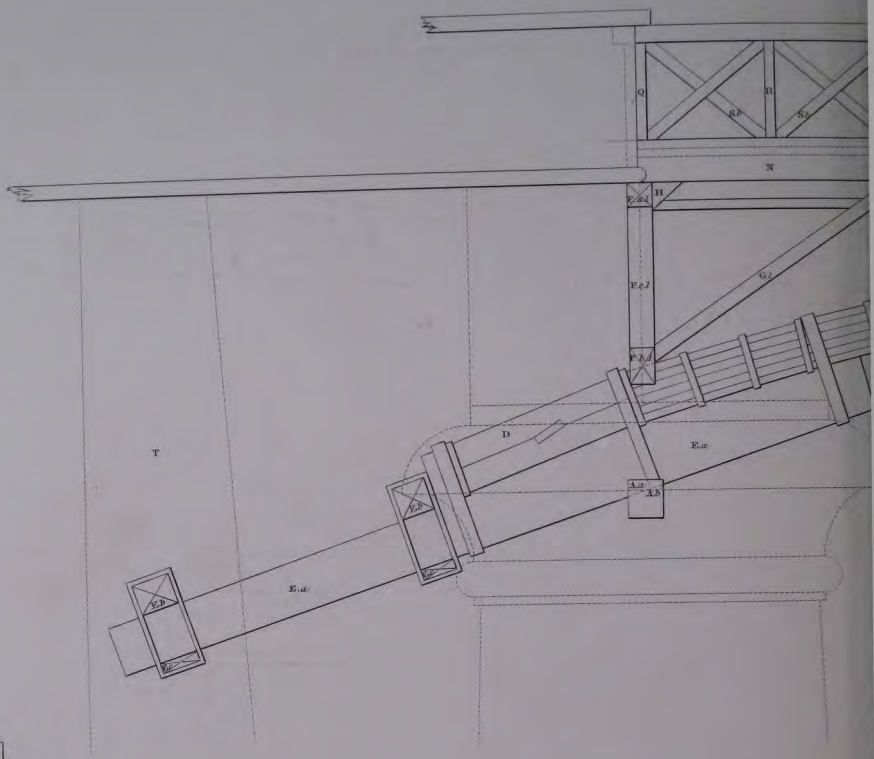


Fig. 2.

Figs. 3. 4. 5. & 6. Framed Girders.

Half section Transverse and Vertical of the Superstructure of the Bridge.

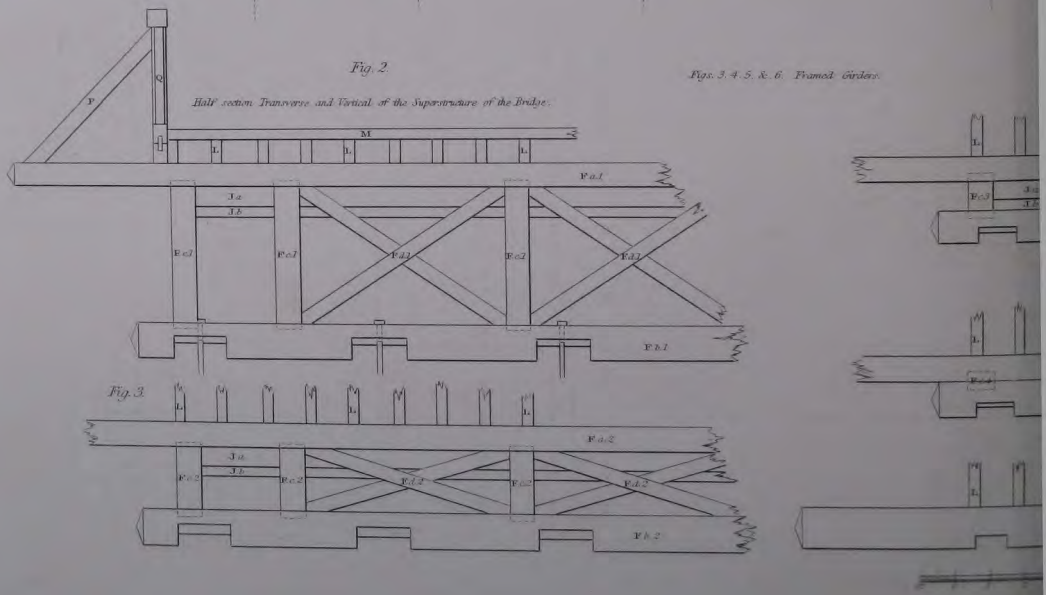


Fig. 3.

Fig. 1.

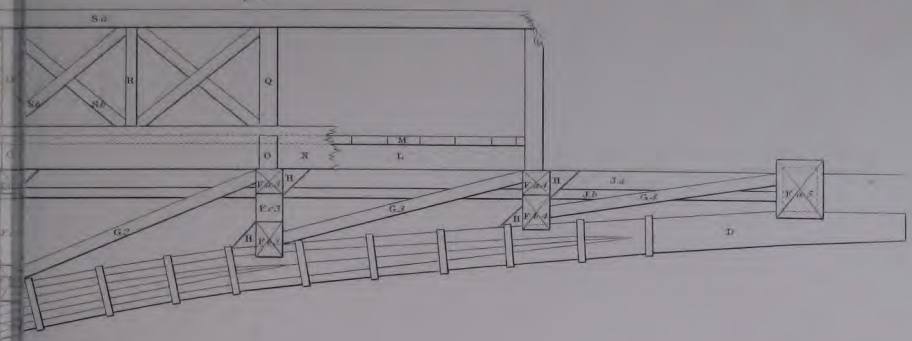


Fig. 9.

End Elevation of a cradle-plate B, supporting the main Beams D, which (bedded on the cleats B.c) are steadied laterally and vertically by the Pier-tie C, and the Saddle C.c.

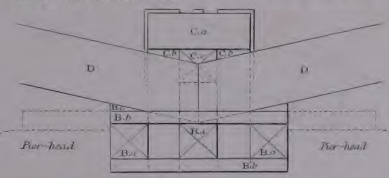


Fig. 10.

Section across the end Pier-plate A, shewing the scarped ends E.a of the main Beams lying in the notches A.a on the cleats A.b.

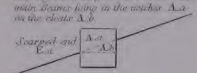


Fig. 11.

Elevation of a Pier-tie C.

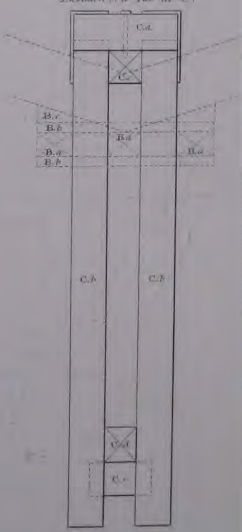


Fig. 4.

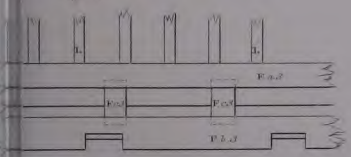


Fig. 5.

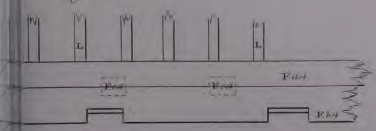


Fig. 6.

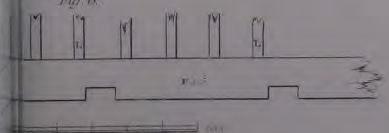
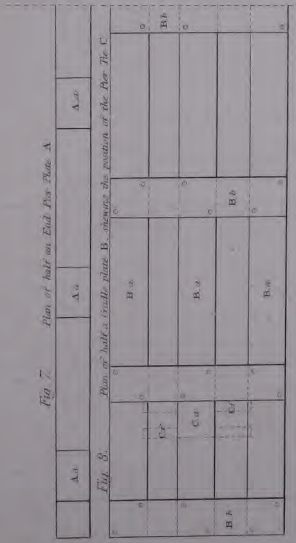


Fig. 7. Plan of half an End Pier-Plate A.

Fig. 8. Plan of half a cradle-plate B, shewing the position of the Pier-Tie C



Carpentry, References and Details.	Plates.	Figure.	Letter.	Class.	No.	Length. ft.	Length. in.	Breadth. ft.	Breadth. in.	Depth. ft.	Depth. in.	Contents. Superficial including ends. feet.	Contents. Cubic. feet.
End pier plates	16, 17	..	A	S. W. 1	2	30	0	1	0	1	0	244	60
Cleats to do.	17	..	A b	Y. W. 4	10	1	6	1	0	0	6	55	7½
Cradle plates	"	8, 9, 10	B										
—— long beams	"	"	B a	S. W. 1	6	30	0	1	0	1	0	732	180
—— cross pieces	"	"	B b	do.	28	5	0	1	0	0	4	392½	46⅝
—— cleats	"	"	B c	Y. W. 4	24	2	6	1	6	0	8	383⅜	60
Pier ties	"	11	C										
—— heads	5	"	C a	Y. W. 3	6	3	0	1	0	1	0	84	18
—— legs	"	"	C b	S. W. 1	12	14	3	1	0	1	0	708	172
—— saddles	"	"	C c	Y. W. 3	2	30	0	1	0	1	0	244	60
—— lower cross beams	"	"	C d	S. W. 1	2	30	0	1	0	1	0	244	60
—— cross bits	"	"	C e	do.	6	2	0	1	0	1	0	48	12
Main beams	16, 17	..	D	Y. W. 1	36	40	0	1 6 / 1 0		1 6 / 1 0		8000	2722½
Scarfed ends to do.	"	..	E a	Y. W. 3	8	23	0	1	6	1	6	1140	414
Do. *in* the wing walls	"	..	"	S. W. 1	4	23	0	1	6	1	6	570	207
—— cross beams	"	..	E b	do.	4	31	0	1	0	1	0	504	124
—— cross plates	"	..	E c	do.	4	31	0	1	0	1	0	333	41½
Framed girders	"	..	F										
Centre fd. grs. upper beam	Same drawing as for the			Y. W. 2	2	36	6	1	0	1	0	296	73
———— lower beam	end framed girders ex-			do.	2	31	0	1	0	1	0	252	62
———— uprights	cept that the scantling			Y. W. 3	12	4	6	1	0	1	0	240	54
———— braces	is larger.			do.	12	7	0	0	6	0	6	174	21
End framed girders	17	2	F a 1	Y. W. 2	2	36	6	0	8	0	8	197	33
	"	"	F b 1	do.	2	31	0	0	8	1	0	209	41½
	"	"	F c 1	Y. W. 3	12	4	6	0	8	0	8	154	24
	"	"	F d 1	do.	12	7	0	0	6	0	6	174	21
Other framed girders in succession	"	3	F a 2	Y. W. 2	6	36	0	0	8	0	8	593	99⅛
	"	"	F b 2	do.	6	31	0	0	8	1	0	629	124
	"	"	F c 2	Y. W. 3	36	2	6	0	8	0	8	272	40
	"	"	F d 2	do.	36	6	3	0	6	0	6	468	56¼
	"	4	F a 3	Y. W. 2	6	36	6	0	8	0	8	593	99⅛
	"	"	F b 3	do.	6	31	0	0	8	1	0	629	124
	"	"	F c 3	Y. W. 3	54	1	3	0	8	0	8	228	30
	"	5	F a 4	Y. W. 2	6	36	6	0	8	0	8	593	99⅛
	"	"	F b 4	do.	6	31	0	0	8	1	0	629	124
	"	"	F c 4	Y. W. 3	54	0	8	0	4	0	4	60	4
	"	6	F a 5	Y. W. 2	3	36	6	1	0	1	0	444	109½
Struts, 1st Bay	"	..	G 1	Y. W. 3	36	8	8	0	6	0	6	642	78
—— 2nd Bay	"	..	G 2	do.	36	7	6	0	6	0	6	558	67½
—— 3rd Bay	"	..	G 3	do.	36	7	0	0	6	0	6	522	63
—— 4th Bay	"	..	G 4	do.	36	6	9	0	6	0	6	504	60⅜
—— Cleats to do.	"	..	H	Y. W. 4	252	1	6	0	6	0	6	756	94½
Wale pieces	16	..	I	Y. W. 3	24	28	6	0	8	0	3	1262	114
Braces, upper	"	..	J a	do.	12	33	0	0	6	0	6	798	99
——— lower	"	..	J b	do.	12	33	0	0	6	0	9	999	148½
Joisting, joists	17	1, 2	L	Y. W. 4	22	210	0	0	9	0	4	10160	1155
——— bridging	(not shown)		(K)	do.	50	22	0	0	6	0	3	1650	137½
Flooring plank	17	1, 2	M	E. 1	..	210	0	25	0	0	3	..	1312½
Side guards	"	"	N	Y. W. 2	2	190	0	0	4	1	3	602	158
—— cleats	"	"	O	Y. W. 3	50	1	0	0	4	1	0	134	16⅝
—— struts	"	"	P	do.	50	5	9	0	6	0	6	600	71⅜
Railing, large posts	"	"	Q	Y. W. 3	50	3	3	0	6	0	6	325	40⅜
——— small do.	"	"	R	do.	50	3	3	0	4	0	4	217	18
——— rails	"	"	S a	Y. W. 2	2	180	0	0	6	0	6	720	90
——— cross braces	"	"	S b	Y. W. 3	192	4	6	0	4	0	4	1152	96

As some of the prices in the following estimate may appear monstrous, especially to those who have lately been at the Cape, I give one specimen of the way in which these prices were framed. They were all more or less based upon data employed in the construction of a large set of prices for Algoa Bay, which I made in 1836, modified, of course, with reference to localities, in the same way that many things in the Algoa Bay set were, with regard to similar matters collected at Bermuda.

Price of Right Yellow-wood in Main Beams,—sawn, kerfed, mortised, hooped, and fixed,—per cubic foot.

	£.	s.	d.
A tapering beam 40 feet × $\binom{1 \text{ ft. } 6 \text{ in.}}{1 \quad 0}$ × $\binom{1 \text{ ft. } 6 \text{ in.}}{1 \quad 0}$ = 71 cubic feet of squared stuff, taking the proper mean of the scantling at, say, 1 foot 4½ inches. For waste, in this kind of wood, in slabs and kerfing, say 2½ inches all round, or ⅖ of the net quantity. Hence to obtain 71 cubic feet, net, takes in gross, or in the log *delivered* from the Kroemie bush, per contractor, 98 cubic feet in choice trees felled expressly, at 2*s.* 6*d.*	12	5	0
Sawing 4 sides, say 220 sup. feet 4 kerfs 280 do.			
say 500 sup. feet, at 1*d.*	2	1	8
Transport, and labour, to and from pit, say	0	2	6
1 Mortise and hard wood tongue, labour and material, say	0	3	6
150 lbs. wrought iron, fixed, in hoops and scarf-bands, at 9*d.*	5	12	6
Labour in bending, 2 carpenters, at 5*s.* 6*d.*	0	11	0
Do. 6 labourers, 3 military at 10*d.*, 3 civil at 2*s.* 6*d.* . . .	0	10	0
Labour in fixing, do. as in bending, but including the halving of the smaller ends	1	1	0
Loss on labour	0	5	0
Price of 71 cubic feet	22	12	2
Price of 1 cubic foot	0	6	4½

'Superintendence' I have considered as referable rather to the Royal Engineers Department generally. Transport (ox-waggon) performed by contract; and the charge for tools and their repairs, as carpenters' tools, borne by the workmen;—the Royal Engineers Department only finding tools when sappers are employed.

ESTIMATE.

			£.	s.	d.	£.	s.	d.
	Road.—Excavators' Work.							
49560	Cubic feet.—Hard sandstone rock, excavated and removed 1 run of 30 yards,	cub. ft. 2*d.*	413	0	0			
3750	,, Clay and gravel, excavated and removed 1 run,	cub. ft. $1\frac{1}{2}d.$	19	10	$7\frac{1}{2}$			
			432	10	$7\frac{1}{2}$	432	10	$7\frac{1}{2}$
	Contingencies 1-10th					43	5	1
	Total Road					475	15	$8\frac{1}{2}$
	Bridge.—Excavators' Work.							
3750	Cubic feet.—Hard sandstone, excavated and removed 1 run,	cub. ft. 2*d.*	31	5	0			
21293	,, do. do. 3 ,,	,, $3\frac{1}{2}d.$	310	10	$5\frac{1}{2}$			
160937	,, Clay and gravel, do. 3 ,,	,, $2\frac{3}{4}d.$	1508	15	$8\frac{1}{4}$			
1125	,, Gravel, screened and washed, in flooring	,, 2*d.*	9	7	6			
	Total Excavators' Work		1859	18	$7\frac{3}{4}$	1859	18	$7\frac{3}{4}$
	Masonry.							
61031	Cubic feet.—Rubble work in backing, &c.	cub. ft. $10\frac{1}{4}d.$	2606	10	$7\frac{3}{4}$			
62107	,, Best rubble work in courses	,, 1*s.* $1\frac{1}{2}d.$	3493	10	$4\frac{1}{2}$			
4268	Superficial feet.—Extra for facing plain ashlar	sup. ft. 9*d.*	160	0	1			
4162	,, do. do. in mouldings	,, 1*s.*	208	2	0			
	Total Masonry		6468	3	$1\frac{1}{4}$	6468	3	$1\frac{1}{4}$
	Carpentry.							
904	Cubic feet.—Sneeze-wood, Class 1, in plates and ties	cub. ft. 8*s.* $9\frac{1}{2}d.$	396	8	10			
2723	,, Rt. Yellow-wood, Class 1, main beams	,, 6*s.* 5*d.*	873	12	7			
1240	,, do. 2, extra lengths, &c.	,, 6*s.* $1\frac{3}{4}d.$	381	0	10			
1619	,, do. 3, framed, &c.	,, 5*s.* $6\frac{1}{2}d.$	448	11	$11\frac{1}{2}$			
1446	,, do. 4, sawn, &c.	,, 4*s.* $4\frac{1}{2}d.$	316	6	3			
1313	,, Els, 1, flooring	,, 3*s.* $4\frac{1}{4}d.$	220	4	$0\frac{1}{4}$			
			2636	4	$5\frac{3}{4}$	2636	4	$5\frac{3}{4}$
	Iron work, &c.							
14359	lbs. Wrought iron, in drilled bands, collared hoops, bolts and nuts, &c.	lb. 9*d.*	542	12	7			
$2\frac{1}{2}$	Cwt. Cast iron in lamp posts	cwt. 20*s.*	2	10	0			
2	Lamps	each 30*s.*	3	0	0			
1679	Sup. ft. Zinc plating to framed girders	sup. ft. 10*d.*	69	19	2			
38221	,, Pitching, twice, to wood work	,, $2\frac{1}{2}d.$	398	2	8			
3750	,, Painting, twice, in lead to do.	,, $2\frac{3}{4}d.$	35	3	$1\frac{1}{2}$			
	Scaffolding, sheers, crab, tackles, rope, &c., bending-frame for beams, steamer, &c.		200	0	0			
	Temporary establishments, of timber-shed, saw-pit, store house, and hut		120	0	0			
			1371	7	$6\frac{1}{2}$	1371	7	$6\frac{1}{2}$
						12335	13	$9\frac{1}{2}$
	Contingencies 1-10th					1233	11	$4\frac{1}{2}$
			Total Bridge			13569	5	$1\frac{3}{4}$
	Total Road and Bridge		£14045	0	$10\frac{1}{4}$			

R. J. Nelson,
Lieutenant Royal Engineers.

VIII.—*Rough Sketch of the Suspension Bridge over the Lahn at Nassau. By* R. J. Nelson, *Lieut. Royal Engineers.*

Plate 18. This slight drawing of the suspension bridge over the Lahn at Nassau is an exact copy of the subject as it lies in one of my sketch-books, accompanying the German portion of a journal which I have kept in some detail for many years. Hence, the outline performance now submitted to my brother officers has no pretensions to the minute precision of documents accompanying a contractor's specification. It is only offered as perhaps affording sufficient hints on general arrangement, and dimensions in detail, to those who have paid some slight attention to the subject of chain suspension bridges. That at Nassau was built (as I was informed) by two brothers, one of whom was an officer in the Prussian Engineers. Its elegance, its great simplicity, and efficiency, do great credit to these gentlemen.

Richd. J. Nelson,
Lieutenant Royal Engineers.

ROUCH SKETCH OF THE SUSPENSION BRIDGE OVER THE L

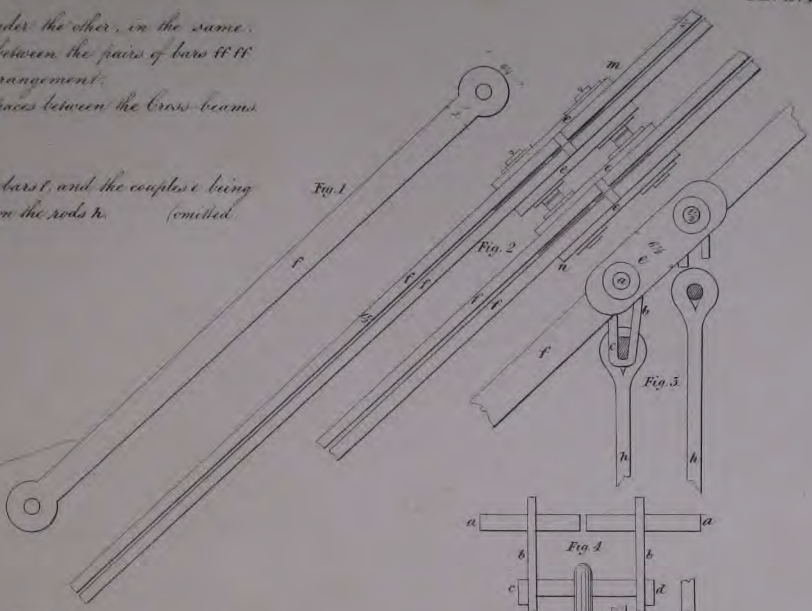
Each side of this Bridge is supported by two double Chains, one of those double
vertical plane; and the Couplings are so disposed that the suspension rods from the
(Fig. 2.) of the lower ones, at about the middle of these last, so as to give an alternating

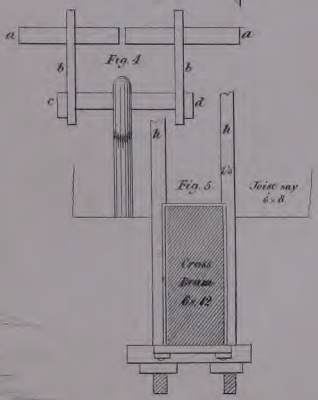
Fig. 1. A single bar. The lengths of these are variable, being projections on the Cab
" 2. Bars and couples in plan, each set of couples mn bearing a pair of
" 3. Side Elevation of d° and Front Elevation of the pair of Rods
" 4. Side Elevation of a Rod hanging on the pin cd and the slings b, from the
" 5. Transverse Section of the River, shewing also the construction of the scarphed c

[illegible] placed under the other, in the same [illegible]
[illegible]ens pass between the pairs of bars ff ff
[illegible]gonal arrangement.
[illegible] the equal spaces between the Cross beams

[illegible] bolts a, the bars f, and the couples e being
[illegible] g hanging on the rods h. (omitted

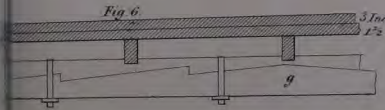
Fig. 1





Total Length. 112 Yds from A to corresp[d] p[t]
Length between pillars 87 yds
Total breadth 24 ft road way 21 ft between the rods
Height of Piers say 25 ft height of Curve 3 ft flush with base p of
Pillars, height of Pillars say 30 ft — 7, 6 squ. at base.
Breadth of Piers 6. 6. From A to Pillar 8 bays. Between pillars 56
7 sets of Joists in the breadth say 6 × 8

Fig. 6.



