THE ROYAL ENGINEERS JOURNAL JUNE 1975 VOL 89 No 2

THE ROYAL ENGINEERS JOURNAL

Volume 89 **JUNE 1975** **No. 2**

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THE ROYAL ENGINEERS JOURNAL

Published Quarterly by The Institution of Royal Engineers, Chatham, Kent ME4 4UG. Telephone Medway (0634) 42669

Printed by W & J Mackay Ltd, Lordswood, Chatham, Kent ME5 8TD

Volume 89 JUNE 1975 No. 2

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Authors alone are responsible for the statements made and the opinions expressed in their papers

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Editorial

ONE SHOULD NEVER UNDER-RATE INSTINCT

As the deadline for the copy to the printers draws near, the Editor of a Journal begins to worry. The brilliant editorials, written well before the deadline, seem to look very ordinary, are no longer topical and, on reflection, should never have been written in the first place!

In this *Journal* the editorial is normally a one page, 560 word, item which is intended to introduce the reader to the articles which follow and/or to make the readers think! This is never easy. The Editor hopes for inspiration, an idea, anything! An old hand once said: "If you are in real trouble, write down an opening and an end then all you have to do is to fill in between and think of a lead title."

The dictionary used by the Editor, it is never far from his left hand, defines *instinct* as: "inborn impulse or propensity, unconscious skill".

This issue of the *Journal*, the second of our Centenary Year, has balance of engineer interests and it deals with the past, present and future. Yet instinct tells me that a number of Members will look at it quickly and never open it again. It is for this reason that I would draw your attention to two articles in particular, not to single them out as better articles than the others, but because they are more likely to be passed over and both are significant contributions to our education as engineers.

"The Structural Assessment of Buildings Subject to Bomb Damage" deals with an important subject in easily understood and practical terms. It does use some "trade terms" but the meanings can be deduced. Any engineer worthy of the name should be capable of assessing damage and making safe by providing "first aid". Repair or rebuilding is a separate problem and has been omitted from the article. The author presented this paper to a "packed house" at the Joint Regional Meeting of the Institutions of Royal Engineers and Structural Engineers in Bradford on 19 February 1975. The interest and enthusiasm shown at the Meeting made the publication of the full text an absolute must.

"Realistic Training—A Contradiction in Terms?" develops the theme of the 1974 Cooper's Hill War Memorial Prize Essay. The development is based on, but is not a selection of, the views expressed in the essays. The author sets the scene in vivid terms, examines the current limitations and suggests some very practical ways of moving towards greater realism.

Part II of "Our Arctic Campaigns" (Part I appeared in December), was to have been published in this issue but has been held back until September because of lack of space. Instinct tells me that this announcement might reduce the "complaints" letters!

Instinct told me that the two articles in the March issue on the reorganization of the Engineers in BAOR would start an exciting battle of words. The opening shots are published in this issue.

In 1975 we also celebrate another Centenary in the Corps, the winning of the FA Cup by the RE Football Club in 1875. It is fitting, therefore, to include a Soccer story to end the 560 words. During WW2 an international full back of the "old school" intercepted a pass and moved forward with the ball. No-one tackled him and he found himself in front of goal. Never before had he been in such a situation—he didn't know what to do! Instinctively he passed the ball back as if to his goalkeeper, a classic full back ploy. An inside-forward following up volleyed the ball into the net.

One should never under-rate instinct. That would make a good lead title!

Realistic Training—A Contradiction in Terms?

COLONEL C J ROUGIER, BA

"The realities of the environment in which the Army has to operate are only too obvious in war, and in counter-subversive campaigns such as Northern Ireland. The role of the Sapper in modifying that environment to our own advantage is then clearly understood by all Arms.

"In peace-time training this does not apply. Indeed, it often becomes convenient to turn a blind eye to the realities of war; exercises, for example, are more fun if no impediments to mobility are imposed. The onus is on the Sapper to educate his fellow soldiers on the probable battlefield environment if only because he must play the major part in dealing with it when the time comes.

"How should this problem be faced in peace-time training?"

BACKGROUND

THIS was the subject of the 1974 Cooper's Hill War Memorial Prize Essay. When the CCRE said how nice it would be to have two essays from each division, and the CRE said he'd be delighted to receive three essays per regiment, I carried on the logical process and told all my subalterns to have a go! It was, I suppose, poetic justice therefore that on the day I gave up command, a letter from the Deputy Engineer-in-Chief arrived, pointing out in the nicest possible way that I was just about to embark on three months gardening leave, and would I write an article for the *Journal* summarizing the views contained in the fifteen essays entered for the prize.