Nassau, 19 May, 1835.

IX.—*Detailed Description of some of the Works on the Rideau Canal, and of the alterations and improvements made therein since the opening of the navigation. By Lieutenant* Denison, *Royal Engineers.*

In the first volume of the Professional Papers, a general description was given by Lieutenant Frome of all the works on the line of the Rideau Canal. In the second volume a more detailed account was given of the two largest dams on the line, by one of which the water was raised about 48 feet, and by the other about 56.

The drawings and descriptions given in the present volume will be explanatory of the several more minute details relative to the locks, gates, machinery of sluices, &c., both as originally constructed, and as altered and improved during an experience of several years' working. Plate 19, fig. 1, is a plan of a single lock of 10 feet lift. Figs. 2, and 3, longitudinal and transverse sections of the same. Fig. 4 is a transverse section of a lock with a wooden floor; and fig. 5 is a plan of a wooden pointed sill, as used in the lower locks very generally when the foundation was good.

The locks were in every instance built of rubble masonry, faced with cut ashlar, and, with one or two exceptions, according to the above plan. In these one or two exceptions, the difference consisted in making the upper gates of the same height as the lower, throwing thus the whole weight of the lift upon the upper, as well as the lower, and doing away with the upper breast-work.

When the ground looked at all suspicious, the section shown in fig. 3 was adopted, an invert being turned between the side walls of the lock chamber; but in other cases, when the foundation was good, a timber floor, as in fig. 4, was substituted; the sleepers of which were generally formed of hemlock, as being very durable under water, and the planking either of oak or hemlock.

The side walls of the chamber were made 5 feet thick at top, and 8 feet at

bottom, with a batter of 3 feet, having counterforts 4 feet square, at the distance of 20 feet apart from centre to centre. Clay puddle was laid behind the walls for a thickness of 2 feet. This, although called puddle, was not entitled to the name; it was merely clay well rammed while moist: the consequence was that in several instances, where great care was not taken to drain away the land water, it made its way through this clay backing, and also through the wall, injuring the work materially.

The masonry was originally laid in common mortar, and pointed with Harwich cement; the frost, however, in the winter, acted very injuriously upon this; and a cement having been discovered in the neighbourhood of Hull, on the Ottawa, which set pretty rapidly under water, a great quantity of this was used, both in grouting work already executed, and setting new work. The following mode of grouting work already executed was found to succeed very well.

A circular hole was drilled in one of the vertical joints, large enough to admit the end of a tin tube about 1 inch and half in diameter; this tube was about 6 or 8 feet in length, and about 8 inches of the end was bent at right angles; about 6 inches from this end a sort of cup was soldered to the tube, which projected about 3 inches all round it, and the use of which was to retain and compress the clay which closed the opening round the tube when inserted in the hole. All the joints of the wall, both horizontal and vertical, near the hole, were pointed with cement, and the tube being inserted in the hole, cement in a very liquid state was poured into the funnel at the top, and the pressure of the head of 6 or 8 feet forced it in every direction into all the openings and vacant spaces in the wall. By this expedient, walls were in many instances made water-tight, when every other attempt had failed; still the original mistake of building the lock with common mortar instead of cement, or hydraulic lime, has caused great injury to the works.

The heavy mass of masonry composing the breast-work upon which the sills and upper gates were placed was built, like the rest of the work, of rubble, faced with ashlar laid in common mortar; no sheeting piles were placed in front of the sill, and although the sill itself was composed of heavy stones, with arched joints, yet the courses of ashlar below it were merely square jointed. The consequence was, that as soon as a head of water was raised against the upper gate, it forced its way through the joints of the apron, and the mass of rubble masonry, and in two or three instances forced the

ashlar of the breast-work out of its place. These instances, however, proved the necessity of taking greater precautions against such accidents; the apron was laid in cement and well grouted, and iron bolts were passed through the sill into the lower courses of ashlar.

The plan shows some paving below the lower gates; it was found advisable, in instances where the ground was soft, and had a tendency to slide, to extend this to a greater distance than shown in the plan, and also to face the banks of the canal with rubble stone, in order to guard against the action of the water from the sluices in the lower gates.

Plate 20, fig. 1, is an elevation, and figs. 2 and 3 a vertical section and plan, of one of the gates of a lock of 18 feet lift, as altered and strengthened.

Fig. 4 is a plan showing the original mode of working the lock gates.

Fig. 5 shows the alterations that have been adopted.

Figs. 6, 7, 8, 9, 10, and 11, are plans and sections of the different blocks and sheaves employed to tighten the chains used in opening and shutting the gates, and give them their proper direction.

Fig. 12 is an elevation, and fig. 13 a section, of the truck upon which the gate moves.

The lock gates were constructed of oak; the scantling of the timbers was in all instances the same, the only difference between a gate for high or low lift being in the number of cross rails. This scantling was found insufficient for the heavy lifts; the curved rails shown in the plan were therefore bolted to the front of the gate, and to stiffen these still more, an iron bar, 5 inches by 1 inch, was let into both the upper and under side of each of these rails, and bolted through them.

The lower end of the heel post had an iron centre, which was let into a box sunk into the stone to receive it; the upper end was secured by an iron collar, keyed to an anchor strap let into the coping, and well bolted. The gates being large, it was not thought advisable to allow them to hang on the anchor strap; a truck was therefore bolted to the lower rail of the gate about 12 feet from the heel part, and was supported upon an iron rail let into the floor of the apron.

Situated as the Rideau Canal was, in the back woods, at a distance from all the resources which in this country are lavished on similar undertakings, every effort was of course made to simplify the machinery employed. In the many experiments that were made for this purpose, several were un-

successful, among which must be noted that shown in fig. 4 for opening the lock gates.

The object of this plan was to open and shut each leaf of the gate by means of a single capstan, as the size was considered to be beyond that which would have allowed the use of a balance beam. Accordingly one end of a chain was fastened to the front of the mitre post of the gate; it then passed through some blocks on the floor of the apron, was carried up the face of the pier, and took two or three turns round the barrel of a capstan; from thence it was carried down the pier, and through the same blocks (though upon different sheaves) as before, passed through a snatch block fastened to the sill, and was attached to the rear of the mitre post. Here, by turning the capstan in one direction the gate was opened, by turning it in the other it was closed; the position, however, of the blocks upon the apron rendered them liable to get jammed by very trifling causes, and the interruption caused by these accidents, especially in a lower lock where the water was necessarily pumped out in order to allow of any repairs, rendered it advisable to adopt the change shown in fig. 5, where a balance beam has been bolted to the gate, and the chain, having been removed from the mitre post, is now fastened to this balance beam, passing through the same blocks as before, which, being removed from the apron, are now fastened down to the coping of the pier. This plan is just as simple as the former, and is said to answer exceedingly well.

Plate 21, fig. 1, is an elevation, and fig. 2 a section, of the sluices adopted at Jones's Falls. Figs. 3, 4, are sections showing the mode in which they originally acted, and fig. 5 shows the alteration adopted.

Fig. 6 is a perspective view, showing the general mode of fixing the sluice gates in the culvert.

Fig. 7 is a plan, and fig. 8 a section, of the cast iron gates as strengthened with wrought iron bars.

Fig. 9 is a plan of the sluice used in the lower gates. Fig. 10 is a section of the same. Figs. 11 and 12 show on a larger scale the mode in which the bar used to open these sluices is bolted to them.

Fig. 13 is a plan of the original sluice gate in the culvert.

Fig. 14 is a plan, and fig. 15 a section, of the cast iron socket for the axle of the gate.

Fig. 16 is a plan, and fig. 17 a section, of a metal strap to replace these cast iron sockets, and fig. 18 is a sketch of the mode of applying it.

Fig. 19 is the elevation of the rack and pinion used in opening the sluices in the gates.

Figs. 20 and 21 are sections of the pinion, and fig. 22 is a section, and 23 an elevation, of the roller which keeps the rack up to the pinion.

Figs. 24 and 25 are elevations of the crab capstan used for opening both the lock gates and sluices.

In all cases the water was passed from one level to another through culverts in the piers, while in the lower locks the sluices were fixed in the gates, as shown in Plate 20, fig. 1. In most cases the sluice gates were fixed as shown in Plate 21, fig. 6; by so doing, however, the pressure on the gate was much increased; an addition of half the lift being made to the head. In the heavy lifts at Jones's Falls, and elsewhere, it was therefore thought advisable to adopt the plan shown in figs. 1 and 2. Here, however, at first, both gates were connected to the same bar, and the pinion acted upon both, some assistance being afforded by a heavy counterpoise attached to one of the bars, as shown in fig. 19. This machinery proved too slight for the exertion of opening both gates simultaneously; and the alteration shown in figs. 1, 2, and 5, was therefore adopted, where the bar is still shown attached to the lower gate, while the upper is acted upon by a chain which does not commence its action till the lower gate is nearly open. These sluices, like those in the gates of the lower locks, turn upon centres placed at some distance behind the face. The original object of placing the centre in this position was to allow the gate, when opened, to lie against the upper part of the opening, and thus leave nearly the whole of the space free and uninterrupted for the passage of the water, retaining, at the same time, the advantage of hanging the gate nearly in equilibrio.

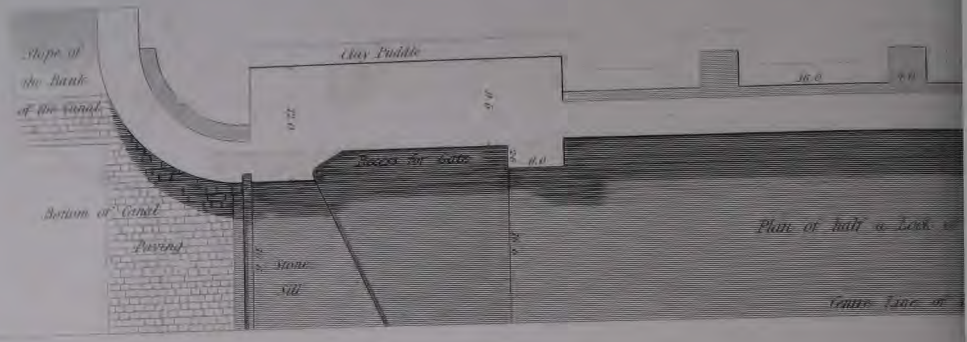
In each leaf of the lower lock gates there are two sluices, figs. 9 and 10, about 5 feet long, and 1 foot 6 inches wide; these were originally joined by a bar, and opened by one rack and pinion at the top of the gate. This single action being found insufficient, each gate has now its own rack and pinion.

The original sluice gates in the culverts were found too weak to resist the great pressure thrown upon them; in some instances fatal accidents occurred from the breakage of a gate while a workman was in the act of opening it: this was remedied by the application of wrought-iron bars, as shown in figs. 7 and 8; an additional support is also given by attaching the chain which

opens the gate to the four angles, instead of the centres, of the top and bottom sides. Failures likewise occurred from the mode in which the gate was suspended in the framing. Iron sockets, figs. 14 and 15, to receive the axles or gudgeons on which the gate turned, were merely let into the oak framing; the great weight of water on the gate sometimes forced the socket through the wood, tearing every thing away before it. A metal journal strap is now not only sunk into the wood, but embraces the whole of it, and is well bolted through it in addition.

The mode of opening these gates is very simple: the chains before mentioned as attached to the angles of the lower end of the gate meet at some distance above it, and from thence a single chain passes up the man-hole, and takes two or three turns round the barrel of a crab capstan; it then descends the man-hole, and is attached, in the same manner as the other end, to the two angles of the upper part of the gate. The gate is suspended nearly in equilibrio, the difference of pressure on the upper and lower halves being sufficient to keep it close; but a slight force applied to the capstan is sufficient to open it.

W. DENISON,
Lieutenant Royal Engineers.



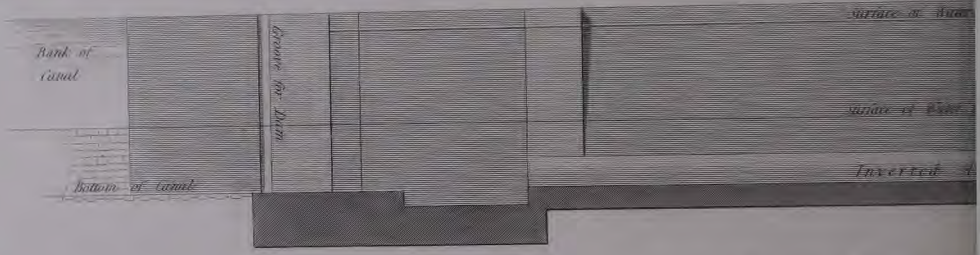
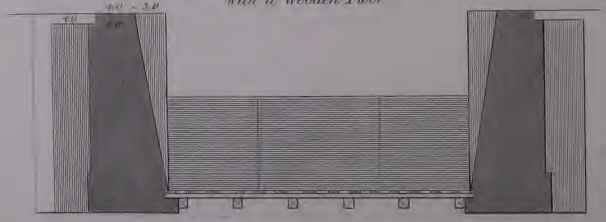
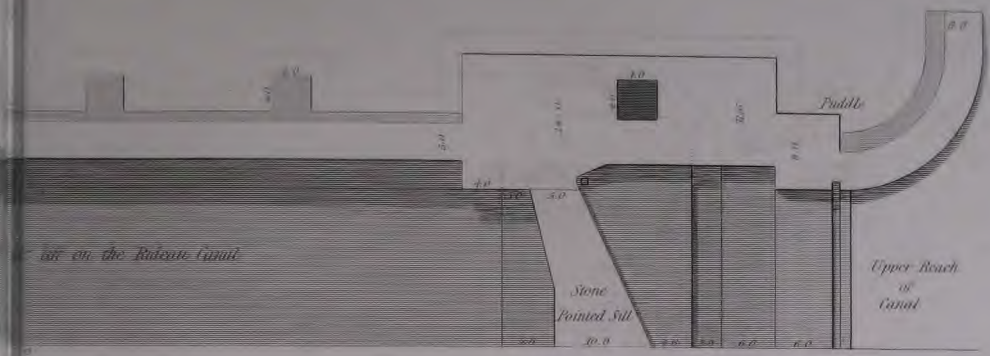


Fig. 4

Transverse Section of a Lock with a Wooden Floor



Plan of a Wooden Sill adopt

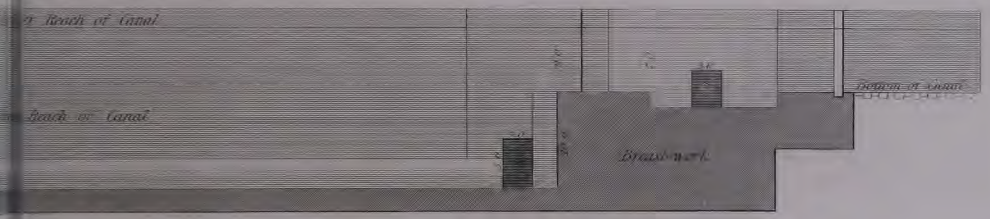


Sill on the Rideau Canal

10 feet Lift on the Rideau Canal

Reach of Canal

Reach of Canal



Some of the Lower Locks on the Canal

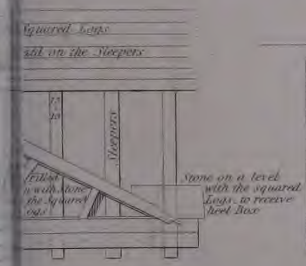
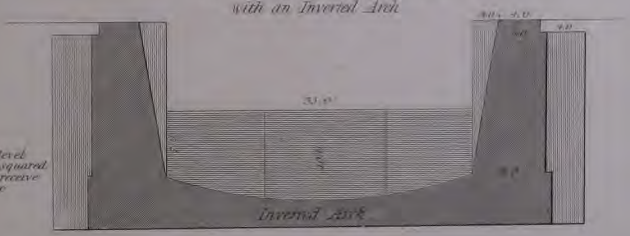


Fig. 3

Transverse Section of a Lock with an Inverted Arch



an Inch

10 15 20 25 30 Feet

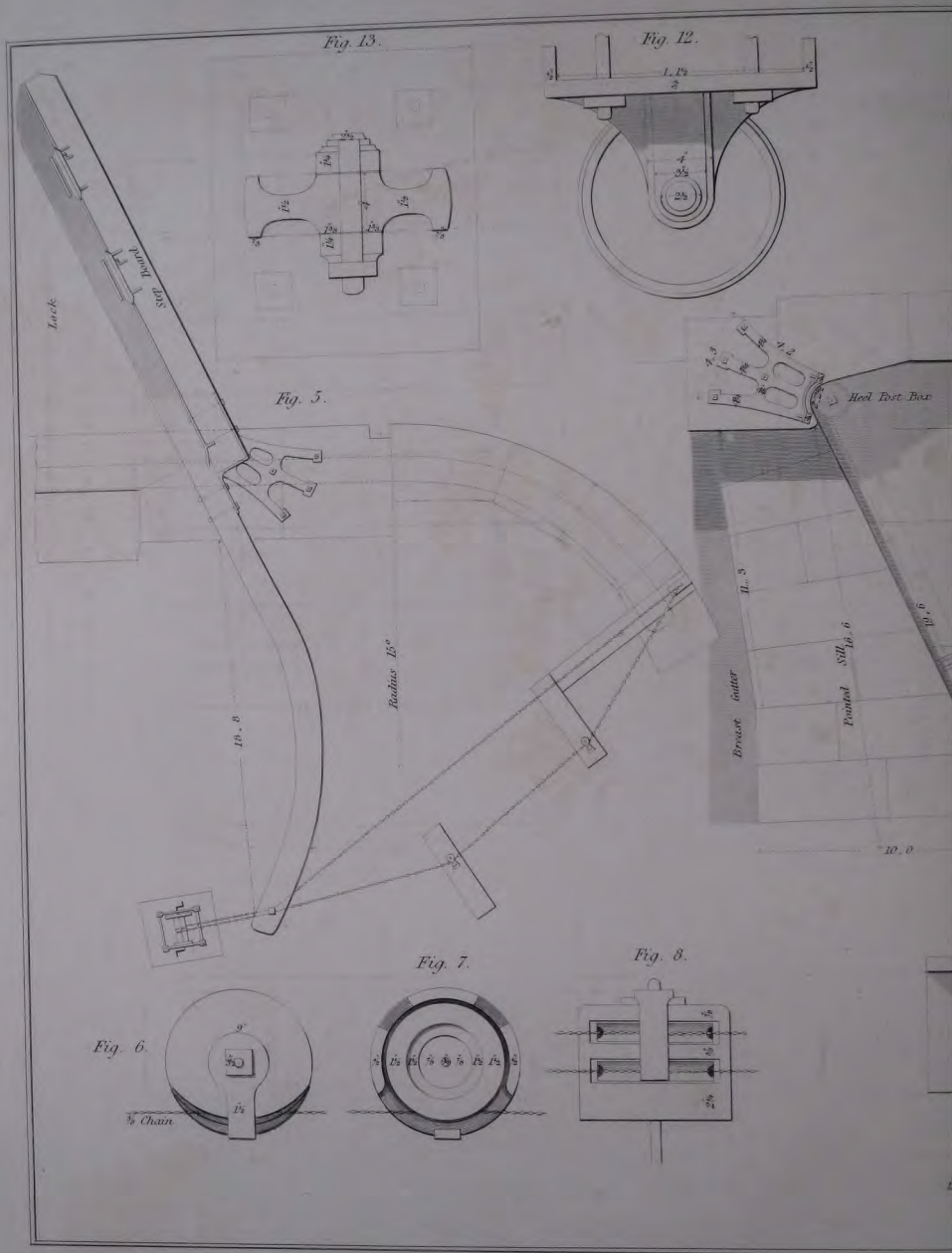


Fig. 13.
Fig. 12.
Lock
Stop Board
Fig. 5.
Heel Post Box
Radius 15'
Breast Gider
Pentrel Sill
Fig. 6.
Fig. 7.
Fig. 8.
⅜ Chain

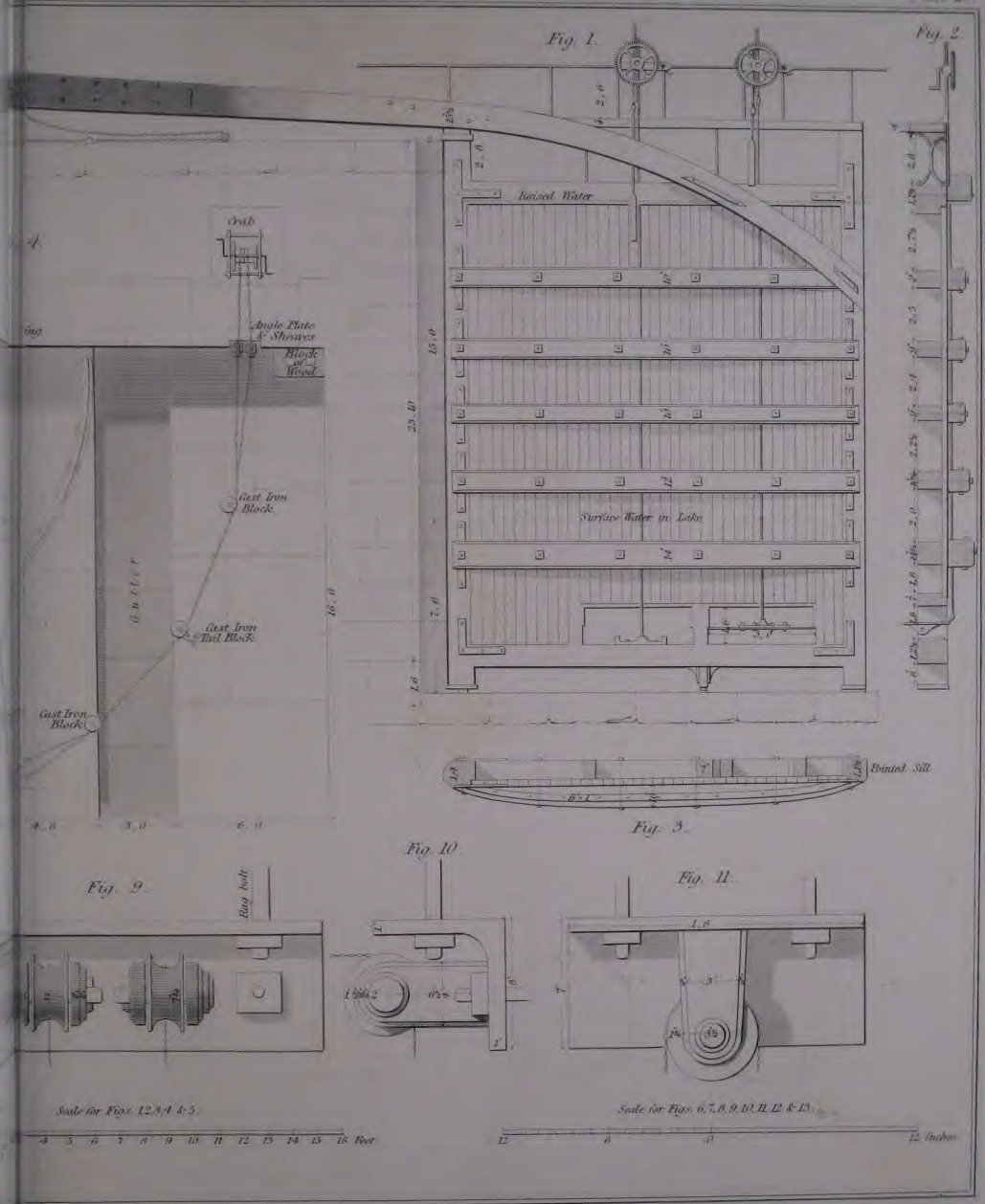


Fig. 1.
Fig. 2.
Raised Water
Surface Water in Lake
Grab
Angle Plate & Sheaves
Block of Wood
Cast Iron Block
Cast Iron Rail Block
Cast Iron Block
Fig. 3.
Fig. 9.
Fig. 10.
Fig. 11.
Scale for Figs. 1,2,3,4 & 5.
Scale for Figs. 6,7,8,9,10,11,12 & 13.

Fig. 1.

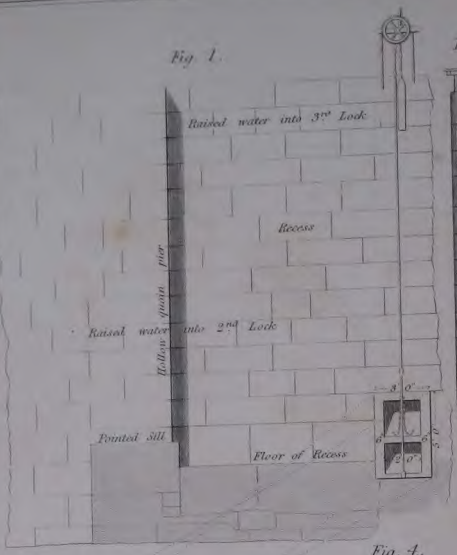


Fig. 2.

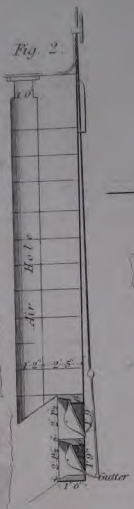


Fig. 12.

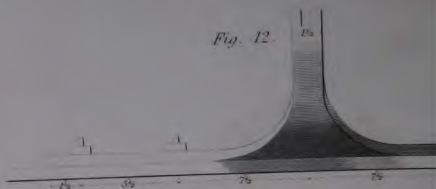


Fig. 11.

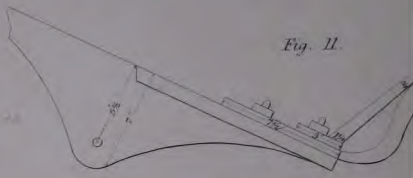


Fig. 9.

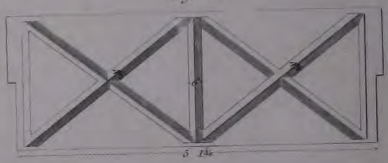


Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

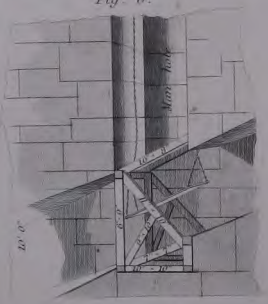


Fig. 20.

Fig. 21.

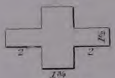
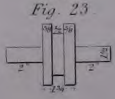


Fig. 22.

Fig. 23.



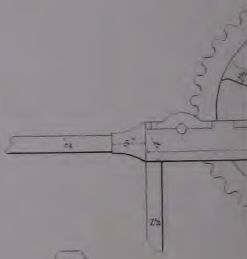


Fig. 24.

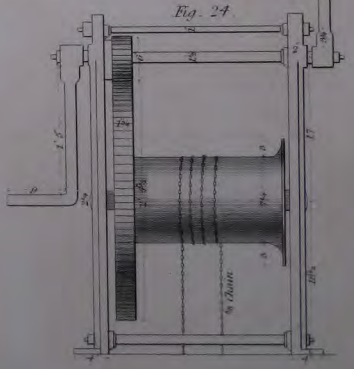


Fig. 7.

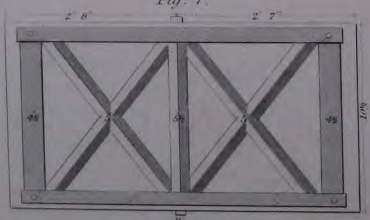


Fig. 8.

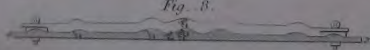


Fig. 18.

Scale for Figs. 1, 2, 3, 4, 5, 6 in. Feet & Figs. 11, 12, 14, 15, 16, 17, 20, 21, 22 & 23 in. Inches.

12 6 0 1 Foot & Inches

Scale for Figs. 7, 8, 9 & 10.

12 6 0 1 1/2 1 1/2 1 1/4 1 Foot

Scale for Fig. 13.

12 6 0 1 2 3 4 5 6 1 Feet

Scale for Figs. 19, 24 & 25.

12 6 0 1 2 Feet

Fig. 17.

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.

Fig. 27.
Contractors Store.

Brick Stone Block

Fig. 25.

Fig. 26.
Mode of landing Timber.

X.—*On the mode of Bending Timber adopted in Prussia.* *By* R. J. Nelson, *Lieutenant Royal Engineers.*

The following paper describes,

1st. The mode of bending beams of wood of any size, to any extent, and in any ordinary form of single curvature, with considerable ease and expedition, after the suitable inexpensive and simple apparatus has once been provided.

2nd. The application of this principle. I have seen it in Germany extensively introduced into such buildings as timber-sheds, cornfactors' stores, forage stores, riding schools, &c., where great span and height were to be obtained, and when the expenses of ordinary roofing and trussing were to be avoided. It is to be observed, at the same time, that the ease with which the Gothic form can thus be given to the largest trees,—the simplicity and boldness of the grand outlines thus obtained,—admit of the display of architectural taste on any scale, from the most primitive and economical, to the most "composite" and expensive; with reference to either the arrangement of the beams,—or of the ornaments which may be superadded as belonging to that class of reliefs of which the purpose in architecture may, perhaps, with sufficient accuracy, be defined to be those minor arrangements of lighter form and colour which prevent

extensive lines from being austere and meagre,
,, surfaces ,, vacant and poor,
,, solids ,, heavy and uncouth;

independently of the judgment displayed in the combination of these "lines, surfaces, and solids," with regard to the purpose and style of the building.

PART I.—THE MODE OF BENDING.

In this figure only three kerfs are shown; it is more usual and advisable to have five. The centre kerf is first cut, reaching from the butt along $\frac{3}{4}$ths or $\frac{4}{5}$ths of Plate 21. Fig. 26.

the length; the saw is then returned on each side to complete the other two kerfs, which stop at 2 or 3 feet short of the butt. When five kerfs are to be made, the two last commence at L, and, like the two preceding, end at G. Fig. 27.

The beam thus prepared is laid on the horizontal frame ABC, in the position IJ. With reference to the above figure (26),

ABC is a frame of rough spars, halved into each other, and firmly picketed, or otherwise fixed, at the angles.

EE′, any convenient number of smaller spars, radiating from B, and halved into, or otherwise secured, to AC and DF.

e e′ e″, cleats spiked down at points giving the intended curve.

In bending the beam, the first thing to be done is to fix the butt very firmly at G, by means of pickets, double cleats *c c*, lashing, &c. Any convenient power, such as crab, block, and tackle, &c., is then applied in a direction about parallel to E′ B; the rope or chain is fixed to H, and the beam is very gradually pulled down to the cleats *c′ c″ c‴* in succession. As soon as the desired curvature is thus given, the cleat *b* on BC is spiked down, and the beam lashed to the principal spars of the frame.

The mortise I is next cut; and a tongue of wood harder than the beam is driven in. Lastly, the beam is hooped at intervals of perhaps 2 feet with iron collars, each closed with screw and nut, or with bolt and rivet. In ordinary cases, these hoops should be of, say, 2 in. $\times \frac{1}{4}$ or $\frac{3}{8}$ in. flat iron.

The beam thus hooped and mortised at I (which is an important part of the process) may be taken from the frame at once, without any fear of its altering its form.

The cleats *c′ c″ c‴* can be fixed permanently to the spars E, and these last placed and secured according to circumstances.

N.B. The natural tapering of the tree squared as baulk is always preserved.

PART II.—ILLUSTRATION.

Plate 21. Cornfactors' and Forage Store.

Near the Baltic, or on the banks of those rivers where large baulks can be readily and economically obtained, and where the value of labour is low, such a building as this has been erected since the war for about £750, the average price of labour having then been from $\frac{2}{5}$ to $\frac{1}{2}$ the present London wages. The circumstances of the case, and the finances of the proprietor, admitted of no attempt at finish; it was a plain effective building, in which economy was

studied in every part, even to the introduction of buttresses and arches in the inside of the gable end walls.[1]

From such observations as a man in a foreign country may make unobserved (and it is frequently very inconvenient to be known to be an observer), roughly noted down at the moment, and secured immediately on his return to his lodgings, I give the details of this building, with such approximate accuracy as circumstances permitted, and as I thought the nature of the case required; always provided, that I never quitted a place without having completed the subject, whilst fresh in my recollection, on a sufficient scale to ensure the general architectural effect, and the principles of construction. This may be readily done as far as regards the exterior of a building: I have copied the ornamental and defensible barrack gateway of a fortress within half musket-shot of two sentries and a main guard, walking up and down in front apparently reading a book, whilst an emphatic and occasional touch of my pencil secured the notion in hand by some rude hieroglyphic, as if I was deeply impressed with the pathos of the work with which I was engaged. The collection of the interior details is a matter of practice and memory; and success depends as much on good fortune, as to repeated opportunities, not always to be commanded: it is here, however, that quickness of *rightly directed* observation and experience enable one to fill in the outline supplied by merely a single and hasty inspection. Like geometrical forms, information on all matters is marked by points; the art of observation lies in the rapid selection of these points, leaving subordinate considerations to follow, and fill up, as matters of course.

APPROXIMATE DETAILS. Plate 21. Fig. 27.

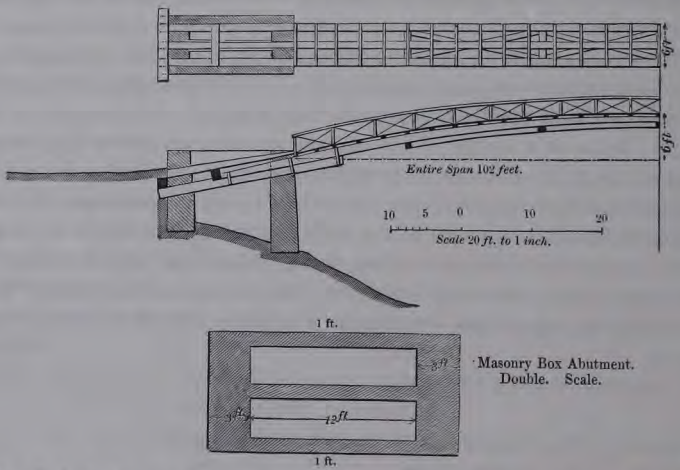
Interior length	about	160 feet.
Interior breadth	,,	55 ,,
Interior height	,,	60 ,,
General thickness of wall	,,	$1\frac{1}{4}$,,
General height of wall	,,	9 ,,

[1] This is not the place to introduce discussions as to the probable success of such a measure under given circumstances, or to bring forward considerations on the reduction of strength occasioned by the cuts in the beams, restored in some measure by the hoops and tongue. The comparison of these last with plank beams will be well worthy of the attention of my brother officers.

No. of Pairs of beams			about	14
Scantling of do. at butt . . .			,,	$1\frac{1}{2}$ ft.
No. of Windows on each side . . .			,,	6
No. of Doors	do.	large .	,,	1
Do.	do.	small .	,,	2

In some of these edifices, wale-pieces, as a diagonal bracing, are introduced to give stability to the general skeleton formed by the beams.

Foot Bridge; 102 *feet span, built with Prussian beams.*



Masonry Box Abutment. Double. Scale.

The little bridge shown above is one of which I collected the details in Germany, in 1835. As something that has been executed, it ought to have taken precedence of the project for the Kat River Bridge, which was based upon it, with such modifications as the purpose of the communication and localities required; one of these last, especially, being the nature of the timber, which rendered the long beams and simple untrussed structure of the above inadmissible under the severe, continued heat of an African Summer.

I may here observe, that one great advantage that bridges thus constructed

possess is that they require no centering whilst raising,—only the slight temporary assistance of spars, &c., which, as uninjured material, are, generally speaking, convertible without loss in the lighter parts of the superstructure.

These kerfed beams are also preferable to plank beams as being obviously stiffer, and in the wood being in nowise crippled by the hoops. In plank beams the strength cannot but be perceptibly reduced by the bolts and joggles.

Where real economy admits of a low outlay in the first instance, perhaps these simple bridges may be introduced to advantage as viaducts for canals, railroads, &c.

The manner in which the thrust is disposed of by the light box abutment seems particularly applicable in the many cases where the loosened state of the soil of a new cutting renders it an expensive business to meet this thrust satisfactorily.

R. J. Nelson,
Lieutenant Royal Engineers.

Devonport, May 27, 1839.

XI.—*Description of the Coffer-dam used in the Construction of the Piers of the Alexandria Aqueduct, being an abstract of a report addressed by Captain* Turnbull *to Lieutenant-Colonel* Abert, *and by him submitted to the House of Representatives of the United States.*

The following Paper is an abstract of a very detailed report forwarded by Captain Turnbull, of the United States' Engineers, to the chief of his department. The report includes a brief sketch of the measures taken to determine the position of the aqueduct,—of the abortive attempts made by the original contractors to fulfil their contract, which rendered it necessary for the directors to take the work into their own hands in the Spring of 1834,—and it then proceeds to detail all the works carried on by Captain Turnbull for the purpose of completing the aqueduct. The most interesting part of the subject to engineers is the construction of the large coffer-dam surrounding the piers; and I feel that I cannot confer a greater benefit on my brother officers than by making them acquainted with the great works carried on by the engineers of other countries, and especially with those in which, like the subject of the present paper, the construction is detailed with great minuteness, and the success or failure of experiments honestly narrated.

BORINGS FOR FOUNDATIONS.

The borings for the foundations were conducted after the method by which the main or framing piles of the coffer-dam for the tide lock at the western termination of the Caledonian canal were fixed to the rock; only that a square box was used instead of a cylindrical one. The box was formed of 3-inch heart of pine plank, 36 feet long, 8 inches in the clear inside, well jointed and banded with flat iron bars; the lower end of the box was shod with flat iron shoes, edged with steel, and fitted on the end of each plank to prevent its being damaged by stones while being driven to the rock; it was then driven in

the ordinary manner of driving a pile as far as it could be without crushing; and was then emptied by means of an auger made in the form of a quadrant of a circle of the same diameter as the inside of the box. The circular side, and one of the straight sides of the quadrant, for 18 inches in height, were made close, of thin rolled iron riveted to the ribs, which were fastened to the corners of the quadrant; from this proceeded an upright shaft, the other straight side being open to the bottom. Iron flat teeth, each $2\frac{1}{2}$ inches long, were fixed with an inclination downwards, so that when the auger turned, these teeth loosened the sand, and prepared it to enter easily into the body of the auger; to keep it steady while turning, there was fastened to the lower side of that corner of the quadrant which was the centre of the circle a pivot six inches long, which passed into the sand and served as a centre for the auger to turn upon. Immediately above this pivot stood the upright shaft, made of inch-square bars of iron, from 5 to 10 feet long, capable of being joined by male and female screws to any required length. Upon this two cross handles were placed; four men turned the auger, and from four to six turns, according to the nature of the stratum through which it had to pass, filled it. It was lifted above the top of the box by a purchase acting from the top of the pile driver, and the sand was cleaned out with a small shovel, by a man standing on the scaffold. At all the borings but one, where a stratum of coarse gravel occurred 2 feet above the rock, the box was driven to within a few inches of the rock, and in all cases when the box was emptied a sounding-rod of iron was dropped into it, which, rebounding several feet, proved that the solid rock had been reached. These borings proved the existence of rock under the entire bed of the river, at an average depth of 28 feet.

By the plan at first proposed, the aqueduct was to consist of twelve arches of stone, 100 feet span, and 25 feet rise; the soffits to be curves of eleven centres; three abutment piers 21 feet thick at the springing, and eight piers of support, 12 feet thick; but the funds failing, a change was made: a causeway 350 feet long was substituted for three of the arches, and it was then decided that it should consist of nine arches of 105 feet span, with two abutment piers, and six piers of support.

The contracts were made for the work upon the latter plan, and the contractor submitted a proposition for a coffer-dam upon a plan which he claimed as original, and this, although reported against by the engineers, the contractors

(having a specific sum for each coffer-dam) decided upon adopting, and they attempted to construct it in the following manner.

Two circular rims, 80 feet in diameter, were supported one above the other by posts,—the lower rims rested upon the mud, the other was at the surface of the water; each rim was formed of pine timber, 12 × 14 inches, in segments of 10 feet in length, connected together simply by iron dogs. In the centre of each segment a rebate was made, through which a pile, with a 2-inch plank spiked upon the back, was driven, to serve as a guide pile; this divided the circumference into spaces or panels of 10 feet, which were afterwards filled with piles of white pine 11 inches thick, planed on the joints, firmly driven into the mud, but not to the rock. It was merely a single row of piles, without puddling to prevent leaks, and without shores to resist the pressure of the water. The piles being driven, a 20-horse engine was set to work to pump out the water; but, after working an hour, the water had risen inside as much as on the out, and every other attempt to empty it failed in the same way. The contractors not having succeeded in executing their contract, the directors declared it dissolved, and gave orders to the engineers to make preparations for carrying on the works with vigour in the Spring. In March, the remains of the circular coffer-dam were removed, and after much consideration, and reference to the best examples of coffer-dams both in Europe and America, the following construction was determined upon.

The figure of the dam a parallelogram 82 feet long by 27 feet wide inside, Plate 22. according to the accompanying Plan.

The inner row of piles were of white oak, 40 feet long, 16 inches diameter at the largest end, with iron shoes pointed with steel, weighing 25 lbs.; they were placed 4 feet apart from centre to centre, and driven to the rock with a ram weighing 1,700 lbs. These piles were connected with a pine stringer 1 foot square, bolted with iron screw-bolts, passing through each pile; the corners were secured with a strong iron strap, and a gib and key.

The outer row of piles, fifteen feet from, and parallel to, the inner row, was also of oak, 36 feet long, and 16 inches diameter at the largest end; they were placed 4 feet apart from centre to centre, and pointed, but not shod or driven to the rock. These were likewise connected by a pine stringer on the outside, 1 foot square, screw-bolted to each pile. The up-stream angles of the dam were cut off, so that the outer row formed a hexagon: the angles were

secured by the stringers overlapping each other 3 feet, and being halved on to each other.

These piles were driven without hoops on the butt ends, as customary. A method recommended by Mr. G. Whistler was adopted, viz., the butt ends were made concave, about three-fourths of an inch deep, with an adze, and covered with a thin sheet of iron simply laid on, by which means, it is believed, a pile may be driven to any depth without injury.

Upon the two rows of oak piles, or rather upon the stringers, a scaffold was framed, upon which the pile drivers were erected for driving the sheet piles, which were of the best North Carolina heart pine: those for the inner row were 40 feet long, and 6 inches thick; they were driven in panels of 16 feet, formed by bolting (the bolts having room to play) two string pieces or guides 18 feet long, and 12 by 6 inches, to two pile planks[1] 8 feet from the foot, the pile plank being between the string pieces. The piles were then suspended in the planes of the pile drivers, placed at the proper distance apart, and lowered in their places; the guide piece sliding against the oak piles,—they were then driven by slight blows of two pile drivers, the ram of one resting on its pile while the other made its blow, and so alternately till the cross pieces or guides rested on the mud; even moderately long blows were found either to shatter the pieces below, or to break the bolts which connected them. Two other similar guide pieces were then placed near the top of the pile plank, 1 foot above high water mark, and the whole of them were screw-bolted to the oak piles behind them. When these panels were fixed around the inner row of oak piles, the sheet piles were driven so as to fill each, commencing at each end of them, and continuing towards the centre, the last or centre pile being wedge shaped; the others were hewn and jointed, with parallel sides; by means of a plane they were sharpened like a wedge, and bevelled on one corner to force them into their places against the adjoining pile: although not shod, they were driven to the rock.