On reading the essays I found that the writers, like my own subalterns, had concentrated more on discussing how to keep the Sapper in the Army Eye rather than on how to educate his fellow soldiers on the probable battlefield environment. Nor do I blame them, for there is little doubt that just as the Army is forgotten by the Nation in peace-time, so are the Sappers forgotten by the Army in BAOR. So, to define the problem more clearly, perhaps a few lines of scene-setting would be in order.

SCENE-SETTING

Training

It is November 1974. A cavalry subaltern is describing to his brother officers in the Mess his part in the counter-attack on Bispingen ridge during the autumn FTX.

"At the 'O' Group my squadron leader gave us our orders for the regimental counter-attack on to Bispingen ridge. For the move round we were the lead squadron, and my troop the lead troop. We'd been in reserve for the first two phases and were longing for something to do. This was our chance. The route was a piece of cake; bash down the main road through Bispingen village, over the stream and into the wood (which was held by the infantry), where we'd form up for the attack. From there it's a gentle canter on to the ridge.

"Well, it all went swimmingly until we approached the bridge in Bispingen village and I suddenly saw it—a landrover with a white pennant on the radio aerial and a cold and miserable looking Sapper officer standing by it. 'Blast!' I thought, 'that's done it—he's sure to say the bridge is blown. I'll try the one at the north end of the village.' My luck was in—there was no-one there—only a Sapper corporal. 'Oi', he said, as we roared across, 'this bridge is blown.' 'That's OK', I said, patting my life jacket dangling on the side of the turret, 'I'm snorkelling.' 'But our tanks can't snorkel.' 'That's what you think', and we were away up the road and into the wood.

"Whilst waiting for the rest of the Regiment to come up, I scanned the ground ahead. It was a lovely clear day and one could see right up to the objective. Nothing; or was that a thin strand of wire crossing our front just short of our objective? Yes, it was. I told my squadron leader—he got on to the radio. 'Hello 9, this is 29. There's a minefield ahead of us. I think I can get round to the right of it. Do you want me to try? Over.' '9 no, I say again no. Our Sunray said he wanted a fast moving, hard hitting attack and that's what we're going to give him. Push on. Out.'

"We pushed on. At the edge of the minefield, a Sapper sergeant leapt out of a bush and waved at me. I thought I'd humour him. 'Ullo, ullo, ullo', I said, doing my impersonation of a policeman, 'what have we got here?' 'This, sir, is a minefield, and you can't go through it!' He was rather pompous. 'Oh come on, Staff, the Commander's watching this attack from the ridge and my Colonel has told us to push on and—er—that's what I've got to do.' 'Sorry, sir. CRE's orders. No-one can drive through the minefield.' I looked round. Half the squadron were already in the minefield, some of them through. 'Well, Staff, if this is a minefield, which it isn't, I'm a helicopter, which I'm not. Driver, advance', and we were off. I looked back. The sergeant was leaping up and down with rage. 'Take care', I yelled back at him, 'or you'll set off a mine!'

"I reached our objective. The Brigade Commander was there, rubbing his hands with glee. 'Splendid', he said, 'splendid. Mobility, that's what I like to see; mobility and dash.'

Reality

It is November 197?. A cavalry subaltern is describing his part in the counter-attack on Bispingen ridge during the recent operations to his fellow officers in the prisoner-of-war camp.

"I suppose I'm lucky to be alive really. Half the Regiment was destroyed and most of the others captured. The thing was a disaster from the word 'go'—and yet it should have been all right. We'd practised enough, and on the same bit of ground, only a year or two ago. Somehow it wasn't the same as it was then.

"Anyhow, at the 'O' Group my squadron leader gave us our orders for the regimental counter-attack on to Bispingen ridge. We were the lead squadron, and my troop the lead troop. We'd been in reserve for the first couple of days and this was to be the first British counter-attack of the war. The Colonel came up. 'I'll get the recce troop to lead you round, Richard.' 'Don't worry, Colonel', I said confidently, 'I know the way like the back of my hand.'

"We set off down the road to Bispingen and almost immediately the first problem hit us—refugees. There were hundreds of them, some with cars, some pulling farm carts piled high with their belongings, some leading animals. I shouted at them to get out of the way, but it made no difference. 'Push on', said the Colonel. We pushed on as best we could and were gathering speed when suddenly my troop corporal in the lead tank disappeared completely. 'God, what's up?' 'He's gone into a crater.' Sure enough, there he was in a bloody great hole, with his track off and his gun sticking forlornly into the ground. 'Push on', said the Colonel. I told my troop sergeant to work round the left side of the crater and back on to the road; I went round the right. Suddenly there was a hell of a bang and his tank caught fire—figures running in all directions. A mine on the edge of the crater probably. We went wide to the right and back on to the road.