The sheet piles of the outer row were of the same scantling as those of the inner row, but they were only 36 feet long; they were prepared and arranged in the same manner as those of the inner row, but they were not driven to the rock.

An earnest desire to husband the company's funds as much as possible was the leading motive for using short piles for the outer side of the dam. It was

[1] These pile planks are in another part of this paper called *panel* or *guide piles*.

hoped that if these were driven a few feet (12 to 15) into the muddy bottom of the river, they might prove to be sufficient for the support of the puddling, at least until the interior of the coffer-dam should be so far emptied as to cause the preponderance of pressure to proceed from the outside towards the interior; and the experiment was the more readily attempted inasmuch as the means were at hand to give additional strength to this part of the work. It was proved, however, that the outer row of piling ought to have been driven to the rock.

The ram used for driving the sheet piles weighed 1,300 lbs.; two pile drivers were employed driving the sheet piles, one worked in the ordinary way by a crank, the other by a tread wheel; the latter proved to be so superior, that the former was altered into a tread wheel. The crank required eight men and a superintendent, and made a blow from the top of the pile driver (40 feet) in seven and a half minutes, while the tread wheel required but six men and a superintendent, and made a blow from the same height, and with the same weight, in one minute and fifteen seconds. The horse pile drivers made a blow in one minute and a half.

Both rows of sheet piling being completed, ties of eleven-inch square pine timber were put in to connect them together; these ties were placed 12 feet apart, and were dovetailed into the heads of the sheet piles; this, from the apparent stiffness of the oak and sheet piles, was deemed to be sufficient, but when the puddling came to be thrown in, the weight of the clay forced the outer row to spring out, drawing the ties through the dovetails. Additional ties were therefore put in at every other oak pile, and they were notched on to the guide pieces, and secured down by rag-bolts, and even these were found not to be sufficient to hold the rows of piles together; for as the puddling advanced, in many places the ends of the ties split off, and it became necessary to pass long and strong screw-bolts through the stringers of both rows of piles. This being done, the dam might have been deemed to be secure, but it even became necessary, as an additional security, to place stringers outside of the sheet piles, to notch them on to the ties, and to rag-bolt them down entirely around both the rows; and even to place three long ties of 14 inches square timber entirely across the dam to keep the long sides together: this was done by driving two oak piles contiguous outside, touching the outside stringer, and two others immediately opposite on the other side of the dam; each pair of piles being connected together by a stout piece of timber across and bolted to

them: the long ties which crossed the dam were formed by scarfing timbers, were notched on to the cross pieces, and secured to a pile at each end by stout iron straps.

These securities were the more necessary, because the stringers, ties, &c. were of white pine which had been left in the circular dam, and which it was necessary to use.

June 14th, the oak piles of dam No. 2 being all driven, preparations were made for building one for the pier (No. 1) next the Virginia shore, upon the site that had been occupied by the circular coffer-dam of Messrs. Martineau and Stewart: this dam was upon the same plan as that of the dam for pier No. 2.

It would have been well if we could have waited to profit by the experience to be gained in employing No. 2, but it was then believed that two piers might be built within the year, and we had to proceed with both. Our experience, however, had taught us to guard more effectually than heretofore against the expansion of the clay puddling, which tended to force the outer and inner rows of piles apart. Ties were therefore placed at every oak pile, and they were notched on to the string pieces, and were rag-bolted to the stringers and oak piles.

Large timbers (14 inches square) were laid from the centre of the outer row of the sides of the dam, crossing the corners to the centre of the outer row of each end, and they were notched on and bolted to every timber they crossed; their ends, too, were made to cross, were halved into each other, and were secured by a bolt. Two long tie pieces were then placed entirely across the dam, dividing it into three equal parts, and notched and well secured.

The up-stream ends of this dam were left square, great difficulty having been experienced in cutting off the corners of the other dam, and the angles were secured by a second set of stringers placed upon the tie pieces of the outer and inner rows of piles, and bolted to the oak piles; they passed and were halved into each other at the corners of the dam: these stringers were continued entirely around the dam, and a piece was also placed at each corner to connect the exterior and interior pile of the angles.

The puddling of No. 2 dam was then brought up to a level with the tie pieces; and pumps having been set to work, the water was lowered in the coffer-dam, till the pressure from without made it necessary to place two tiers of shores within the dam, the lower one being 8 feet below high water mark. Below these, short pieces were wedged between the oak piles and the sheeting:

a third tier of shores was placed on the surface of the mud, and the excavation was commenced.

Six feet of mud having been removed, it was found that several of the oak piles were broken, and that the great pressure had caused the braces at the end to crack. Immediate steps were taken to secure the work by doubling the number of shores at the original surface of the mud, and by placing a fourth tier at its then surface; but before this could be done, a leak occurred, which soon filled the dam; the leak was caused by the great weight of water outside forcing the mud from beneath the puddling into the dam under the foot of the panel or guide piles, which, as before remarked, were not driven to the rock. The puddling, however, soon settled down and stopped the leak. From the same cause leaks constantly occurred, which were all stopped in the same way, and the puddling which had settled was replaced at top. The increase of weight caused the stringers of the outer row to crack, and the wall of the dam to spread a little; and the long ties, which were before described as extending entirely across the dam, were now put in.

The excavation continued, with various interruptions, till the beginning of January, when a portion of the masonry was founded on the rock. The interruptions were all caused by the water, mud, and sand being forced from under the puddling into the dam; some even had been forced from the outside under the outer row of sheeting piles, which settled a few inches, showing that both rows should have been driven to the rock.

In No. 2 coffer-dam the same failures occurred, but the puddling, having been left in the dam during the Winter, had become so consolidated that it would not settle when the mud was removed from below it; and various expedients were used to force it down. The pumps were turned upon the puddle to soften it; piles were driven through it; a heavy ram was used to force it down: a smooth pile was driven to the cavity below; this was then drawn, and a communication thus opened with the leak; at low water the pumps were turned upon the puddling, dry powdered clay was thrown in, and, being carried down by the force of the water, it filled the cavity below and stopped the leak.

Early in the season preparations had been made for constructing a dam for the southern abutment, and it was commenced on the 1st of July, with such modifications and improvements as the experience gained on the first and second dams suggested.

The abutment being 34 feet long and 21 feet thick, with circular wing walls

13 feet average thickness at base and 69 feet long, the dam was formed so as to enclose the area of the abutment, and leave a small space between the interior of the dam and the masonry.

The interior framing of the dam, as low down as the surface of the mud, was built upon the shore, and was then launched and floated to its position. The framing was as follows: the lower stringers to rest upon the mud; timbers 18 inches square were laid upon the trace, and simply halved and bolted together at the angles; upon the inside of these, posts 18 inches square and 16 feet 6 inches long were erected, 8 feet 6 inches apart from centre to centre; in the main body of the dam, and in the wings, they were arranged to divide the space uniformly.

These posts were notched on to the stringers, and against the posts were placed shores of 15 inches square timber. The shores were cut bevelling at the ends, and corresponding notches were cut in the posts, with oak wedges underneath the shores, for the purpose of relieving them when required to be taken out.

The posts and shores were secured to the stringers by two iron straps, with an eye in one end, let into the stringer by a mortise, through which a bolt was dropped by a hole bored from the top. The opposite ends of the iron straps were secured to the shores by a gib and key passing through a mortise in the shores and straps.

Above these, 4 feet 6 inches in the clear, was placed another set of stringers and shores, the stringers 16 inches, and the shores 14 inches square, arranged and secured as those below. Nine feet above this, the top tier, on a level with high water, was placed. The stringers of this tier were 13 inches square, and the shores were 12 inches square. The shores of this tier were not bevelled at the ends as the others, but were set square against the posts, and secured simply by a frame bolt passing through the stringer and post into the ends of the shore.

The ends of the dam were braced by timbers of the same dimensions as the shores in each set, let into the stringers with a bearing joint, and secured by a bolt. The frame was then braced, to prevent its racking, by pieces of sheet piling placed diagonally on its sides, and bolted to the posts on the inside.

The outer sides of the stringers were dressed, and each set placed fair above each other.

This framing was floated to its position on the axis of the aqueduct, and was made to sink in the water by proper weights, until the lower stringers rested upon the mud. The pile drivers were placed upon opposite sides of the frame, each with a sheet pile suspended in the planes, and as soon as the frame was arranged in its place the piles were dropped, and driven and bolted to the stringers, thus securing the frame in its position. The sheet piles were then driven all around, resting against the faces of the stringers, without "panel piles" or other guides, and *every* pile was driven to the rock. With respect to the outer rows of piles of this dam, they resemble those heretofore constructed, with the exception of the "panel piles," which were dispensed with, and in their stead temporary guides were used, and withdrawn as the sheet piling progressed. Every oak and sheet pile in this row was also driven to the rock. The stringers and ties were all of white oak. The stringers were bolted together, and the joints were covered by short pieces that embraced, each, from five to seven oak piles. The ties were placed at every other oak pile. Before the advantages of this *new* mode of construction are enumerated, it may be advisable to point out what are considered defects in the old. In the first place, then, the interior row of oak piles used in dams Nos. 1 and 2 were found to be not only *useless* but *pernicious*, inasmuch as they could not be procured of precisely similar diameters, and they could not be worked to *pattern* without great expense, and even then it was nearly impossible to drive them, to so great a depth, so accurately as to preserve the alignment all the way down.

2nd. The irregularity of the oak piles then affected the sheet piling, because the guides by which they were driven rested against the oak piles; the sheet piles were thus often made to pass each other, and leave open joints. In dam No. 1, a badly driven oak pile, which projected very much into the dam, was cut out, and others that were out of line required to be notched, and, of course, much weakened, in order to place the stringers for the shores in line: nevertheless, the stability of the dam did not appear to be at all affected. Hence the opinion that these oak piles were both useless and embarrassing.

3rd. The panel or guide piles were found to have caused nearly all the leakage in dams Nos. 1 and 2. It was under them that the sand and gravel and water found their way into the dams.

4th. The water in the first dams required to be pumped out to certain depths before a tier of shores could be placed, and when it was pumped out

Plan and Section of the Cofferdam for one of the

PIERS OF THE POTOMAC AQUEDUCT.

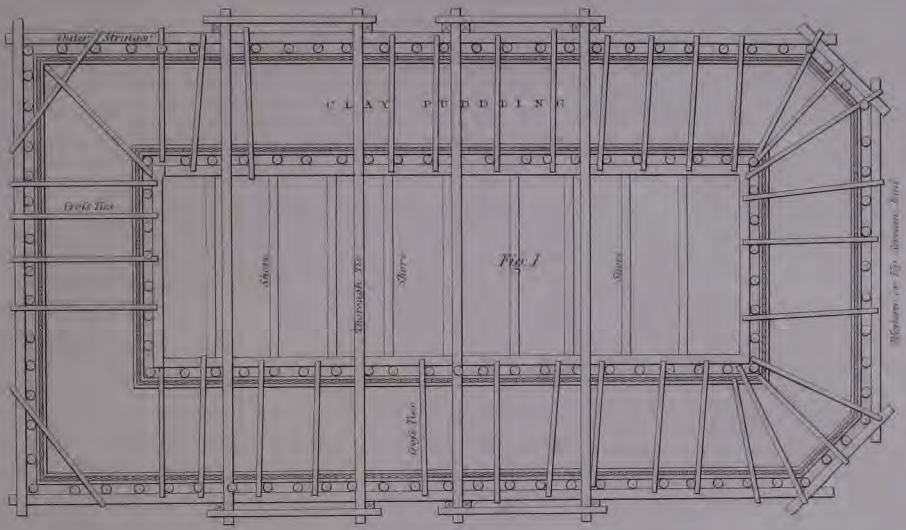
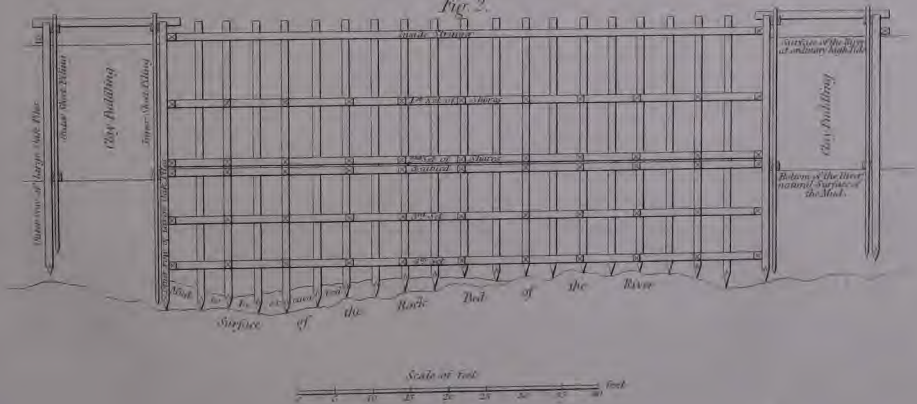


Fig. 2.



the space between the oak and sheet piles allowed the sheet piles to spring inwards, by the weight of the puddling, before it was possible to block in between them all around.

Another objection is, that the length of each stringer and shore has to be determined, framed, and fitted, before they can be keyed up, and this not for one tier only, but, in fact, every tier has to be so framed and fitted inside of the dam; an operation involving great inconvenience and delay. All these objections, and they are serious ones, are believed to be obviated in the mode of construction ultimately adopted.

In it, every pile being driven to the rock, the only apprehension of leakage will arise from open joints of the sheet piling; and if this should occur, and it may, by the point of a pile being turned by an obstacle in driving, the joints can be sufficiently closed by driving another pile to cover the opening, there being no panel or guide to prevent it.

The inner row of sheet piles being in immediate contact, or resting against the stringers of the shores, there can be no possibility of their springing with the weight of the puddling or pressure of the water, without crushing the shores.

And the shores themselves are made to act as ties, by means of the iron straps at their ends, and prevent the dam from spreading from the weight of the puddling, and of the water in the dam, as the tide ebbs, (the dam being tight, and having been filled by high water flowing over the top, or by other causes).

XII.—*Description of the one-arch Wooden Bridge, of 205 feet span, at Paradenia, with an account of the execution of the work and the means employed in throwing it across the river Mahavillaganga, in the island of Ceylon. By Captain* Oldershaw, *Royal Engineers.*

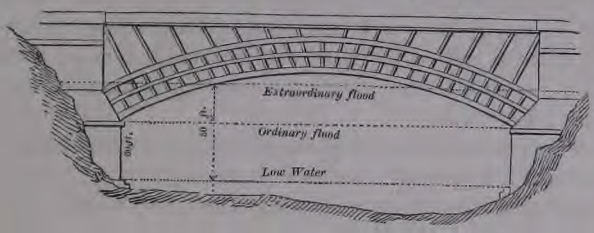
The military road from Columbo to Kandy having been traced by Officers of the corps of Royal Engineers, a ferry, by means of a flying bridge, was established over the Mahavillaganga at Paradenia, four miles from Kandy; but as the sudden and great rise of the river during the change of the monsoons often rendered the passage dangerous, and sometimes impracticable, besides at all times causing great delay, it was determined to throw a one-arch wooden bridge across the stream at that place. The execution of this work was intrusted to the Engineer and Quarter-Master-General's departments, the former to raise the abutments, and the latter to prepare and throw over the arch.

The abutments were accordingly built from plans submitted to the commanding Royal Engineer, and under the direction of Captain Brown, R.E.

On their completion, the Quarter-Master-General's department requested that the centering for the bridge might also be put up by the engineers who had been employed in erecting the abutments. Some remarks relating to the execution of this work will form the substance of the following memoir, but before entering upon them a few observations must be made on the river and its remarkable overflow in 1835 and 1836.

The Mahavillaganga rises in the neighbourhood of Adam's Peak, about 4000 feet above the level of the sea, and runs with considerable velocity through a mountainous region, finally emptying itself near the harbour of Trincomalee, having traversed an extent of from 150 to 200 miles. It is subject to sudden rises from rains which fall during the change of the monsoons, but from all the information which could, at the time of commencing

the bridge, be obtained from the oldest inhabitants, the rise had never exceeded 30 feet; indeed, the nature of the country seemed to give abundant evidence of the fact, as the flat ground on each side the river extends in many places for several miles. The abutments were accordingly raised so as to give the spring of the arch an elevation of 30 feet above low water. This height was not, however, sufficient, for in the year 1835 the river rose 45 feet, and the year following 50 feet, thereby covering up 20 feet of the wooden arch,



and rushing through it at the rate of many miles an hour, bearing down trees and masses of "jungle" from the surrounding country. But though the alarm was great, and no expectations were entertained of the bridge bearing up against such an unlooked-for pressure, it stood unmoved.

The abutments, 35 feet thick in solid masonry, and 75 feet high, being completed, timber consisting chiefly of ebony was procured from the surrounding woods, not only to form the centering, but to construct the necessary machinery for putting it up. This machinery consisted chiefly of a hanging platform, suspended from moveable shears standing upon the projecting part of the abutment, and kept in its position by means of blocks and tackles. Plate 23. Fig. 5.

This platform regulated the distance between each row of piles, and as one row became complete, having a tie beam and connecting pieces, the whole platform, shears, and pile driver, were moved forward to the next row; and so on until the river was crossed. Upon this stage the circular part of the centering was formed, consisting of king-posts, braces, &c. Plate 23. Fig. 2.

The river did not rise to any considerable height during the operation, and one row of piles, which could not be driven on account of the rocky bottom, was stepped into holes cut by means of long borers driven by sledge-hammers in 12 feet water, divers occasionally going down to clear out the holes: had

the river risen, diving bells had been provided, and would have been resorted to. This row of piles was also secured by a frame which was let down and loaded with stones.

Plate 23. Figs. 1 & 2.

The great advantage of having practised shearing in a rapid river was very much felt, and the assistance rendered by well-trained elephants was invaluable.

As soon as the centering was completed, and ready to receive the arch, —which was composed of blocks of satin-wood and Manilla, and beautifully executed,—it was given over to the Quarter-Master-General's department, and the remaining part of the work was accomplished in so satisfactory a manner that, on striking the centering, the arch stood immoveable, positively not sinking a single inch.

The scantling of the timbers composing the centering was as follows:

a. Piles, from 1 foot to 1 foot 6 inches in diameter.
b. Tie beams placed over the heads of piles, 8 inches by 8 inches.
c. Connecting beams, uniting the rows of piles, 8 inches by 8 inches.
d. Wedges, 2 feet high, 8 inches wide.
e. Beams to receive the king-posts, 8 inches by 12 inches.
f. King-posts, from 12 inches by 12 inches to 8 inches by 8 inches; the centre king-post 12 inches by 12 inches at the top and bottom, and 8 inches by 8 inches where it is reduced to receive the braces. The remainder diminish in scantling as they recede from the centre to 4 inches by 8 inches.
g. Braces, those in the centre are 6 inches by 8 inches, and the others diminish in scantling to 4 inches by 4 inches as they recede from the centre.
h. Stays between the ribs of the centering, 4 inches by 6 inches.
i. Circular pieces forming the curve of the centering, 8 inches by 12 inches.
k. Tie beams placed over the ribs of the centering, 8 inches by 12 inches.
l. The beams which span the wide opening, 8 inches by 10 inches.
m. The beams placed underneath the long ones to strengthen them, 8 inches by 10 inches.
n. Stays or braces to *m*, 8 inches by 8 inches.
o. Tie beams on the small piles, 8 inches by 8 inches.
p. Small piles, from 1 foot to 1 foot 3 inches in diameter.