"We were now approaching Bispingen village and it didn't take much intelligence to see that we weren't going to get through it. The place was a shambles; telegraph posts and lines lay across the road, buildings had disintegrated into piles of rubble and twisted reinforcement, some were on fire. You couldn't see the road at all. A few people were wandering around in a dazed sort of way and someone was crying from under a pile of rubble. A thick pall of smoke came from the direction of the BP garage. I started to work my way round the edge of the village towards the bridge—there it was just visible through the smoke. A tremendous explosion—masonry and mud flying through the air and it was gone, followed shortly by one at the north end of the village. Saboteurs? Sappers? It didn't make any difference;

there was no bridge now. How deep was the stream? I didn't know, but it was our only hope and I made for it. That too was a disaster as someone had dammed it or a water main had burst or something and the ground on either side was flooded. The first tanks got bogged immediately and the rest of us juddered to a halt. With all this rubble around and some Sappers, perhaps they could make a route across or build a bridge or something—yes, what about a Chieftain bridgelayer? I asked on the radio for Sappers—there aren't any with us. A noise suddenly drowned the roar of the tank engine, there was a dull thud, a flash and the tank on my right quivered, shook and burst into flames. I looked up to see a MIG 22 climbing away; behind, three more were diving towards us. 'Push on', said the Colonel.

"We got over the stream eventually (thanks to a Chieftain bridgelayer in the end), but by this time we were two hours behind our planned time and had lost five or six tanks. Everyone from the Corps Commander downwards was apparently telling us to push on or we'd be too late. We climbed up the slope out of the mud and dirt and into the safety of the wood.

"Or so I thought. But it was soon clear that the wood was not a happy place in which to be. As we neared the centre I saw the track ahead blocked by fallen trees and branches—it reminded me of the storm damage in BAOR in 1972. The infantry holding the wood had clearly been shelled to hell. There were three tanks behind me. Turn round—we couldn't—back up. Suddenly a whine and a crump—I ducked inside the cupola and shut it. Shelling. I wondered what it would be like. On TEWTS the Gunners always said they could knock out tanks, and we always said they couldn't. Now we'd see. My driver backed into a tree. The tank shuddered as a shell landed nearby. I looked through the periscope but the front prism had shattered. The radio wasn't working either—probably lost the aerial—must get out of this wood.

"It took us an hour to extricate ourselves. I worked my way round the side of the wood ready to start the attack. I looked at the ground ahead but could see little. The woods around us were still being shelled sporadically and ahead of us a couple of tanks were burning. The smoke and dust, coupled with the autumn mists that normally hang over the North German Plain made it difficult to see anything. I looked around. We had about twenty tanks and a few of the infantry who were attacking with us. It was clear that a complete squadron was adrift somewhere; hardly surprising under these conditions. It would be getting dark soon. The omens were not good. 'Push on', said the Colonel.

"We left the wood and moved towards our objective in battle formation. We were moving fast now and would make a difficult target for an enemy tank gunner. This was more like it. I felt a sudden surge of exhilaration as I saw the other tanks on my flanks and behind me; all of us bumping and pitching towards our objective. Suddenly an explosion over on the left and a tank slewed to a halt, with smoke pouring out of it—another next door door to me. What was this—a minefield, I suppose. The infantry were out of their APCs and on their feet now. Another explosion, this time on a turret and the gun bent and distorted—anti-tank fire at a guess. Then the sound of a thousand drums beating inside my head. I was thrown against the cupola, round the turret and sucked on to the floor. I lay there, all the breath squeezed out of me. My legs wouldn't work. It was hot—very hot—flames, smoke—must get out. Somehow I dragged myself up and out through the hatch and fell to the ground. I lost consciousness.

"It was at about this time, I subsequently learnt, that the chemical attack started."

INTRODUCTION

It seems rather late in the day for an introduction, but perhaps the two scenes depicted above, however exaggerated and tactically inaccurate they may be, give some measure of the gap between the autumn FTX and the probable battlefield environment. The problem is how to reduce that gap.

This article briefly examines the limitations placed on peace-time training and then suggests ways in which such training could be made more closely to resemble the probable battlefield environment. With the precedent of the essay writers before me, I will occasionally stray from the straight and narrow to ride a few hobby horses!