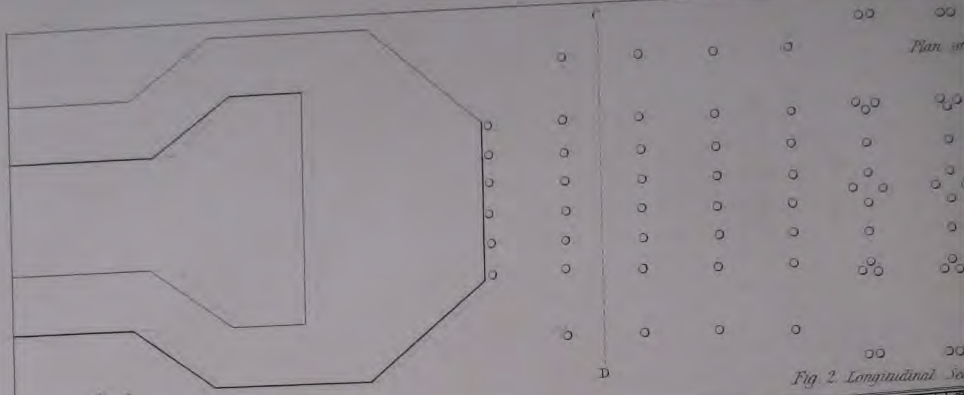
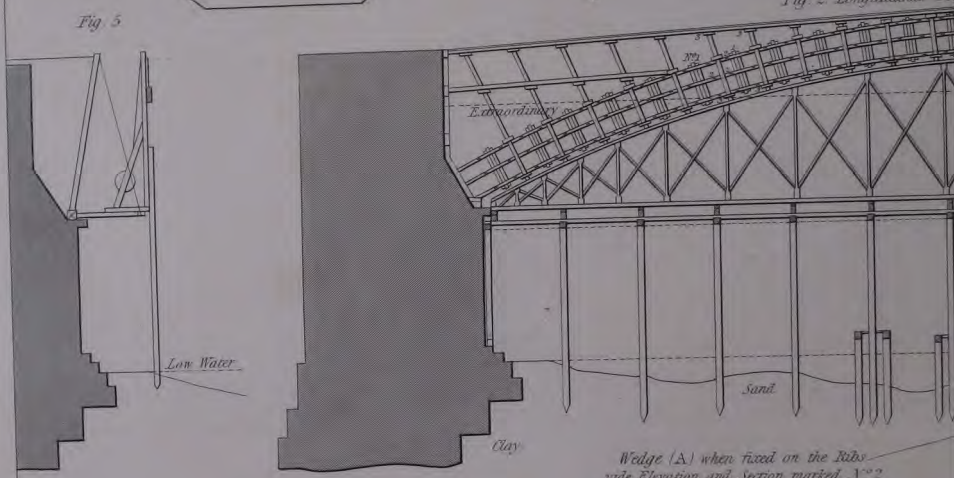
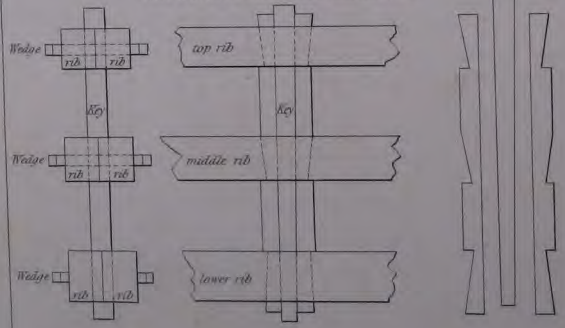


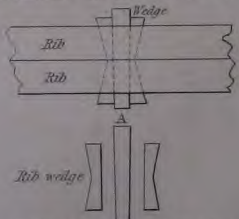
Fig. 5



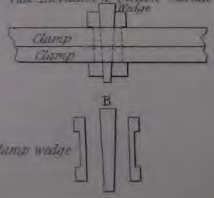
Key when fixed on the Ribs
vide Elevation and Section marked N°1

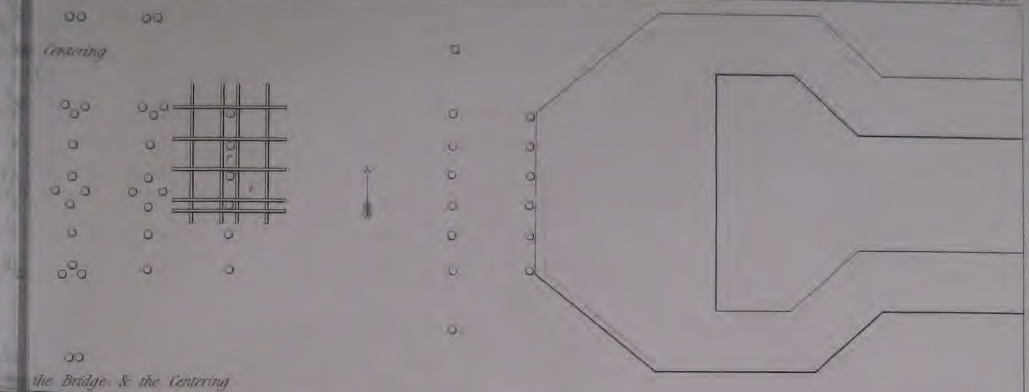


Wedge (A) when fixed on the Ribs
vide Elevation and Section marked N°2



Wedge (B) when fixed on the Clamps
vide Elevation & Section marked N°3





the Bridge & the Centering

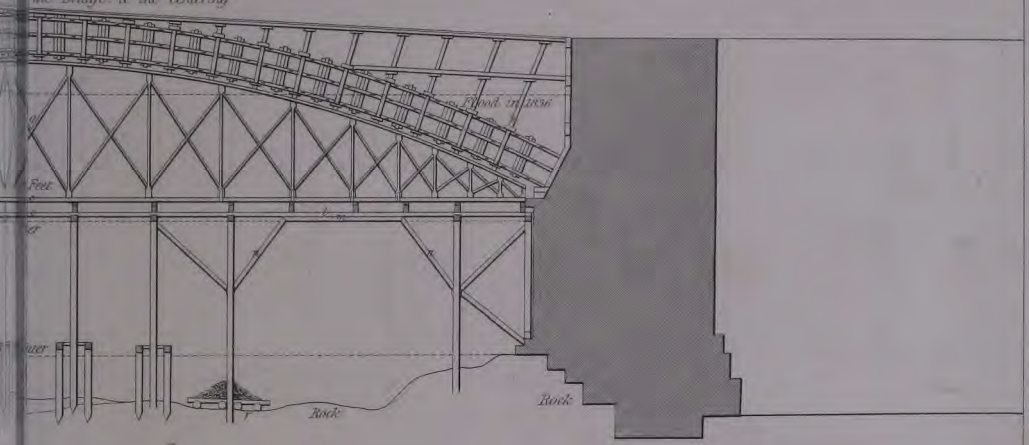
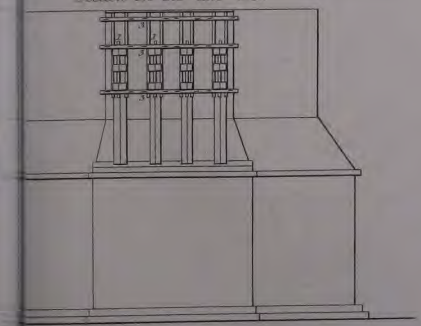


Fig. 3
Section on the line C.D.



Scale for the Plan & Sections

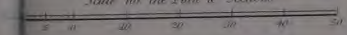
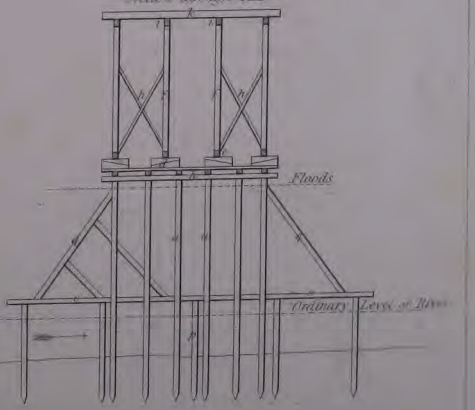


Fig. 4
Section through A.B



...ers, 26 High Holborn

q. Stays supporting and defending the rows of piles, 6 inches by 8 inches.
r. Frame-work loaded with stones to secure the row of piles.

CHARLES OLDERSHAW,
Captain Royal Engineers.

The bridge itself is constructed upon the same principle as that over the Portsmouth river in North America, and which is described by Sir Howard Douglas in his work on Military Bridges. There are some slight differences in the details, owing to the position of the roadway, which in the present instance is carried above the arch, while in the American bridge it is supported on the centre rib of the three. In Tredgold's Carpentry the following observations are made upon this system of construction. "If the three ribs had been placed close one above the other, and firmly connected together, the bridge would have been much stronger to resist any unequal load; as then they would have formed a solid beam equal in depth to the sum of their depths. But it would have been still better to have made the same quantity of timber into two ribs with cross ties, and diagonal braces between them. The manner of connecting the parts by means of dovetail keys and wedges is not a good one, as the timber must be much weakened by mortises so large as they require, and a very slight degree of shrinkage renders them useless. And it is still more objectionable as applied to the long radial pieces. These would have been much better notched on in pairs and bolted through."

In the Ceylon bridge, owing to the quality of the timber of which it is composed, the risk of shrinkage is not great. The radial pieces which support the roadway are notched upon the ribs, and connected by the clamps; and this constitutes the principal difference between it and the Portsmouth bridge.

W. D.

XIII.—*Description of a Series of Bridges erected across the river Ottawa, connecting the provinces of Upper and Lower Canada, and especially of a wooden arch of 212 feet span which crossed the main branch of the river. By Lieutenant* Denison, *Royal Engineers.*

The river Ottawa, which forms for a great distance the boundary between the provinces of Upper and Lower Canada, flows in a south-easterly direction from the country a little to the south of Hudson's Bay: it is second only in size and importance to the St. Lawrence, discharging at all seasons of the year a very large body of water, which in the Spring and Summer is greatly increased by the melting of the snow in the higher latitudes where the river has its source. At these seasons the rise of the flood water (varying of course according to localities) is from 12 to 18 feet. The average breadth of the river from the point where it joins the St. Lawrence to the Falls of the Chaudiere, a distance of about 120 miles, is at least half a mile, but in some places, like the St. Lawrence, it expands into lakes of one or two miles in width.

At the Chaudiere Falls the bed of the river (which is there cut through a stratum of limestone) is divided into several channels by rocky islands, and the total breadth much diminished.

The main body of water, after being precipitated over a fall of about 30 feet, rushes through a chasm 212 feet in width, while the remainder finds its way in thinner sheets down several smaller channels, some of which are used in the Spring for the purpose of floating down the rafts of timber (red and white pine principally) which are prepared every Winter on the banks of the streams which fall into the Ottawa, and which pass by this route to Quebec.

At this point, which is situated about half a mile above the entrance of the Rideau Canal, it was decided to erect a bridge, which it was imagined would not only prove a great benefit to the country generally, but also be of essential

service in carrying on the works of the Rideau Canal, by enabling the contractors, and other persons employed, to supply themselves with provisions and stores from the settlements on the north bank of the river. The American market, however, proved so much the cheapest, that but a very small proportion of the consumption was supplied from these settlements.

The following short description will serve to give a general idea of the chain of bridges forming the communication from one bank to the other. On the north side two dry stone arches of 57 feet span, built of the rough limestone quarried on the spot, were connected by a sort of causeway of rough stone, erected on a low rocky island; from the abutment of the second arch to another small rock not more than 30 feet wide in one direction, and 60 feet in another, which formed the north side of the main channel, the distance was about 180 feet; this was spanned by three simple trusses similar to that shown in Plate 24, fig. 4. As the water here was very shallow in the Summer season, no difficulty was experienced in bolting wooden sills or sleepers to the rock; on these the necessary uprights were raised to support the string pieces or tie beams of the trusses.

The small rock before mentioned formed the northern abutment of a large arch of 212 feet span which crossed the main channel; the south end of this arch rested on a rocky island about 100 yards in width. A channel, about 80 feet wide, separated this from another small island, and this channel was crossed by a simple truss (Plate 24, fig. 4), supported by standards bolted to the rock. This last island was separated from the south or Upper Canada bank of the river by a channel about 120 feet wide, which was spanned by a single arch constructed upon the same principle as that over the main channel.

Sufficient has here been said to give a general idea of the system of bridges; I shall now proceed to describe the construction of the large arch of 212 feet span, and the mode by which it was erected across a torrent, the depth of the bed of which, and the violence of the current, rendered any attempt to establish a centering resting upon piles or piers in the river itself altogether impracticable.

Plate 24, fig. 1, is an elevation of the bridge. Each rib was composed of two concentric curves 15 feet apart, connected together by braces and king-posts, which formed a series of trusses from end to end. Three sets of these arches, 12 feet apart (figs. 2 and 3), formed the support of the bridge, and gave a double roadway.

The lower string piece was made of two thicknesses of red pine, 12 inches wide and 15 inches deep, forming one rib 30 inches deep and 12 wide. These timbers were cut to the curve, scarfed, and well bolted together.

The upper string pieces were formed in the same manner, but the timber composing them was only 8 inches deep, thus forming, when connected, a beam 12 inches wide and 16 inches deep.

The braces by which this upper string piece was supported were of red pine, 12 inches wide and 4 inches thick; they abutted end to end throughout the arch, and passed alternately inside and outside of the king-posts, to which they were slightly bolted; they were also bolted together at the points where they crossed each other.

The king-posts of oak were 14 inches broad and 4 inches thick; they passed through mortises cut in both the upper and lower string pieces. Mortises 4 inches wide and about 15 inches long were made through the king-post at points just above the upper and below the lower string pieces,—through these, pieces of pine 12 inches deep and 4 inches thick were passed, notched upon the ribs, and all were then brought to their proper bearings by wedges driven tight in the mortises.

Diagonal braces were inserted, both at the top and bottom, between each king-post, and a cross beam in the centre of each bay was notched down upon the lower string piece.

The roadway was formed of white cedar logs, split in half, and pinned down to the lower string piece; longitudinal planks were spiked down upon these to take the wheels of carriages passing.

As before stated, the depth of the channel and strength of the current precluded all idea of establishing piers as supports for the centering of the bridge while erecting; it was therefore decided to suspend the centering, or rather to erect a rope bridge, upon the platform of which trestles for the support of the lower string pieces of the bridge might be erected: when these were once formed across and well bolted together, it was imagined that sufficient support for the remainder of the structure would be obtained.

Plate 24. Fig. 1.

Hemp and chain cables were procured from the dock-yard at Kingston, and stretched over trestles erected on the banks of the river, their ends being made fast to platforms of timber buried in the ground. The cables were supported by struts from the shore, and also by chains or guys passing over higher trestles. A large scow was moored with great difficulty in the middle

of the river, and in this a strong trestle was erected which gave some support to the centre of the curve. To provide against the fluctuations in the height of the water, this last trestle was formed as shown in Plate 24, fig. 5, where the centre beam, resting upon a screw jack, slides up and down between two fixed cheeks or uprights. Upon the cable trestles were erected, and the timbers of the bridge, which had been framed and put together on the shore, were laid upon them. When the lower ribs were once fixed, the work proceeded rapidly, and by the end of March, 1828, the bridge was complete, with the exception of the roadway of split logs.

The Spring floods now commenced, and large masses of ice were carried down the Falls. On the first of April a heavy block struck the scow moored beneath the bridge, and raised one end of it, breaking two of the suspending chains and shaking the bridge itself very much; and on the 2nd the framework gave way, and the whole was precipitated into the river.

This failure was attributed to the shock received from the ice the day before. On recommencing the work, the only alteration made in the general plan of construction was to insert some diagonal framing between the lower ribs. The scow, which had been sunk by the fall of the bridge, was not replaced, the loss of its support being compensated for by some additional cables to the rope bridge. The construction was then proceeded with as before, and by the end of 1828 the bridge was passable.

In the Spring of 1829 it was found that the 4-inch braces were too weak to withstand the pressure thrown upon them; they were very much crippled, and had they not been bolted together at the points where they crossed each other, would probably have given way; they were accordingly gradually removed, and 8-inch braces substituted for them in the haunches of the arch, while 6-inch stuff replaced them in the crown of the arch. Several iron straps were also added, connecting the braces to the string pieces, and to each other; but in spite of all these attempts to stiffen the bridge a gradual settlement took place, which kept increasing from year to year, till at last, in September, 1835, it was reduced to the state shown in Plate 25; soon after which it again gave way.

Fig. 1, in Plate 25, shows not only the state to which the bridge was reduced, but also the proposed mode of strengthening it by chains. The numbers underneath the king-posts show the rise at those points above the horizontal chord of the arc. The versed sine of the arc, which originally was

12 feet, was then reduced to 2 feet 11½ inches, while to the right and left of this central point a rise of 3 feet 1 inch and 3 feet 1½ inch is shown, indicating that the curve, instead of being convex on the upper surface, was then concave.

The other figures show the state to which the braces, king-posts, &c. were reduced. The heads of the braces, notwithstanding the attempts to tie them together with iron straps, have every where been drawn apart. Towards the two ends of the bridge, where the king-post passed through the beam of the roadway as well as the main rib, the tendency of the settlement of the latter was to push the end of the king-post further from the shore, while the action of the beam of the roadway was precisely the contrary; the consequence was, as may easily be conceived, that the king-post was broken across, as shown in figs. 2, 3, 4, 5, 6, 7, and 8.

On referring to Plate 24, fig. 1, which gives the elevation of the bridge as originally constructed, it will be easy to account for its failure.

In the first place there was no abutment to the upper string piece, which, instead of adding to the strength of the bridge, only increased the load upon it.

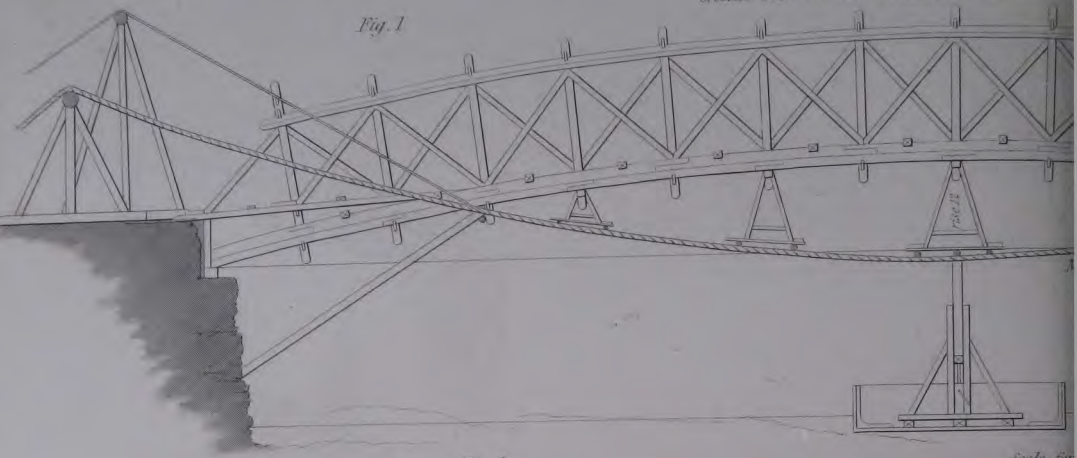
Secondly, the arrangement of the roadway threw an unnecessary and unequal strain upon the haunches of the arch, which, as before stated, caused the fracture of the king-posts.

The whole bridge, in point of fact, was supported upon the lower string pieces, or on three curved beams, 30 inches deep by 12 inches wide; for, from the mode in which the irregular settlements took place, as shown in the various figures of Plate 25, it is evident that the braces and king-posts afforded little or no support to the structure: had they been of any assistance, the heads of the braces would not have had the tendency to separate from each other, as shown in the drawings. The large mortises through the lower string pieces, for the reception of the king-posts, must have weakened the bridge very much; it would have been a much better plan to have made the king-post double, and notched it upon the outside of the string pieces. Had the upper and lower string pieces been framed together, making one beam 3 feet 10 inches deep by 12 inches wide, or had the same system of framing as shown in the drawings been adopted, making the braces and king-posts much shorter, and taking care to have a solid abutment for the whole system of frame-work, carrying the roadway upon the upper rib instead of upon the lower, the bridge would probably have proved a solid structure, and have lasted as long as the materials

ELEVATION OF A WOODEN BR

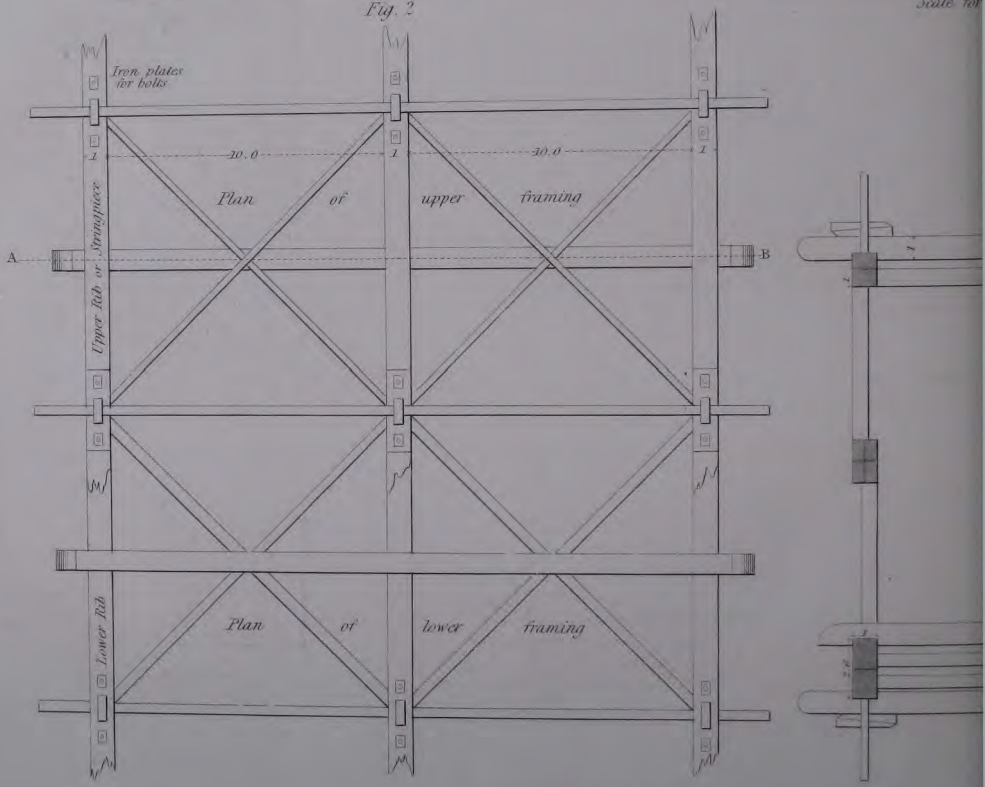
erected over the River Ottawa at the falls of

Fig. 1

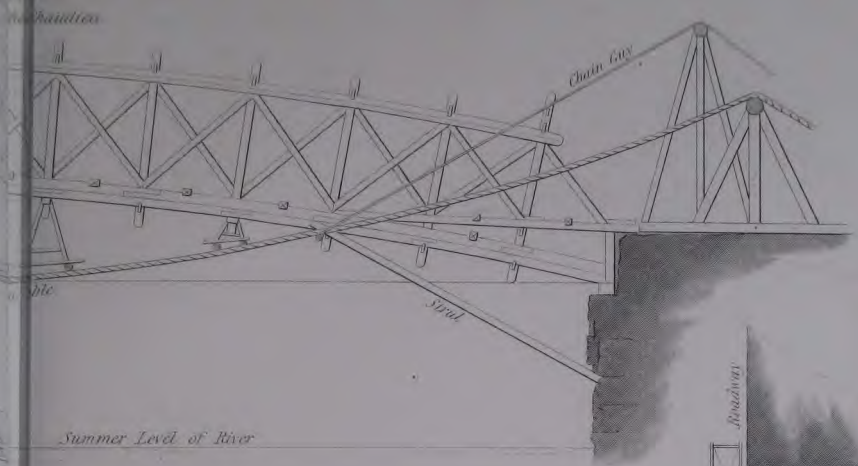


Scale for

Fig. 2

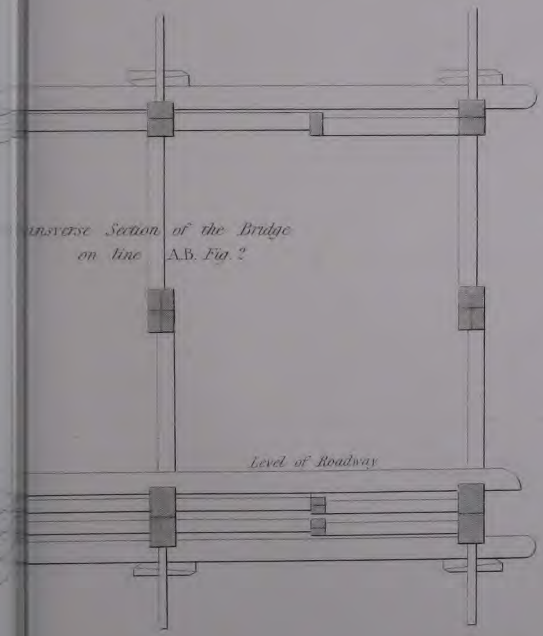


Scale for Fig 2. and 3.—Six feet to an inch



20 feet to an Inch

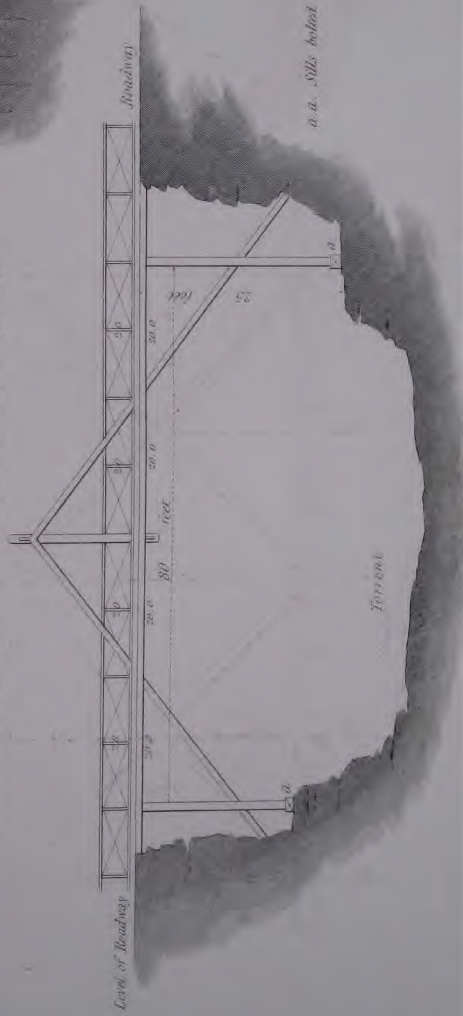
Fig. 3



Transverse Section of the Bridge on line A.B. Fig. 2

Fig. 4

Elevation of a Bridge over the Wet Channel at the falls of the Chaudiere



Second brace from North end of Bridge.