LIMITATIONS TO REALISM

The main limitations to realism in training are peace-time restrictions, safety, and finance. They are so obvious that they almost speak for themselves. *Peace-time restrictions* because not even the Germans—who are a good deal less restrictive about training rights than we are in the United Kingdom—appreciate roads being cratered and buildings and woods demolished, let alone river banks being dozed in. Less serious restrictions, such as the need to clear river crossings or bridge sites with the authorities seven weeks in advance also limit realism, in that exercises have to be manipulated so that the right river is crossed at the right place at the right time, which naturally removes any spontaneity from the proceedings. *Safety* because quite understandably the risks of war are not acceptable in peace. And *finance*, not only because any damage done on exercises has to be paid for, but also because any significant improvement in realism is likely to be costly.

These three limitations are almost sufficient to sound the death knell for any bright idea aimed at improving realism in training. There are, however, two other hurdles that stand in the way. The first is that to make an exercise realistic takes an inordinate, perhaps disproportionate, amount of time both in the planning and execution. Dress up men and women as refugees, make up men as casualties, pre-position a Chieftain that needs a pack lift—they can all be done, but at a price in both time and precious manpower.

The second hurdle is the "Battling Brigadier" syndrome. The Brigade—or possibly Divisional—FTX is the exercise high point of the year. The Brigade Commander wishes it to be a success and to be judged so by those taking part. This it will not be if they sit around waiting for the Sappers to breach a minefield, fill a crater or build a bridge. Thus, as the subject of the essay suggests, the realities of war are forgotten and few impediments to mobility are imposed. The result is a fast moving and exciting exercise which everyone enjoys. Who can blame the Battling Brigadier? But is it realistic training? Somewhere, somehow, there should lurk a British compromise as a solution to the problem.

TOWARDS GREATER REALISM

Two-Pronged Attack

Educating one's fellow soldiers on the probable battlefield environment needs to be a two-pronged attack. One prong is demonstrating what it will be like, the other is making training more realistic. There are a number of ways in which both attacks can be strengthened.

Demonstrating the Battlefield Environment

Films have frequently and successfully been used to demonstrate the battlefield environment by showing scenes from the last war. Perhaps it was time that a training film was made, in glorious technicolour, illustrating what to expect in a more modern and realistic manner.

Demonstrations, too, have their place and I imagine every regiment has arranged a demonstration on the role of the Sappers for its affiliated brigade. I wonder how many, however, have shown the effects of a barmine on a tank (which can be done on the tank hulls on Munsterlager Range, for example), have demonstrated a cutting charge on steel, blowing a crater, and have allowed an armoured regiment to drive through a minefield (there are now smoke inserts for the barmine as well as the Mark 7). Such practical demonstrations make a greater impression than any amount of talk or film.

A rather more costly suggestion is the use of a simulator. They have been used for years to teach pilots to fly and could realistically be used to teach drivers to drive in the conditions likely to be found on the battlefield. Most of the scenes in the situation described earlier could be simulated, together with sounds—and even smells! The commander and driver would have to take the correct action to extricate themselves from trouble, whilst enemy targets could be introduced to keep the gunner busy. The same simulator could be used for almost any vehicle, be it Chieftain, FV 432, Scorpion or 4 tonne.

Umpiring

Anyone who has attempted to stop a tank or even an APC crossing over a bridge or through a minefield will realize what a fruitless task it is. No matter how senior an umpire is, how well briefed, how determined to paint a realistic picture of the devastation surrounding him, he is not well placed to argue with the fifty odd tons of steel approaching him at 20 mph. It is possible that the tide will turn in the tank versus umpire battle with the introduction of Simfire. An umpire's gun can now be used by an umpire overlooking a minefield or a bridge which had been "destroyed" physically to immobilize any tank which enter the minefield or cross the bridge. At a stroke Simfire may strike a blow for realism—and for the Sappers!

Battle Simulation

Battle simulation is a laborious but valuable and comparatively cheap way of increasing realism on the training battlefield, but has the disadvantage that it is repetitious, boring, and of little training value for the sappers who do it. It also takes them away from their proper task in support of the formation or unit with which they are training. A possible solution might be the formation of a UK and a BAOR Battle Simulation Team to be responsible for all Sapper bangs in exercises from troop/platoon upwards. Such a team might consist of a QMSI and six sappers. Having offered up one of my own QMSIs in the hope that Assault Pioneers in BAOR could be centrally trained (but that's another story), I am at a loss to know where such a team would come from. It could, however, provide a dramatic improvement in realism at all levels, at minimum cost both financially and to the Corps, whilst at the same time preventing the misemployment of Sapper troops during exercises.

Suffield

The Suffield Training Area in Canada provides a unique opportunity to reproduce the conditions of the battlefield environment. One would hope that if Sappers were not actually employed in producing those conditions, they would at least be in demand in maintaining the mobility of the battle group in such an environment. And yet, sadly, this does not seem to be the case. The almost total sum of their work, certainly in 1974, consisted of breaching minefields by hand—six times—some by day and some ("I'm going to bed now; make sure you've breached that minefield by the time I get up"), by night.