Middle line of framing broke from the bolt hole as shown at a. since 1. Sep.r 1857.

This brace is bent 2 Inches sideways

Fig. 2

Fig. 1

shewing

The figures shew

South end of Bridge

Rock

1.st South end of Bridge

E. View

2.nd King post

Fig. 3

Middle line of King

Fig. 4

2.nd

South End

Lower or East Side

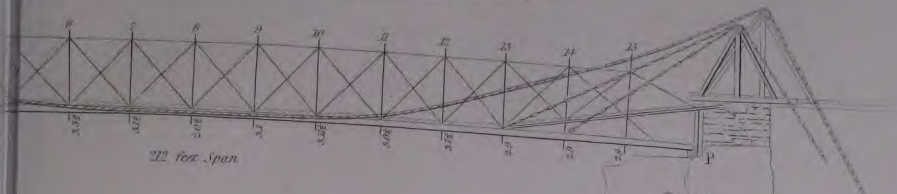
Fig. 5

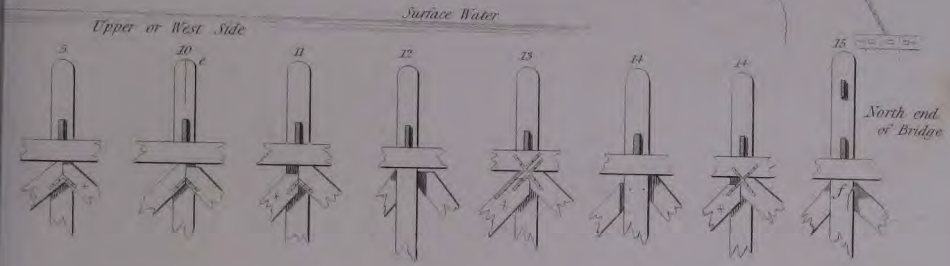
2.nd

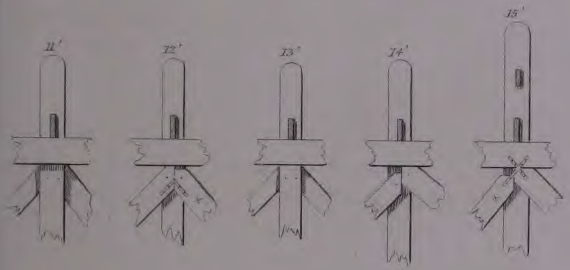
KETCH OF CHAUDIERE BRIDGE,

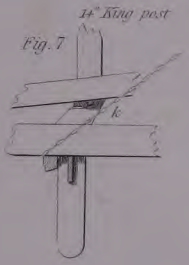
te 19. Sept.r 1835. and proposed mode of strengthening it

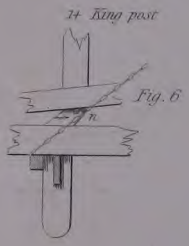
from the bottom side of the string-pieces where they rest on the logs O P

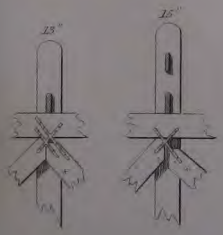










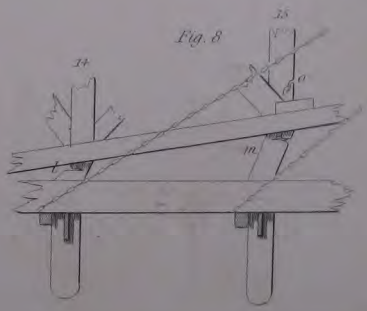


References

a. b. c. d. e. f. g. h. } parts of the bridge

l. m. n. o ——— } broken

* Wood-work drawn from the Iron plates



of which it was composed, which in such a situation, exposed to the drift of spray from the Falls, and alternately wet and dry, could not have been many years.

Plate 24, fig. 4, is a sketch of the bridge thrown over one of the channels at the Chaudiere Falls. I have introduced this sketch merely to show to what an extent a simple form of framing may be carried. The scantling of the double beam forming the tie or support to the roadway was, I think, 12×24, the braces 12×12, the king-posts 14×4, of oak, the rise of the truss 15 feet. Three of these trusses supported a double roadway, 24 feet wide in the clear.

Over Wood Creek, at Whitehall, to the south of Lake Champlain, a wooden bridge of 80 feet span was supported by three simple trusses; the breadth of the roadway was 30 feet, divided into two by the centre truss.

The scantlings of this piece of framing were as follow:

Tie beam, 16×9 inches.

Main braces, 14×9 inches.

King-post, 15×9 inches.

Small braces from bottom of king-post, $9 \times 5\frac{1}{2}$ inches.

Post from head of small braces, $9 \times 5\frac{1}{2}$ inches. These were strengthened by iron bars $1\frac{3}{4}$ inch square.

Beam connecting the bottom of the three king-posts, $15\frac{1}{2} \times 9\frac{1}{2}$ inches.

Do. of the three small posts, 12×9 inches.

The rise of the truss was only 12 feet.

These simple forms are very well adapted to a country like America, where timber is cheap and plentiful, and can be procured of any scantling, and where labour is dear, and simplicity of form therefore very desirable. These forms will contrast with the plan given by Lieutenant Nelson for a bridge over the Kat River at the Cape of Good Hope, where the difficulty of procuring timber of large scantling or length, and the tendency of such timber, if procured, to warp and twist, from the heat of the climate, rendered it advisable to frame the bridge in a more elaborate manner with smaller scantlings and shorter lengths.

W. Denison,
Lieutenant Royal Engineers.

XIV.—*Description of a Barometer that requires no corrections either for Zero or for Temperature.* *By* Samuel B. Howlett, *Esq., Chief Draughtsman, Ordnance.*

All barometers require a zero correction, either by reading from a guage point, or by afterwards reducing the observations according to the relative capacity of the tube and cistern; and then, before observations can be compared together, they must be reduced to a standard temperature.

Having succeeded in making a barometer suitable for meteorological purposes that requires no corrections of any kind, and as the construction is perfectly new, probably a description of the instrument may be acceptable.

Paradoxical as it may appear, my barometer presents every reading at the standard temperature of 32° without requiring a thermometer, or any adjustments or calculations whatever, even though the actual temperature of the air at the moment of taking the observation may be the extreme of either heat or cold.

The annexed diagram will show the principle of my contrivance:

a a. The case, 37 inches high, and $2\frac{3}{4}$ inches deep and wide, with a door, and a small opening behind the upper part of the tubes to admit light when fixed against a window.

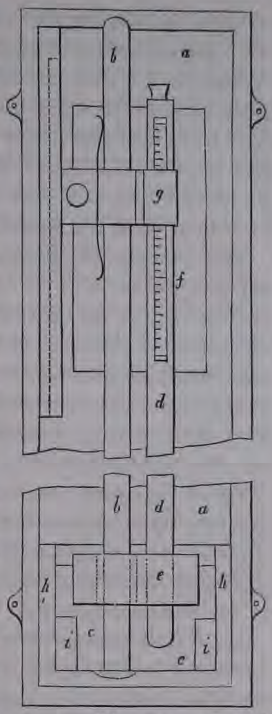
b b. The barometric tube, $\frac{1}{5}$ inch in bore.

c c. The mercury in the cistern.

d d. A common tube of the same bore as the other, and $33\frac{1}{2}$ inches long, having the sealed end downwards, and fixed in a square wooden or glass float *e*, 1 inch thick; and this tube is filled with mercury to the height of $29\frac{1}{2}$ inches, having 28 inches above the level of the mercury in the cistern, and $1\frac{1}{2}$ below, and bears a floating ivory scale *f*, 3 inches long, forming, together, a scale of 31 inches above the cistern.

g. A slide consisting of two pieces of brass tube, with a spring and steadying piece, embracing the glass tubes *b b* and *d d*, from the under edges of which slide the height of the barometric column and its altitude on the scale are taken to $\frac{1}{100}$th inch, and, by estimation, to thousandths.

h h. The cistern, being a square box, well dovetailed, with blocks *i i* in the angles to render less mercury necessary.



It is obvious that as the float which bears the scale rests on the mercury in the cistern, no adjustment or correction for zero is required.

It has been stated that the scale consists of mercury to the height of 28 inches above the cistern; hence it may be said that no correction for temperature is necessary, because the mercurial portion of the scale expands by heat in the same proportion as the mercurial column by which the pressure of the atmosphere is weighed. When once the scale is adjusted to read correctly at 32° of temperature, every altitude of the barometric column will be given by the scale the same as if the air were at that temperature; because, like measuring brass by brass, mercury is measured by mercury, and whatever effects are produced by heat, those effects are common to both columns.

But as the pressure of the atmosphere varies between 28 and 31 inches, and as the mercury in the scale is no higher than 28 inches above the cistern, there would appear to be no correction for temperature for the upper 3 inches on the ivory scale. It will, however, be seen that the glass tube which forms the scale is sunk $1\frac{1}{2}$ inch below the level of the cistern; hence the correction for temperature is provided to the middle of the ivory floating scale, or to $29\frac{1}{2}$ inches, causing an excess of correction for temperature for every observation below $29\frac{1}{2}$ inches, and a deficiency for every observation above $29\frac{1}{2}$ inches. Hence, to show the maximum error of my barometer, let two very rare and

extreme cases be supposed: if the column be 31 inches, at the temperature of 70°, the scale would indicate ·005 inch too much; and if the column be 28 inches, at 70°, then the scale would indicate ·005 inch too little. It is plain that, owing to this cause, an error of, say, a quarter of a hundredth of an inch would now and then occur; but, on the other hand, it may be fairly urged, that in no construction of the barometer at present known can even the zero be set to within that quantity of the truth, besides several other sources of error from which my barometer is free.

The correction for capillarity, being a constant quantity, is allowed for in adjusting the scale.

Unfortunately my barometer could not, without difficulty, be made portable. If I wished to remove it to a distant place, I should securely cork the glass tube containing the scale, so that it might be safely packed, and the mercury in the other tube and in the cistern I should put into a bottle, and when I had fixed the case at its destination I should refill the barometric tube either cold or boiled according as it was originally done.

Supposing a person knows how to perform the very easy operation of filling the tube of a barometer and placing it in its cistern, if the construction described were adopted, it would, I submit, do much towards obviating the difficulties referred to by Sir John Herschel in page 220 of the 2nd vol. R. E. Professional Papers.

But it may be inquired by what means I at first adjusted the scale of my barometer to read correctly at 32°, as it would be an objection if it could only be adjusted when the air happened to be at 32° temperature; and it may also be inquired what should be done to restore the original adjustment of the scale, in case a portion of the mercury should by accident escape from the tube.

As a standard by which to adjust my barometer, I placed by it an excellent mountain barometer; while adjusting the scale, the reading of the standard was 30·053 inches, at the temperature of 61°, which, when corrected for zero and reduced to the temperature of 32°, was 29·965 inches, assuming that mercury expands $\frac{1}{10,000}$ of its bulk for 1° of Fahrenheit. Having derived from the standard the true altitude of the barometric column, at 32°, nothing more was necessary than so to adjust the quantity of mercury in the scale of my barometer as that the ivory portion of that scale should indicate the altitude of the barometric column to be 29·965 inches, and the adjustment was complete.

The method of adjusting the scale, just described, assumes that some standard barometer is resorted to in the usual manner; but should it be required to set off the scale in inches from the cistern, then the $29\frac{1}{2}$ inches must be increased according to the correction due for the difference between 32° and the actual temperature of the mercury at the time of marking that altitude on the scale. For example, the $29\frac{1}{2}$ inches of the scale should, at 32°, be true standard measure; but at 70° it should be 29·500 + ·112 = 29·612 inches above the cistern, the ·112 inch being the change in the specific gravity of the mercury, occasioned by the expansion from 32° to 70°.

Should any mercury escape from the tube which forms the scale, the original adjustment may be easily restored; for on the tube I have a mark that was cut opposite 29·500 of the scale, that being the depth of the mercury in the tube, as stated before, and against it is noted 50°, being the temperature of the mercury at the time the mark was cut on the tube. Now, if some of the mercury should escape, and if at the time I replace it the temperature should be, say 70°, I should put into the tube just enough mercury to cause 29·441 inches on the ivory scale to coincide with the mark; that is to say, the 29·500 inches on the scale, at 70°, should be ·059 inch higher than the mark on the tube, (being the correction due for 20° expansion,) which mark was cut opposite and in a line with the $29\frac{1}{2}$ inches of the scale when the mercury happened to be at 50° temperature.

Between this new barometer and the standard I have made numerous comparisons, at the greatest variations of temperature and atmospheric pressure that have occurred during four months, and none of the discrepancies amount to the one-hundredth of an inch; and I do not know to which these errors should be attributed: possibly to the standard, which requires to be corrected for capacity and temperature, and should also be corrected for its brass scale, before the true altitude at 32° can be obtained.

It should be known that the observations published monthly by the Royal Society, as taken by their barometer, are deceptive, until reduced to the standard temperature. These observations, in Summer, are often half a tenth or a tenth of an inch too high, as compared with those taken in Winter. At the foot of the tables it is stated that the observations are given as taken by the instrument without any corrections whatever; and it is presumed they are given in this state to avoid cavilling questions as to the data that might be adopted in correcting them. But all the observations taken by my new

instrument are given at once in a perfect state, at the standard temperature; and they are as strictly to be regarded as apparent observations, as merely instrumental admeasurements, as those taken by any other barometer. In short, I propose that a compensating scale shall be applied, as I find, by my instrument, that the compensating principle is as valuable to the barometer as it is to the pendulum of a clock.

Samuel B. Howlett,
Chief Draughtsman, Ordnance.

XV.—*Notes to aid in correcting the operation of ascertaining the Heights of Mountains by means of Boiling Water; furnished by Major* Ord, *Royal Engineers.*

The following notes and extracts were taken by Major Ord for his private use and amusement from an article in the Journal of the Asiatic Society of Bengal, by the Editor, Mr. James Prinsep, Secretary to the Society, an indefatigable philosopher and meteorologist.

This work is not to be procured in Europe, nor indeed without difficulty in Asia; hence, short and imperfect as the extracts are, they are placed at the disposal of the corps without hesitation, as the original can scarcely have fallen into the hands of any of the Officers, to some of whom they may prove interesting as matter for scientific investigation, but to many more as essential to accuracy in the employment of perhaps the most simple and beautiful theory yet arrived at for obtaining approximatively the heights of mountains.

The boiling point is that degree of heat at which the elastic force of aqueous vapour is just capable of counterpoising the pressure of the atmosphere, or the weight of the column of mercury in the barometer. The method then of discovering the law of progression of the tensions has generally been the exposure to heat of a portion of water in a closed vessel, as a glass tube or small boiler, under the pressure of a column of mercury, measuring the height to which this latter is raised at different temperatures.

To determine the elastic force of aqueous vapour at high temperatures, the French Academicians Prony, Arago, &c. have extended their experiments to 435° of Fahrenheit, or a pressure of 24 atmospheres, which they measured by the absolute pressure of a column of mercury 60 feet high in a glass tube attached to the tower of a church; and Daniell has since worked with single glass tubes 40 feet long in his water-barometer experiments.

Experiments prove that the elastic force of steam follows a geometrical ratio

with arithmetical increments of heat, and Tredgold's formula appears the best; his exponent is 6, with a co-efficient: thus, if

$$f = \left(\frac{t+100}{177}\right)^6; \text{ or } t = 177\, f^{\frac{1}{6}} - 100,$$

in logarithms: $\log. f = 6 \log. (t+100) - 2{\cdot}247968.$

Table of Tensions calculated by Tredgold's formula.

Degrees.	Inches.
212	30·00
210	28·86
202	24·68
200·75	24·07
200	23·71
190	19·35
189·5	19·15
182	16·35
180	15·67
178·25	15·10

This correction is found, however, to be necessary:

Deduct from the number in the column of inches, 0·01 inch × No. of degrees below 212.
The difference at 180° will be

180° . .	15·67 inches . .	log. . .	1·19511
	15·35 „ . .	log. . .	1·18611
	540 feet or 90 fathoms =		·0090

which is too great to be overlooked.

All then who possess thermometers divided into degrees and 10ths may convert them into measures of heights by paying attention to the following precautions.

1. The 'prime' boiling point 212° should be accurately verified by comparison with a good barometer, for the divisions of the instrument makers are not to be trusted within the requisite limits.

2. The metal or wooden scale should be cut off at some height above the bulb, as otherwise it is very difficult to obtain the temperature correctly, or even to obtain full ebullition, on account of the rapid abstraction of heat by the metal scale in particular.

3. The vessel (metal) closed with a cover or cork through which the thermometer may pass, so that the bulb may remain a trifle above the surface of

the water, and there should be an opening for the escape of the steam; even a shaving-pot may answer.

4. When the thermometer has been observed at the foot and at the summit of a mountain, deduct the number in the column of feet (Table 2) opposite the boiling point below from the same opposite to the boiling point above, which gives an approximate height, to be multiplied by the number opposite the mean temperature of the air in Table 3 for correct altitude.

Example.

Boiling point at upper station		201·5° =	5451 feet.	Table 2.
Ditto at lower station		211·3 =	356 ,,	,,
		Approximate height	5095 feet.	
Temperature of air above	35°			
Ditto below	50			
Mean	42·5 =	Multiplier	1022	Table 3.
		Correct altitude in feet	5197·9	

5. When the boiling point at the upper station alone is observed, and for the lower the level of the sea or the registry of a distant barometer is taken, then the barometric reading had better be converted into feet by the usual method of subtracting its logarithm from 1·47712 (log. of 30 inches), and multiplying by ·0006, as the differences in column of 'barometer' vary more rapidly than those in the feet column.

Example.

Boiling point at the upper station 185°	=	14548 feet.	
Barometer at Calcutta (at 32°) 29·75.			
Log. difference = 1·47712 − 1·47349 = ·00363			
	× ·0006 =	−218	
	Approximate height =	14330	
Temperature at upper station	76°		
Do. at Calcutta	84		
Mean	80 =	Multiplier	1·100
		Correct altitude	15763 feet.

6. Assuming 30 inches as the average height of the barometer at the level of the sea (which is too much), the altitude of the upper station is at once obtained from Table 2; correcting for the temperature of the stratum of air traversed, by Table 3.

Table II.

To find the Barometric Pressure and Elevation corresponding to any observed Temperature of Boiling Water between 214° and 180°.

Boiling point of water.	Barometer modified from Tredgold's formula.	Logarithmic differences or fathoms.	Total altitude from 30·00 in. or the level of the sea.	Value of each degree in feet of altitude.	Proportional part for one-tenth of a degree.
°			feet.	feet.	feet.
214	31·19		−1013		..
213	30·59	00·84·3	507	−505	..
212	30·00	84·5	0	−507	..
211	29·42	84·9	+509	+509	..
210	28·85	85·2	1021	511	51
209	28·29	85·5	1534	513	..
208	27·73	85·8	2049	515	..
207	27·18	86·2	2566	517	..
206	26·64	86·6	3085	519	52
205	26·11	87·1	3607	522	..
204	25·59	87·5	4131	524	..
203	25·08	87·8	4657	526	..
202	24·58	88·1	5185	528	..
201	24·08	88·5	5716	531	53
200	23·59	88·9	6250	533	..
199	23·11	89·3	6786	536	..
198	22·64	89·7	7324	538	..
197	22·17	90·1	7864	541	54
196	21·71	90·5	8407	543	..
195	21·26	91·0	8953	546	..
194	20·82	91·4	9502	548	..
193	20·39	91·8	10053	551	55
192	19·96	92·2	10606	553	..
191	19·54	92·6	11161	556	..
190	19·13	93·0	11719	558	..
189	18·72	93·4	12280	560	56
188	18·32	93·8	12843	563	..
187	17·93	94·2	13408	565	..
186	17·54	94·8	13977	569	57
185	17·16	95·3	14548	572	..
184	16·79	95.9	15124	575	58
183	16·42	96·4	15702	578	..
182	16·06	96·9	16284	581	..
181	15·70	97·4	16868	584	..
180	15·35	97·9	17455	587	..
					59

The fourth column gives the heights in feet.

Table III.

Table of Multipliers to correct the Approximate Height for the Temperature of the Air.

Temperature of the air.	Multiplier.	Temperature of the air.	Multiplier.	Temperature of the air.	Multiplier.
°		°		°	
32	1·000	52	1·042	72	1·083
33	1·002	53	1·044	73	1·085
34	1·004	54	1·046	74	1·087
35	1·006	55	1·048	75	1·089
36	1·008	56	1·050	76	1·091
37	1·010	57	1·052	77	1·094
38	1·012	58	1·054	78	1·096
39	1·015	59	1·056	79	1·098
40	1·017	60	1·058	80	1·100
41	1·019	61	1·060	81	1·102
42	1·021	62	1·062	82	1·104
43	1·023	63	1·064	83	1·106
44	1·025	64	1·066	84	1·108
45	1·027	65	1·069	85	1·110
46	1·029	66	1·071	86	1·112
47	1·031	67	1·073	87	1·114
48	1·033	68	1·075	88	1·116
49	1·035	69	1·077	89	1·118
50	1·037	70	1·079	90	1·121
51	1·039	71	1·081	91	1·123

Enter the above table with the mean temperature of the stratum of air traversed, and multiply the approximate height by the number opposite for the true altitude.

Example.

On Pedrotallagalla[1] water boiled at 193·3°; hence its approximate height = 7702 feet.

Temperature at Columbo at 10 A.M., 23rd Jan., 1837 $79\frac{1}{2}°$

At Trincomalee 78

Mean temperature at the sea $78\frac{3}{4}$

[1] The top of the highest mountain in the Island of Ceylon; its summit, like those of all the range, of which Adam's Peak is the next in height, though far better known in the East, is composed of a smallish-grained, dark-coloured, and somewhat friable granite, hornblende usually occupying the place of feldspar, and being richly studded with garnets. From this point the horizon is distinctly seen by the naked eye at a distance of 112 miles. At this time the magnificent blossom of the Rhododendron Arboreum appeared to cover the hill with a rich crimson cloak, whilst the air was perfumed with the various species of the Orchideous Parasytic, prized so much just now in England as 'Air-plants.'

[2] Mean temperature at the sea	$78\frac{3}{4}$	
Temperature on the height	54	
Mean temperature of stratum traversed	$66\frac{1}{2}$ = Multiplier	1·072
	× Approximate height	7702
	True height	$8256\frac{1}{2}$ feet.

W. R. Ord,
Major Royal Engineers.

March, 1839.

In the 8th vol. of the Transactions of the Geographical Society, Lieutenant-Colonel Sykes has given a paper "on the use of common thermometers to determine heights." He makes use of precisely the same tables as those in the foregoing paper, and has given the results of a variety of observations made simultaneously with barometers and thermometers. The differences of altitudes determined by the two modes of observation vary from 8 to 107 feet; a sufficient proof that the thermometer may be depended upon for approximative results.

The tables of temperatures and pressures given by different persons who have made experiments on the elastic force of steam, differ a good deal from each other, as will be seen by the table annexed, which has been communicated, with the following remarks, by Lieutenant Harness, Royal Engineers.

Temperature. Fahrenheit.	Robison.	Ure.	Tredgold.	Tredgold corrected.	De Luc.
210	28·65	28·80	28·86	28·85	28·782
200	22·62	23·60	23·71	23·59	23·183
190	17·85	19·00	19·35	19·13	18·947
180	14·05	15·165	15·67	15·35	15·371
170	11·05	12·050			12·441
160	8·65	9·60			10·117
150	6·72	7·530			8·208

De Luc's formula reduced to inches of mercury by Horsby is as follows, $\frac{99}{\cdot 899}$ log. $z - 92{\cdot}804 = h$, where h = No. of degrees of Fahrenheit above the freezing point, and z = height of barometer in tenths of inches. This is an inconvenient form; it ought not to be necessary to deduct 32 from the nominal

[2] At this time Major Ord had, under the sanction of the Commander of the Forces, bi-horary thermometric observations carrying on at these two nearly opposite stations on the Ceylon coast (as well as at Kandy), upon the principle recommended by the British Association.—W. R. O.

temperature, or to divide the result by 10 for inches and decimals. Changing it in this respect, and putting t instead of h (a more expressive letter for temperature), it would stand thus:

$$\log. z = \frac{t - 49{\cdot}3183}{110{\cdot}1223},$$

making the pressure at $180° = 15{\cdot}371$ inches, agreeing nearly with Tredgold after applying the correction.

With such considerable differences as shown above, it would not be right to found a table entirely on one set of experiments, or one particular formula. The experiments made by Wollaston and others have determined with great accuracy the value of a difference of a degree of Fahrenheit in the boiling temperature, when the barometer ranges between 31 and 28 inches, which difference is equivalent to a pressure of ·589 inches of mercury. This may be considered equal to a difference of 517 feet in altitude.

To obtain a number for the other end of the scale, Ure's and Robison's tables may be referred to, and it will be seen that although their absolute pressures at 160° and 170° differ considerably, the change due to the difference of temperature does not. Between 165° and 166° the altitude due to the change of a degree in the boiling temperature may be taken at about 635 feet, and a table formed by adding the same 2nd differences.

The only data, however, that can really be relied on for forming a good table are actual comparisons of barometers and boiling points; and unless these have been made with the same barometer and thermometer, especially the latter, the results are diminished in value.

In the Philosophical Transactions, vols. 33 and 43, there is some information on this subject, and the following are taken from them:

Cavallo with the same thermometer found at—

	Barometer.	Boiling point.
Bologna	30·21	213·5
Genoa	28·60	210·4
Modena	26·61	207·3
Lunenburgh	25·75	205·1
Mont Cenis	24·03	201·2
	23·91	201·1

He also found that the alteration of an inch in the barometer from 28·86 affected the boiling point 1·743.

At the top of Mont Blanc Saussure found water boiled at 187°. Martin Folkes in 1744 found the boiling point on the Pic du Midi 15° of Fahrenheit lower than at Bayonne, and $18\frac{1}{2}$° lower than at Bourdeaux. The height of Mont Cenis is given as 6,778 feet, that of Mont Blanc as 15,668.

XVI.—*On the Decomposition of Metallic Iron in Salt Water, and of its Reconstruction in a Mineral form. By Lieut.-Colonel* Reid, *Royal Engineers.*

Considerable attention has been given of late to the effect which salt water produces in corroding iron; in consequence of that metal being now used for facing wharfs, and other works exposed to the sea. Some papers have been published on the subject, but their object has been, I believe, only to ascertain the durability of iron as a material when in contact with salt water.

I am not aware that public attention has ever been directed to the curious change which takes place when iron, in contact with silicious pebbles and other stones, is immersed in salt water.

My attention was first drawn to this subject from a desire of acquiring a better knowledge of those laws of Nature which regulate the cohesion of solid particles; and from a conviction that the study of these laws would afford the best means of improving our knowledge for practical purposes.

Almost every one has observed pebbles adhering to old anchors which have long lain under the sea. Engineers who have had to remove piles from sea walls or harbours have also noticed similar effects, for the iron shoes at the points of the piles have generally a mass of pebbles strongly incrusted around them. Even in what we call fresh water, (but which on analysis always is found to contain salts in solution,) this effect in a smaller degree is observed.

Having had occasion to reset part of what are called breakwaters at Portsmouth, which are covered every tide by the sea, I was there enabled in many instances to notice the effects here alluded to. Some of the examples afforded beautiful specimens, and of several varieties, of the carbonates of iron of perfect forms. When examined with a powerful lens very delicate needle crystals were often distinctly visible; these last which I observed were white. Those resembling carbonates of iron varied from black to brown, and to bright

yellow: some of the browns were of a very rich colour. These specimens were not found at Portsmouth only; at Hurst Castle planks of considerable dimensions, which the gales had broken from the groins, were found firmly incrusted with silicious pebbles. It was not at first easy to discover from what cause the pebbles adhered to the wood, but on sawing a plank longitudinally it was found to have been driven full of iron scupper-nails. The flat heads of these nails were almost touching each other; the heads had nearly disappeared, and in their place a black shiny crystalline matter had been formed, which firmly united a layer of pebbles to the plank. The opinion I formed on this was that voltaic action takes place between the metallic iron and silicious pebbles when immersed in sea water. If this be the case, we can scarcely doubt but that something of the same nature will occur between iron and other stones, when similarly placed. Part of the breakwaters at Portsmouth were set with very thin sheet iron, between blocks of Swanage stone, as an experiment: in a month afterwards, sand and small pebbles were found firmly fixed between the iron and the stone; and black crystalline matter, such as had been found at Hurst Castle, appeared forming, and the experiment, as far as it has been observed, seemed satisfactory.

After thus setting the breakwater with stones, alternating with plates of sheet iron, I observed that Mr. Cross had previously pursued studies somewhat similar, and that he was satisfied that iron, when in contact with silex in a fluid medium, exhibits electric phenomena. An observation to this effect will be found in Mr. Leithsad's work on electricity.

The subject of the formation of crystals by voltaic electricity, which is one of great interest, is now making considerable progress, and the object of this paper is to endeavour to show that the pursuit of the study may be practically useful when applied to hydraulic works; and that it well deserves to be ascertained whether plates of thin iron, alternating with stones, and placed under the sea, will not be found to form solid rock, with crystalline veins. Mixtures of iron filings, sand and gravel, let down to the bottom of the sea through tubes, might perhaps consolidate and form a stable foundation for light-houses, and other works for which it is very difficult to form a base.

Those parts of the Portsmouth breakwaters set with the thin sheet iron will be found between the saluting battery and the spur redoubt, and are visible on close inspection. The experiment has been varied, somewhat in the manner above alluded to, by authority of the Admiralty. Unserviceable iron water

tanks from ships of war have been filled with gravel, mixed with iron turnings and a small quantity of lime, in the construction of a groin opposite to Haslar Hospital. The greater part of this groin will be covered by the tides; and thus a good opportunity will there be afforded of observing the effects of iron in contact with pebbles when immersed in salt water.

W. Reid,
Lieut.-Colonel Royal Engineers.

XVII.—*Report on the Effect of Climate on Yorkshire Paving, communicated by Colonel* FANSHAWE, *Royal Engineers.*

A REPORT having been received from the Mauritius that the Yorkshire stone coping which had been supplied for that station was either of a bad description, or not calculated to withstand the great power of the sun in that climate, a considerable portion of it having blistered and peeled, references were consequently made to other tropical stations and to Bermuda, where stone of this nature had been used.

From Barbadoes the reply was that the experience of that command had in no case shown that solar heat has had the effect of blistering or peeling Yorkshire paving, and that the defect complained of was more attributable to the quality of the stone than to the climate.

The Jamaica Report stated that on examination of the Yorkshire flag-stone, measuring 14 inches wide and 3 inches thick, used in coping the wall that surrounds the barracks at Up-Port camp, being about 2,000 yards in length, and having been laid ten years, some few stones were found partially honeycombed to the depth of $\frac{1}{4}$ to $\frac{3}{8}$ of an inch, which is attributed to the bad quality of the stones rather than to the effect of the climate,—the deteriorated flags having been in all probability obtained from the upper beds of the quarry, the greater part being to all appearance perfectly sound and showing no indication of blistering or peeling.

The Bahama Report stated that upon a careful examination of the Yorkshire stone used for flooring and pavement in situations exposed to the heat of the sun, it was not perceived to have blistered or peeled, or to have been otherwise affected beyond what might be expected from common wear and tear.

The Bermuda Report stated that in many instances Yorkshire stone exposed to the weather has not suffered sensibly from such exposure, whilst in

others it has been blistered and peeled off in laminæ from $\frac{1}{10}$ to $\frac{1}{16}$ of an inch in thickness.

A quantity not set, and so exposed from four to five years, has undergone no sensible change, which is likewise the case with that on the top of the tower in the main ditch, laid about eight years since.

Exposed to the alternate action of the sea and sun at the landing places in the dock-yard at Ireland Island, the Yorkshire flagging had failed.

Yorkshire flagging is of very different qualities. The best is found in the lower part of the quarry; that from the upper part is usually composed of several laminæ, disposed to split, and will in all probability fail. But there seems no reason to doubt, from the above experience, that by a proper selection of quarry, or of stone at the quarries, the Yorkshire flagging will be found to withstand the effects of a tropical climate.

XVIII.—*Report of Paving Stables at Brighton.*

Royal Engineers' Office, Brighton,
4th February, 1839.

Sir,

In reply to your letter, dated 17th ult., respecting the experimental pavement tried in the cavalry stables at this place, I now send an extract from the Officers' diary, written by Captain Alderson, descriptive of the wooden block paving proposed and executed by him in January, 1838. The alterations suggested by Captain Alderson of making the fall 2 inches instead of 4, and the grooves $\frac{3}{4}$ of an inch in depth and width instead of $\frac{1}{2}$ an inch, have been tried, and are certainly improvements on the original plan.

See vol. ii. page 271.

The stall first done has been constantly in use for upwards of a year, and does not appear to stand the wear and tear quite so well as was anticipated, the lower part of the stall immediately under the horse's hind feet being already worn down at least $\frac{1}{4}$ of an inch. More time, however, will be required to judge of its durability. The expense of this mode of paving amounts to 2*s.* 3*d.* per foot superficial.

The pebble pavement laid in concrete, with Purbeck horse pitching paving placed immediately under the horse's feet, which was put down in August, 1837, appears to answer tolerably well, and is doubtless a decided improvement upon the common pebble paving. The expense of this amounts to 6*d.* per foot superficial; the common pebble pavement to $3\frac{1}{4}d.$ per foot superficial.

I am disposed to think that a stall paved two-thirds of its length from the bottom with Purbeck horse pitching, and the remaining one-third at the top with common pebble paving laid in concrete, would be the most durable, and

on the whole the least expensive. The cost would be 11*d.* per foot superficial.

I have the honour to be,
Sir,
Your most obedient humble servant,

C. O. STREATFIELD,
Captain Royal Engineers.

Lieutenant-Colonel Graydon, K.H.,
Commanding Royal Engineer.

XIX.—*Experiments tried at Quebec as to the properties and adhesive qualities of the following Cements, by order of Colonel* Nicolls, *Commanding Royal Engineer, dated 17th November*, 1834.

Names of Cements.	Nature of Experiments.	Description of Experiments.	Result of Experiments after 7 months winter, the coldest day 29° below zero.
English or Harwich.	Pointing . . .	On the 1st October, 1834, one-third of thirty-four square feet of the left angle of the flank of the interior of the parapet of St. Ursule bastion was pointed with the three cements enumerated in the margin. The cements were applied by three masons at the same time to the raked out joints. In working, the Harwich set first of the three; the Quebec (or Lieut. Baddeley's) set within the half hour; but the Hull (Mr. Wright's*) took an hour to set. The latter kept its colour like the Harwich, but the Quebec changed from a rich freestone colour to that of a bluish grey.	Harwich best! Next best, Hull.
Canadian or Hull, on the Ottawa, generally used on the Rideau Canal.	Building . . .	On the 2nd October, 1834, a trial of these cements was made in building a stone wall of four courses, with coping of the same materials laid on edge, the site of which was in an embrasure of the left flank of St. Ursule bastion. N.B. The first two courses were commenced in dry weather, but the third in a heavy shower of rain (which continued for the remainder of the day), which made the Quebec and Hull run out of the joints ere they could set, but the Harwich set nearly as fast in as out of the rain; a most decided advantage over its rivals. It was thought advisable to withdraw the workmen for this day, taking the precaution to cover the work until the next morning, when the dryness of the weather enabled the masons to complete the work.	Harwich *best!* The two others have stood very well indeed, and to all appearance will remain so for years.
Quebec, made from the Black Rock, by Lieut. Baddeley.	Plastering, in water	On the 17th October, 1834, an experiment was tried in building a triangular well, sunk in the ditch under the left flank of the same bastion, which was plastered with the three cements, and the water raised in it as high as the top of the fifth course, which remained in that state during the winter.	Harwich the only one that stood the test.
		The above were inspected by Colonel Nicolls on the 25th May, 1835.	

		cement: on the 24th of February, 1835, in the presence of Colonel Nicolls, Lieut. Baddeley, Lieut. Gordon, Mr. Masson, the Master Mason, and Mr. Houston, the Acting Overseer of Works, the following experiments were tried, viz.:	
Harwich	Adhesive qualities of the cements.	1st. The two bricks cemented together with Harwich cement sustained $5\frac{1}{2}$ cwts.;	And were separated with 6 cwts.
Hull		2nd. The two bricks cemented together with Hull cement, $3\frac{3}{4}$ cwts.; the time occupied in placing the weights upon the scale until the separation took place was only about four minutes.	Were separated with 4 cwts.
Quebec		3rd. The two bricks cemented together with Quebec cement sustained $9\frac{1}{2}$ cwts. This experiment took ten minutes, when the iron hook of the scales gave way.	Separated with $10\ \frac{3\ 9}{1\ 1\ 2}$ cwts.
		Another experiment on the adhesive qualities of Quebec cement.	
		The adhesive surface was a rectangle of iron of 18×3 inches, and consequently contained 54 square inches. The cement was $\frac{3}{10}$ in. in thickness, and the surfaces had been cemented together twenty-one days.	
		Sustained . . . . . 406 lbs.	
		Broke with . . . . . 420 lbs.	

N.B. Method of mixing the cements into a working state, viz.:—

Harwich Cement . . .	6	measures of cement.
	2	do. of sand.
	4	do. of water.
Hull do.	6	measures of cement.
	2	do. of sand.
	3	do. of water.
Quebec do.	6	measures of cement.
	2	do. of sand.
	$2\frac{3}{4}$	do. of water.

The measure used for the cement, as well as the water, was a common tin of 1 pint.

Alex. Gordon,
Lieutenant Royal Engineers.

XX.—*Proof of an Earthen Ware Pipe for Lieutenant Denison.* *By Mr.* Bramah.

Being desirous of ascertaining the extent to which common earthen ware pipes might be depended upon for the conveyance of water under the pressure of a head of several feet, I placed a common draining pipe, of the dimensions stated below, in the hands of Mr. Bramah, who very obligingly constructed the necessary apparatus and carried on the experiment, of which the following are the details. W. D.

Dimensions: length, 20 inches, with small taper; diameters, 3·65 over and 2·5 within, and 3·3 over and 2·3 within.

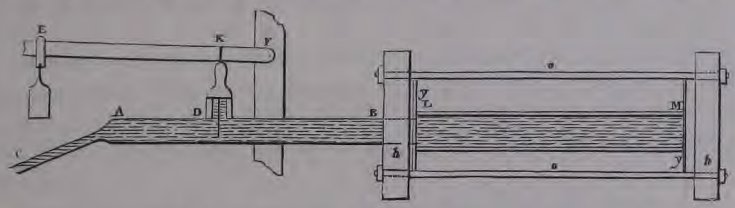
In order to ascertain the strength of the above pipe to resist the pressure of a column of water, before the escape of the water through the pores of the pipe, and also the total amount of pressure it could bear without giving way, the following apparatus was employed.

A piece of lead pipe A B, about 2 in. in diameter, was attached to C, the pipe of a hydrostatic press pump; into the upper side of this pipe a valve D was fastened, having its inside diameter $1\frac{5}{8}$ in.; this valve was kept down by the pressure of a lever E F, the load on which was gradually increased from time to time when the valve allowed any water to escape; K F, the distance of the bearing of the lever from the centre of motion F, was $2\frac{5}{8}$ in., and the weight was hung on the lever at E, 21 inches from the centre, so that the arms of the lever were as 8 to 1. Hence a weight of one pound gave a pressure on the valve of 8 lbs.; the diameter of the valve D being $1\frac{5}{8}$ in., its area is very nearly 2 in., but the 8 lbs. of pressure being distributed over the whole surface of the valve, or 2 inches, the actual pressure on each superficial inch would be 4 lbs. Wherefore 1 lb. hung on the end of the lever would give a pressure of 4 lbs. on the inch of surface of pipe.

The ends of the earthen ware pipe L and M were filed quite even, and closed by a piece of patent felt *y*, *y*, cloth, bedded in white lead and putty.

Two pieces of wood *h*, *h*, were then placed on the ends of the pipe on the outside of the felt, and bolted firmly together by two screw bolts *o*, *o*, in the direction of the length of the pipe, so as effectually to prevent the escape of any water at the ends of the pipe. The lead pipe was passed through one of the pieces of wood at B into the earthen ware pipe, and all the joints were secured in such a way as to prevent the escape of water.

The apparatus was then filled with water by means of the pump, and pipe C, 12 lbs. being placed on E, the end of the lever, which gave a pressure of 48 lbs. on the inch of pipe. The water was forced in till the valve allowed it to escape, with no signs of water escaping through the pipe L M; the weight was gradually increased, and the water pumped in till 25 lbs. had been placed at E, or a pressure of 100 lbs. on the inch of L M. The water began to ooze



through the pipe L M at numerous pores, and as the weight was increased the water escaped in larger quantity, though the water that escaped in this way was not at all considerable.

With 50 lbs. on the end of the lever, or a pressure of 200 lbs. on the inch of the pipe, it burst in the direction of its length, about one-half the length at the small end giving way at both sides of the pipe.

From the above it appears that a column of water 231 feet high would escape through the pipe, and twice that altitude of water, or 462 feet, would burst it.

This proof gives great strength to the above pipe, but, being a solitary experiment, no very satisfactory conclusion can be drawn from it; the pipe was coated inside and outside with Boyd's Patent Tar, which it is supposed vastly increased its power of retaining the water, by filling up the small pores through which the water would have otherwise passed more freely. The

diameter of the pipe was but small, and of course the quantity of surface exposed to the straining force was not very considerable.

Before any accurate result can be obtained, it would be necessary to repeat the experiment in a variety of different ways and under different circumstances. It is probable that with a small pressure continued for a length of time the water would partially find its way through the pipe, and thus ultimately impair its strength.

XXI.—*Description of a Drawbridge on the London and Birmingham Railway, at Weedon.* *By* Captain Jebb, *Royal Engineers.*

The London and Birmingham Railroad crosses a branch canal at Weedon, which communicates between the Grand Junction Canal and the extensive storehouses and magazines belonging to the Ordnance Department at this station. As it was provided in the Act of Parliament that a drawbridge should be placed over this branch canal, in order that the water communication might be preserved, Mr. Stephenson, the chief engineer, designed a bridge for this purpose, which, having been submitted for the approval of the Master-General and Board of Ordnance, was sanctioned by them, and has been recently completed.