The problem is, of course, well known and most of the solutions are costly. There is a real danger, however, that unless Sappers at Suffield have the same freedom to "do their thing" as do other arms, we will become the Cinderella of the teeth arms and the vital part that we have to play on the battlefield will be forgotten until it is too late.

The emphasis on hand breaching of minefields at Suffield is also unfortunate in that it is an operation which shows up the Sappers in the worst possible light—slow, ponderous and old-fashioned. It is to minefield breaching that the Battling Brigadier is likely to take the greatest exception. If it is going to ruin his exercise, might it not also ruin his operation? Is it conceivable that he is right and we are wrong? Do we breach too slowly? Should we hand breach at all? It bears thinking about.

Minefield Breaching

It is hardly surprising that since the last war emphasis has been placed on the laying of minefields rather than their lifting. The drills that we use for the latter at present were developed from those used to breach the minefields at El Alamein. And yet one must seriously question whether any potential enemy is going to have the time or inclination to lay minefields of that size. One must question whether we will ever be able to accept the delay that hand breaching imposes and, above all, one must question whether, with modern surveillance devices, a hand breaching party would have any chance whatsoever of completing its task without being detected and destroyed.

I would suggest that in minefield breaching we need to be able to do two things; first, to lift our own mines when out of contact with the enemy (for example for a counter-attack, the route of which must pass through our own minefield), and secondly, rapidly to breach an enemy minefield. For lifting our own minefields, when their design and location are known, we ought to be able to develop a simpler and faster drill than we have at present. For breaching an enemy minefield we must rely on Giant Viper, for at present it is that or nothing.

Surely the time has come to accept that hand breaching of an enemy minefield under observed fire is no longer an operation of war?

Battle Group Training

Shortly after units from BAOR first started their annual pilgrimage to Northern Ireland, excellent facilities were built to reproduce the sights and sounds of the Ulster battlefield. It is perhaps surprising that after almost thirty years no such facilities exist for reproducing the BAOR battlefield environment. And yet most training areas are as near to a blasted heath as anywhere on this earth. How much effort would it take to simulate a battlefield environment?

Imagine yourself as part of an all arms battle group. It, like all other battle groups in BAOR (or in NORTHAG), is about to take part in the annual "Battle Group Battle Run" competition. The course stretches out in front of you, across the training area for ten miles. This year it is an "Advance" course—last year it was "Mobile Defence". The course has been constructed over the last few weeks and none of you know what hazards you will meet.

You set off. The armour opens fire almost immediately at enemy recce vehicles in the edge of a wood (none of the enemy targets are, of course, real). A concentration of enemy tanks is reported some miles ahead by a Phantom returning from a sortie. A Harrier is tasked, and will be controlled by the Secondary FAC. Some heavy cratering requires plant assistance before the A1 echelon can get forward; the Sappers set to work. The Battle Group continues its advance. Enemy infantry are spotted ahead. An attack is mounted with fire support from the Gunners and tanks. Meanwhile the Sappers are building an MGB over a stream to get the wheels forward. Two tanks are damaged and there are some casualties—they must be dealt with. It is getting dark and the Battle Group is told to consolidate and prepare for an enemy attack. Infantry and tanks must be dug in and routes need to be cleared through the wood just behind you. Sappers and Assault Pioneers work together to surface lay a minefield to give some protection in the short time available. The armoured attack comes in just after first light. Swingfire opens fire, followed by tank guns, Vigilant and anti-tank weapons. The attack is beaten off, you have been at it for eighteen hours and the battle run ends.

It may be a fanciful suggestion, but there *are* ranges in Germany where such a battle run could be laid out and where live firing could take place against hard targets. Too like Suffield perhaps, but then the Suffield month comes round all too seldom and finance severely restricts the amount of equipment available there. A competition of this sort would undoubtedly encourage inter-arms co-operation and battlefield efficiency. The real problems of the battlefield environment could be more realistically portrayed; so many and varied are they that different ones could be highlighted each year.

Formation Exercises

And so we come back to the Battling Brigadier, struggling to produce a formation exercise which will be realistic as well as fun. He has sensibly sent for you, his affiliated engineer regimental commander, early in the planning stages to discuss the problems with you.

"I realize of course", he says, "that I cannot write a totally realistic exercise reproducing the environment of the battlefield whilst driving across the villages of Northern Germany. However, the new battlefield environment film, the simulator, more realistic exercise play at Suffield and the Battle Group Battle Run Competition have gone some way towards giving soldiers the feel of the battlefield. Within the obvious limitations of peace-time soldiering, I want to write a fast moving but realistic exercise for the Brigade. My problem is that every time I try to introduce some sappering, it bogs down everyone else—almost literally! Mine laying, mine clearing, bridge building, not to mention those monster machines you use for shifting muck about the place—I'm not going to have you sappers ruining MY exercise! However, there is one worthwhile task I'd like you to do. I thought we could use your Regiment to produce some really good Sapper bangs to add a spot of realism to the whole affair."

You take a deep breath. "Much as I like your idea, Brigadier" (the tactful approach), "we now have an SBT (Sapper Bangs Team), who will be able to give you all the realism you need, including smoke and even a nuclear if you want it. Quite honestly, if the Sapper planning advances hand in hand with your operational planning, I see no reason whatsoever why we shouldn't play a proper part in your exercise without ruining it. Let's take your points one by one. First, minelaying. You're right, it is a slow and tedious business and very often does not fit in with the time frame of an FTX. However, there is a practical alternative. The Divisional CPX is to be held next April. The first few days will be spent in exercising the staff in the mobilization procedure and this time frame is ideally suited to minelaying. Why don't you suggest to the GOC that the CPX should be an FTX for the Sappers? I know that 1st Division did this in 1973 and it worked well. If you want to put some minelaying into your exercise, however, it can still be done without holding everything up if it's properly planned. The umpiring can be left to the Simfire team with their Umpire Gun who will police the minefields (and demolitions), much more economically and efficiently than in the past. Next, mine breaching. Well, we don't do it by hand any more—or not enemy minefields anyway. Using the Viper it is a much speedier operation and one which, as you well know, requires the proper co-ordination of all arms at Brigade level, so I think everyone will be busy then. Bridge building—well, we can slap an MGB over all but the largest rivers in a couple of hours so there should be little delay. If you don't like that, you can always get your armour across using a Chieftain Bridgelayer and get us to build an MGB for the Brigade wheels. Likewise, there is no reason why plant work should hold up the exercise. I see that you plan to cross a training area—we could blow some craters and let the tanks find their own way round whilst the Sappers produce a route for the wheels. There are plenty of other tasks that you can give us which will add realism to the exercise without inhibiting it—an M2 crossing of the Weser, Harrier pads, water points, nuclear decontamination centres . . ."

"Good God! Steady on!", says the Brigadier, horrified at the mention of nuclear decontamination centres, "But I take your point. With good planning and forethought, Sappers can play their true part in exercises and, more important, can add to the realism of the battlefield environment without bringing the whole thing to a grinding halt. OK, we'll give it a try."

Let's hope he does.

* * * * *

Some Uses of Glass Fibre Reinforced Cement

CAPTAIN D R SUMMERS, RE, BSc

INTRODUCTION

In Vol LXXXVII June 1973 of the *Royal Engineers Journal*, Major C Spottiswoode, RE, BSc, MICE, AMBIM, gave an account of how glass fibre reinforced cement was successfully employed as a bullet proofing material against small arms fire. The tests did show, however, that GRC has potential in other fields. Research was initiated at the Royal Military College of Science, Shrivenham, to look into some civil engineering applications of this medium.

BACKGROUND

Plain concrete will lack tensile strength and will probably crack if reinforcement is not incorporated. Steel reinforcement is normally used, but this is expensive and in short supply, furthermore it is costly and time consuming to bend and fix.

Formwork is another item which increases the complexity and expense of concrete work, it takes time to set up and it has to remain in position for several

Photo 1. The spraying rig and vacuum mould.

Some Uses Of Glass Fibre Reinforced Cement (1).

days until the concrete has cured sufficiently. The re-erection of wooden shuttering reduces its useful life.

There is a need for a new method whereby shelters can be rapidly constructed. At present the construction of concrete-block sangars, for example, is governed by the speed of a skilled bricklayer. The use of glass fibre reinforced cement, GRC, can simplify, speed up and therefore reduce costs in many areas of concrete construction.

AIM

The aim of this article is to describe the manufacture and some of the uses of GRC.

MANUFACTURE

Continuous glass fibres are chopped into lengths of about 25 mm and are introduced into a cement based matrix by means of a patented gun. A convenient matrix consists of 1:1:2 of fine sand, pulverized fuel ash and ordinary Portland cement. A special type of glass fibre can be used to minimize the effects of alkali attack. Water is then added to produce a smooth, creamy slurry. The spraying rig and vacuum mould are shown in photo 1.