Plate 26 will serve to explain the principle upon which the bridge is constructed, and the mode in which it is adjusted in its place as a portion of the line of railway, and removed, when necessary, for the passage of boats.

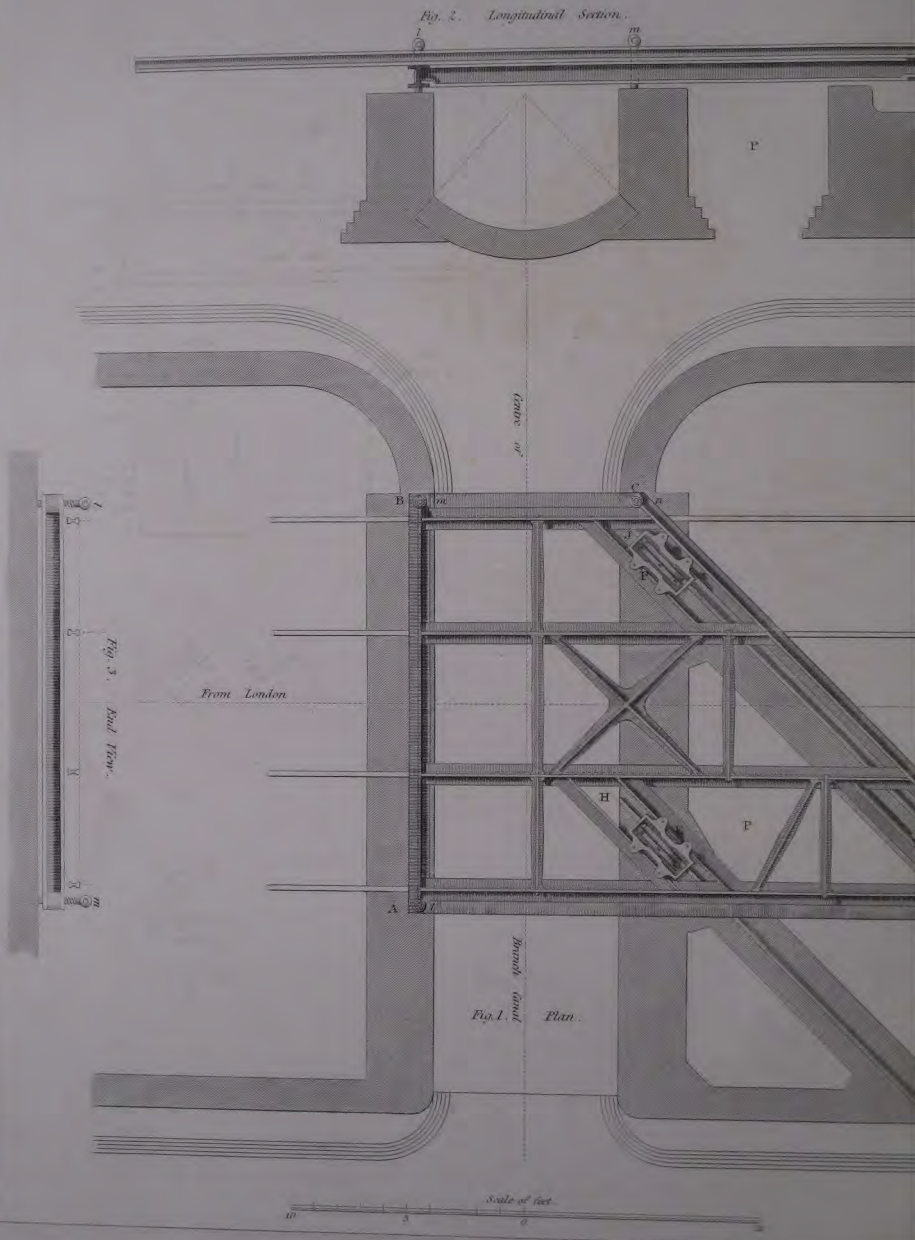
Fig. 1, is a horizontal section through the middle of the main frame, showing a plan of the line of railway and the canal, with the bridge in its place; ABCD is a cast iron frame, which carries the chairs for the rails. This, when in its place, is supported at the angles by four large screws, *l*, *m*, *n*, *o*, and, when a passage along the canal is required for boats, is removable upon the three wheels, E, F, G, which work on two rails, HI and JK, fixed on the solid walls, which appear below, at an angle of 45° with the line of the railroad. Such weights as may be necessary for adjusting the centre of gravity of this mass, so that when in motion it may rest fairly on the three wheels, are placed on the broad flanges in the line CD and about the wheel G.

The platform of the bridge is covered with cast iron plates, bolted down upon the main beams by $\frac{1}{2}$-inch bolts. These beams are placed at the same

distance apart as the rails on the line of road, and chairs bolted down to them with $\frac{7}{8}$-inch bolts serve to support the line of rails across the bridge: both the chairs and the plates have a thickness of patent felt between them and the main beams.

It will be obvious that the proposed object of removing the bridge is effected by rolling it bodily out of the way on the lateral rails, laid at an angle of 45°, until the passage of the branch canal is clear. The force necessary for this purpose has hitherto been applied in a very simple manner, by inserting iron crow-bars into the holes shown in the circumference of the wheels: this mode, however, is tedious, and as expedition is an object under the circumstances, an apparatus, the nature of which will be understood by referring to the explanatory sketches, figs. 4 and 5, is to be placed in the vacant space PP under the bridge, by which its removal will be accomplished in about three minutes. This apparatus consists of an endless chain, connected with the under side of the bridge by the pin S, working over the circumference of two lanterns Q and R; one of these is in connexion with a train of wheel-work having a power of 20 to 1: by working this then in one direction the bridge is withdrawn, and in the other it is replaced in its proper situation. It has been before stated that when the bridge is in its place it is supported by four screws at the angles; these are found of the utmost advantage in adjusting the bridge to its proper level as a portion of the railway, and in supporting it in that position. If the bridge, carrying as it does the main line of rails, was left supported on the three wheels, the passage of trains would not only cause a great wear and tear in the parts connected with these wheels, but would jar and shake the carriages very much: however accurately the work may be laid down, some play must be allowed, and if the weight of a carriage be thrown upon that part of the frame-work which forms the bridge, it would descend, while the opposite side would rise, and the rails of the fixed road and those of the bridge would no longer coincide in level. The four large screws at the angles are intended to obviate this inconvenience. When the bridge is run up into its position in the line of road, these screws are worked round by a lever until their points are inserted into sockets prepared for their reception, and from these points of support the bridge is then screwed up and accurately adjusted; the three wheels E, F, and G, being at the same time raised from the lower rails H I, J K, and the four screws becoming the only points on which the bridge rests.

PROPOSED DRAW BRIDGE OVER THE



VERNMENT BRANCH CANAL AT WEEDON.

to Birmingham

D

Fig. 4.

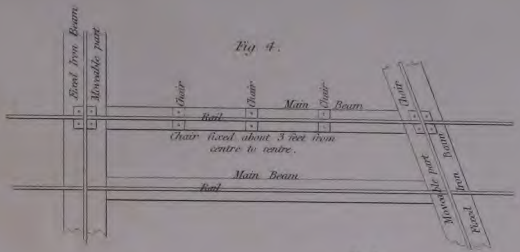


Fig. 5.
Plan of covering plate.

a, a, ¾ inch bolts with long heads say 3 inches by 1 inch and ¾ thick. four of them in each plate going through the upper web of the Main beam.

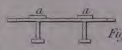


Fig. 6.

Fig. 7.
Section of Main Beam shewing Chair upon it.

The chair held down by two ¾ inch bolts with nuts under the upper web of the Main beam.

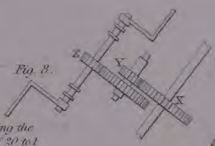


Fig. 8.

Gane motion for working the Bridge with a power of 20 to 1 5 minutes will be sufficient to open the Bridge.

Fig. 9.

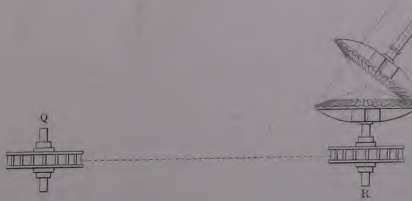
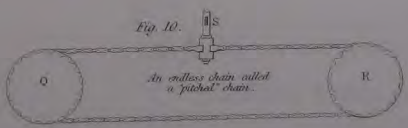


Fig. 10.



Engraved by R. Elkington.

30 High Holborn.

Since it has been in operation it has been found in all respects extremely well adapted for the purposes proposed, being easily removed when required for the passage of boats, and affording as solid a bearing for the railroad as if the rails had been permanently fixed on blocks or sleepers.

J. JEBB,
Captain Royal Engineers.

XXII.—*Table of the Description and Weight of the Packages of various Articles of Traffic.* *By Major* Harry D. Jones, *Royal Engineers.*

Jersey, May 13, 1839.

The following Table has been prepared in the hope that the information it contains may prove useful to the Members of the Corps. My attention was directed to the subject in consequence of having been required on many occasions to ascertain the weight in *tons* of various articles of merchandize as packed for trade or for exportation; the details herewith given were not to be found in any book to which reference was made; after the Table of Weights and Measures in the Pocket Books for Engineers, &c., a list will be found of various articles, setting forth the weight or contents of certain quantities of each, without regard to the *quantity* contained in each package as sent into the market.

The list herewith given contains the names or denominations of almost every article of the export or import trade as enumerated in the printed lists supplied by the Custom-house Officers; inquiries were made of several collectors, shipping agents, and persons engaged in trade, both in London and Dublin: the weights or quantities opposite each article may therefore be considered tolerably accurate, at any rate sufficiently so for any calculations that an engineer may be called upon to make in the preparation of returns to show the weight to be transported on railways, or as to the amount of tonnage required where vessels are concerned.

Articles.	Nature of, Name, or Description, of Package.	Weight or Number.	
Ashes	Barrels,	6=1 ton.	
Bleaching Powders	Casks,	$2\frac{1}{2}$ to 7 cwt.	
Bacon	Barrels,	6=1 ton.	
,,	Bale,	$2\frac{1}{2}$ cwt.	
Barley	Sack,	20 stone.	
,,	Quarters,	4=1 ton.	
Barm	Cask,	8 cwt.	
Beans	Hogsheads,	$5\frac{1}{4}$ cwt.	
,,	Quarters,	4=1 ton.	
Beer or Ale	Barrel,	$3\frac{1}{4}$ cwt.	
,,	Hogsheads,	$5\frac{1}{4}$ cwt.	
Beef	Barrel,	3 cwt. 7 lbs.	
Books	Cases,	1 cwt. to 5 cwt.	
Bran	Sack,	1 cwt.	
Bread	Bags,	1 cwt.	
Butter	Cask,	90 lbs.	
,,	Firkins,	$\frac{3}{4}$ cwt.	
Candles	Boxes,	20 lb. to 40 lbs.	
Cattle, 1st class	..	$1\frac{1}{2}$=1 ton.	upon an average divide the number by 3 for tons weight.
,, 2nd do.	..	2=1 ton.	
,, 3rd do.	..	3=1 ton.	
,, 4th do.	..	4=1 ton.	
Coal	Tons,		
Coffee	Barrel,	$2\frac{1}{2}$ cwt.	
Cotton, Manufactured	Package,	$3\frac{1}{2}$ cwt.	
,,	Yards,	.....	divide the number of yards by 6000 for tons.
Drugs	Packages,	2 cwt.	
Earthen Ware	,,	$3\frac{1}{2}$ cwt.	
Eggs	Boxes,	10=1 ton.	
,,	Number,	.....	divide by 28,000 for tons.
,,	Crates or Kishes,	6 cwt.	
Flax	Bales,	10 cwt. average.	
,,	Bushel,	48 lbs. 1 qr.	
Flax Seed	Cask,	$3\frac{1}{2}$ cwt.	
Feathers	Bags,	2 cwt.	
Fish	Barrel,	$3\frac{1}{2}$ cwt.	
Glass	Casks,	1 cwt.	
Glue	Hogshead,	10 cwt.	
Haberdashery	Package,	$3\frac{1}{2}$ cwt.	
Hair	Bales,	3 cwt.	
Hams	Barrels,	$3\frac{1}{2}$ cwt.	
,,	Casks,	12 cwt.	
Hardwares	Package,	$3\frac{1}{2}$ cwt.	
Hides, untanned	Number,	40=1 ton.	
,,	Bundles,	70 lbs.	
Honey	Casks,	$\frac{1}{2}$ cwt.	
Horses	Number,	10 cwt. each.	
Horn Tops	Hogsheads,	8 cwt.	
Iron, wrought	Packages,	$3\frac{1}{2}$ cwt.	
Leather	Package,	5 cwt.	
Linen	Boxes,	$3\frac{1}{2}$ cwt.	
,,	Yards,	.....	divide by 6000 for tons.

Articles.	Nature of, Name, or Description, of Package.	Weight or Number.	
Linseed Meal	Casks,	10 cwt.	
Linen Cloth	Boxes,	6=1 ton.	
,, Yarn	Bales,	10 cwt.	
Machinery and Mill Work	Packages,	3½ cwt.	
Muriatic Acid	Carboy,	60 lbs.	
Oatmeal	Bags,	2 cwt.	
Oats	Sack,	24 stone.	
,,	Quarters,	.....	divide by 6 for tons.
Oil	Casks,	8 cwt.	
Oxen	.....	5½ cwt. each.	
,,	Number,	.....	divide by 3 for tons.
Paper	Bales,	20 lbs.	
Peas	Bags,	2 cwt.	
Pork	Tierces or Casks,	4½ to 5 cwt.	
Pigs	Average,	½ cwt. or 80 lbs.	divide the number by 15 for tons, upon the average this will be found very nearly correct.
,, 1st class	Large size,	5=1 ton.	
,, 2nd do.	Smaller,	7=1 ton.	
,, 3rd do.	Middling size,	15=1 ton.	
,, 4th do.	Small size,	23=1 ton.	
Poultry	Crates,	2 cwt.	
Quills	Bales,	2 cwt.	
Rags	Bags,	2 cwt.	
Rum	Hogshead,	56 to 58 gal.	
,,	Gallons,	.....	divide by 224 for tons.
,,	Cask,	8 to 32 gal.	
Runnet	,,	1 cwt.	
Salt	Bushel,	56 lbs.	
Silk	Bale,	1½ cwt.	
,, Manufactured	Yards,	.....	divide by 6000 for tons.
Sheep	Number,	60 lbs. each.	divide the number by 33 for tons.
Sugar	Hogshead,	10 cwt.	
Tallow	Casks (Irish),	15 to 18 cwt.	
	,, (Foreign),	8 to 13 cwt.	
Tanners' Waste	Packages,	3 cwt.	
Tea	Chest,		
Timber	Log from 40 to 120 feet,	1 to 3 tons.	
Tinned Plates	Boxes,	3½ cwt.	
Tongues	Firkins,	1 cwt.	
Tow	Bales,	1 cwt.	
Vetches	Sacks,	2 cwt.	
Vinegar	Cask,	8 cwt.	
Vitriol	Carboy,	60 lbs.	
Wine	Casks,	12 cwt.	
Wheat	Barrel,	20 stone.	
,,	Quarters,	4=1 ton.	
Whisky	Puncheons,	10½ to 12 cwt.	
Wool	Bales,	3 to 10 cwt., average 6 cwt.	
,,	Package,	3 cwt.	
,,	Bags,	2½ to 9 cwt.	
Woollen Manufactures	Yards,	.....	divide by 6000 for tons.

Observation respecting Freights.

Cattle	Charged Per head.
Pigs	Do.
Hides	Always per ton.
Linen and Silk	By measurement.
Cotton Manufactures . . .	Do.
Machinery and Mill Work . .	By weight.
Glass, China, Earthen Ware . .	By measurement.
Haberdashery	Do.
Wrought Iron	By weight.

HARRY D. JONES,
Major Royal Engineers.

APPENDIX.

Notes on Lintz.

Since our last publication the following Notes on the intrenched Camp of Lintz have been forwarded to us by a retired Officer of Engineers, who has visited that place and minutely inspected the works.

The fortifications of Lintz have attracted the attention of many scientific military men, but the most decided opinions on the works there have been published by Captain Allard, of the French Corps de Génie, in the Spectateur Militaire of the following dates: viz. January 1834, and February and April 1835, under the heads "Fortifications de Paris, et Campagne de France, 1814;" "Bataille de Toulouse en 1814;" "Défense de Varsovie en 1832;" "Tours Maximiliennes," with "Conclusion."

The following paragraph has just appeared in the public newspapers, and it is only important as confirming the idea of the great interest attached to this system of defence by the great military powers of Germany.

"The Austrian government," says a letter from Vienna, "has come to a decision on the long suspended question of the federal fortresses, and pronounced in favour of Ulm in Wirtemberg, which is to be formed into a fortress of the first order, and made the Place d'Armes of Southern Germany. It is believed that the system of detached forts, after the plans of the Archduke Maximilian, and which have been adopted at Lintz, will be followed. The second fortress will be Rastadt, in the grand duchy of Baden, opposite Strasburg; and others will be raised in the Black Forest," &c.

As Captain Allard's plans and description have not been found quite correct, the following Notes are offered as "Amendments."

The "Plan de Lintz et de ses Environs" must be considered as giving a very imperfect idea of the intrenched camp of Lintz, being just sufficiently

correct to mislead. The western line of towers from Nos. 6 to 14 is considerably more advanced than in the plan; and those on the south side of the river occupy a second ridge in advance of the town. This ridge, extending from Pestlingberg, and gradually declining in height until it finally terminates at the Vienna road, must be considered as the principal front of the position, and as having commanded the greatest attention. The ground is peculiarly adapted to the system of towers employed, each tower on the ridge being for the most part placed on a circular commanding knoll, and the whole so adapted that they mutually flank each other, and would afford efficient support to troops acting offensively or defensively in their immediate front, which it is to be presumed is one of the principal objects required in an intrenched camp. The distance between the towers varies from 300 to 600 yards, as the form of the ground and the exposure to attack would appear to dictate. For instance, the towers Nos. 6 to 10 on Captain Allard's plan occupy broken ground, and this is the most vulnerable and important point of the position. In consequence, these towers are not more than 300 or 400 yards apart, and any attacking column or field-battery would be exposed to the concentrated fire of three towers, independent of any field-battery that might be placed by the defenders on any advantageous point. And here it may be particularly impressed on the minds of Officers, that their works are not intended as purely defensive fortifications, but as an intrenched position, where a defeated army might repose in security or act offensively under their protection, as occasion may present itself.

Pestlingberg, placed on the summit point of the ridge, has two principal fronts of fortification directed towards the north-west. Three large towers occupy the place of bastions, and they are connected by curtains, with a ditch, revetted counterscarp, and good glacis. The ditches are well defended by casemates connecting the towers with the body of the place. Were this point not strongly fortified, it would be found, in the possession of an enemy, to be a key to the position from whence the line of towers might be successively destroyed on the left bank of the Danube.

The general dimensions of the towers on Captain Allard's plan I presume to be correct, or nearly so, but there are some parts which are very much the contrary, and which are intimately connected with their efficiency. Referring to the "Coupe suivante ABC, &c., and Plans of the Towers" it may be stated that the bottom of the ditch is about 12 feet in width, equally all round. The

glacis extends to about 70 yards in front, and is continued generally to half the circumference, when it is abruptly cut off to the natural level of the ground, so as to allow four howitzers on the upper floor to see to the flanks. This is a very material circumstance, and it is extraordinary that Captain Allard should not have so described it on his plan.

The ditch is defended and seen into from the lower windows, which are grated. On the upper floor the embrasures, 15 in number, are of the ordinary size, and have also gratings. There are several minor circumstances in the construction of these towers, (vide the Plan,) which also require correction, such as the interior communications, &c.; but as they do not affect the efficient defence, they are not particularly noticed here. One trifling circumstance will illustrate this. The bridge across the ditch is represented as drawing up against the wall of the tower, whereas in reality it is drawn horizontally within the tower by chains passing over pulleys, being supported when pushed forward by beams resting on the bottom of the ditch.

On the deck or platform there are eleven short 18-pounders, requiring four gunners each; but it is doubtful whether the platform will allow them all to be directed on one point, allowing sufficient space between the guns for working them with facility. The officer commanding sits on a revolving seat placed over the cap covering the communication with the lower stories, and here there is an amendment required,—this opening not being in the centre of the tower, but over the second circular casemate.

Referring to the gun-carriage—the block *d* runs in a groove in the platform about 8 or 9 inches deep, the small wheels running on the surface. The platform is 9 feet wide, and in front a circular space has been left, wherein are piled the shot for each gun. The parapets are not revetted on their interior, but the earth is sloped off.

These towers have temporary coverings of wood, which can be easily removed in case of necessity and as easily replaced. These are necessary to protect the platforms, gun-carriages, and floor, which if exposed to wet would soon decay; and also to prevent the deck being swamped by heavy rains, which would inevitably be the case were there no roof, as there are no drains or channels to convey away the water.

The accommodations for a complete garrison of 300 men, though confined, would be well ventilated and lighted, and the arrangements in the interior are very complete; but, except in the case of an actual attack, the greater part of

the troops might be encamped in the rear of each tower, which would obviate all difficulties.

This system of intrenched camps is becoming very general both in Germany and France, in preference to fortified towns surrounded by an enceinte of bastions and curtains. Vauban and Cormontaigne, and others of that school, appear no longer to be considered as authors equal to the emergencies of the modern system of warfare; and with the example of the greatest military nations of the Continent before our eyes, would it not be well for us to consider seriously that we, like them, have extensive frontiers to be watched and defended in Canada and India, and whether security can be afforded on a more efficient or cheaper plan than that so ably followed out at Lintz?

T. K. S.

NOTE TO PAGE 36.

The lines thrown up in rear of Chelmsford in 1803, under authority of the "Defence Act," were of a connected trace, and almost of a semicircular contour, the chord of which, extending from the hexagonal fort on Gallywood Common, on the extreme right, to the Star Redoubt at Widford, on the extreme left, measured two miles.

NOTE TO PAGE 39.

It is stated by a French author that Napoleon on his advance into Belgium in June, 1815, was deterred from marching a column of his army by the road of Mons from apprehension of the resistance and delay it might encounter from a field-work which had been thrown up on Mount Palisel, to command the approach from Maubeuge, by the British Engineers under Lieutenant-Colonel Carmichael Smyth, a few weeks previously.

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