With this set-up, a skin of GRC from 5mm to 10 mm thick can be produced. If a sheet is required, the GRC is sprayed in layers on to a vacuum mould, and the vacuum is then applied to remove any free water. After the mould has been inverted and the vacuum released, the GRC mat drops free and can be moulded by hand into the required shape. At this stage, the GRC has the consistency of a wet blanket and will remain pliable for about half an hour. An alternative method of application is to spray directly on to other absorbent materials, for example, breeze-block walls. This produces a rendering which binds the blocks together and forms a semi-permeable covering.

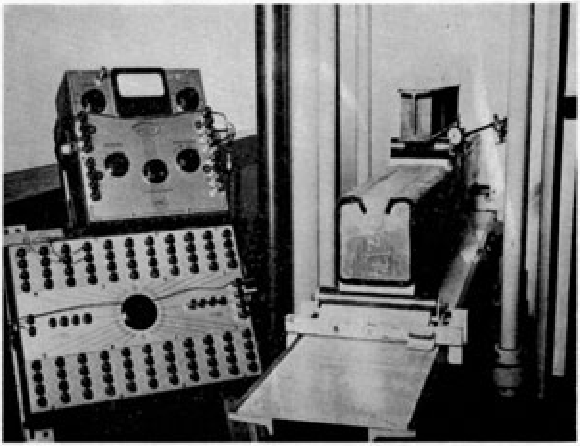


Photo 2. A composite beam of GRC and plain concrete.

Some Uses Of Glass Fibre Reinforced Cement (2).

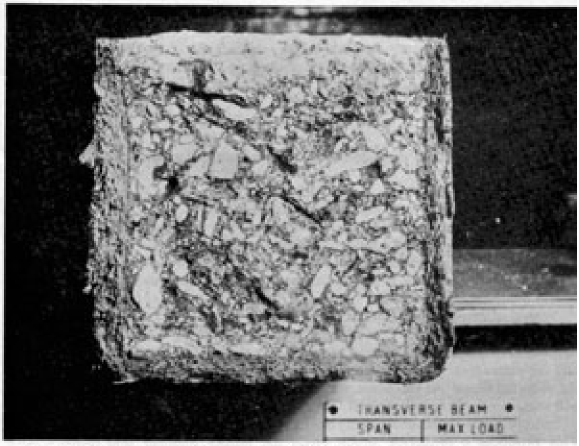


Photo 3. Fracture plane of channel section GRC and plain concrete composite beam.

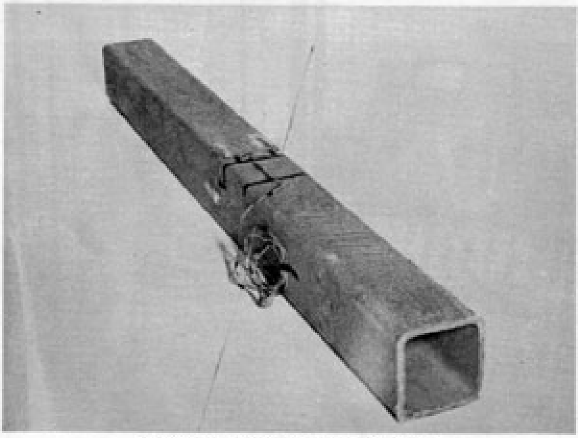


Photo 4. GRC hollow box section for columns.

Some Uses Of Glass Fibre Reinforced Cement (3 &4).

PERMANENT FORMWORK

The suitability of this medium for the manufacture of permanent formwork was investigated by casting channels of rectangular cross-section out of GRC, and after they had cured, they were simply supported and filled with plain concrete. When the concrete had cured for fourteen days, the beams were tested to destruction by the gradual increase of a central load. The channel was made by draping a GRC mat over a wooden former, which was removed after a few days. The early channels were made with a lip to ensure a good bond between the GRC and the concrete, as shown in photo 2.

This, however, proved to be unnecessary as there was no bond failure, even at the plane of fracture, with simple U-channels. (Photo 3)

Tests which were carried out on permanent shuttering filled with plain concrete showed that a beam 165 mm (6½ in) square would support foot traffic over 2 m spans. The yield load was 7 kN (¾ ton).

Hollow box sections were made by pressing together the edges of the mat after a U-channel had been formed. (Photo 4)

This type of formwork would be ideal for columns in structures. Unfortunately it was not possibly to carry out tests to compare the properties when filled with plain or reinforced concrete.

RENDERING

In order to build quickly a strong wall using non-skilled labour, it is only necessary to stack sandbags, bricks, breeze or concrete blocks into the required shape without mortar, and then to spray both sides with GRC from a pump which could be mounted on a ¾ ton vehicle. The skin locks the blocks together in a few hours. Tests were done on a section of wall which consisted of three standard breeze-blocks, held together by a 5 mm skin of GRC on both sides. (Photo 5)

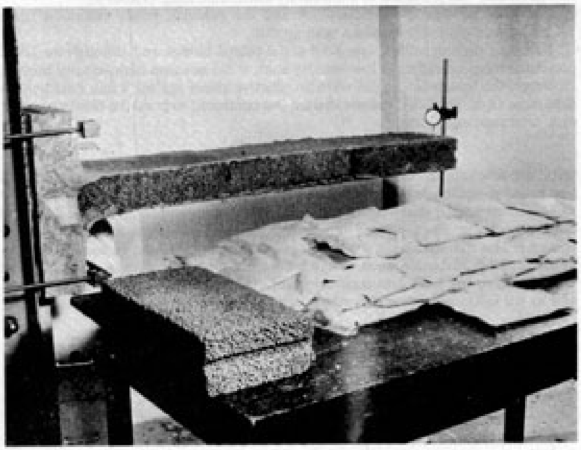


Photo 5. "Breeze block" beam.

Some Uses Of Glass Fibre Reinforced Cement (5).

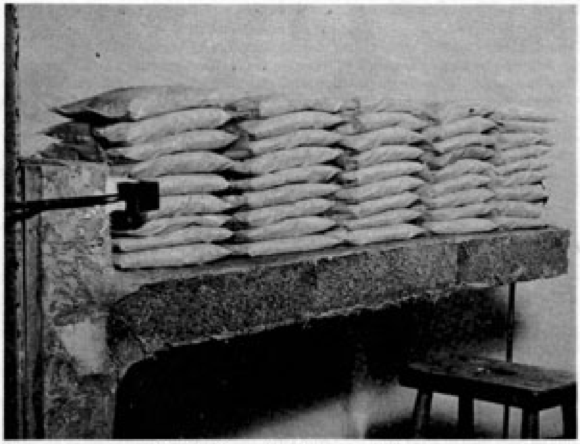


Photo 6. "Breeze block" beam under load.

The blocks were sprayed in the vertical position, and GRC was used to attach them to a concrete base. The whole structure was turned through 90 degrees after two days, and was subjected to a uniformly distributed load. (Photo 6)

The joint between the breeze-block and the concrete finally fractured when 1.4 N/mm run (96 lbs/ft run) had been applied.

Bullets of varying calibre were fired at the coated blocks, and although the GRC prevented the penetration of low velocity shot, it did not stop high velocity rounds. However, the breeze-blocks did form an effective shield against 9 mm ammunition fired from 15 m. The GRC did not shatter, but continued to bond the blocks together even after repeated firing.

CONCLUSION

GRC will revolutionize certain aspects of the construction industry. This is especially true in the manufacture of concrete columns, as permanent formwork for beams and soffits and as special cladding for walls. GRC is able to withstand intense heat and does not shatter when pierced by either hammers or bullets, as does ordinary concrete. This material is unsuitable for bullet proofing, but can be used to contain bullet proofing materials, such as sand, concrete blocks or man-made fibres. The GRC fibres spring back into their original position after the passage of the bullet, and so the GRC is, to a certain extent, self sealing.

* * * * *

Construction of Tai Ling Rifle Range April 1973-January 1974

MAJOR D H G CORSELLIS, RE, B.Sc

INTRODUCTION

THIS is the story of a project which, certainly in its initial stages, was a classic example of how an engineering project should *not* be organized. It later developed into a very challenging engineering task which, over a period of nine months, fully employed two field troops and at times the whole of 67 Gurkha Field Squadron. Furthermore the project was completed on time and well within its financial budget.

This article is not a detailed engineer report on the project. It is merely aimed at giving a general description of the project, and bringing out the lessons learnt.

As far as we can find out, this is the first new gallery range to have been built entirely by British military engineers since the Second World War.

A project report has been written by the Project Officer, Captain C A Lowe, RE, BSc.

BACKGROUND

The increasing urbanization and development of Hong Kong and the New Territories, have reduced the number of rifle ranges available to the Garrison. To make matters worse, in early 1974, one of the existing ranges was due to be closed for at least six months for conversion to ETR. And this all at a time when marksmanship was the most important training objective in the Army. In late 1972 therefore, the Deputy Commander Land Forces gave the highest priority to the construction of a new 300 yd rifle range, somewhere in the Colony, to be completed by February 1974.

After a great deal of reconnaissance by the Training Staff, Small Arms experts, and Hong Kong Government agencies, a site was chosen alongside the existing 600 yd range, at San Wai in the New Territories.

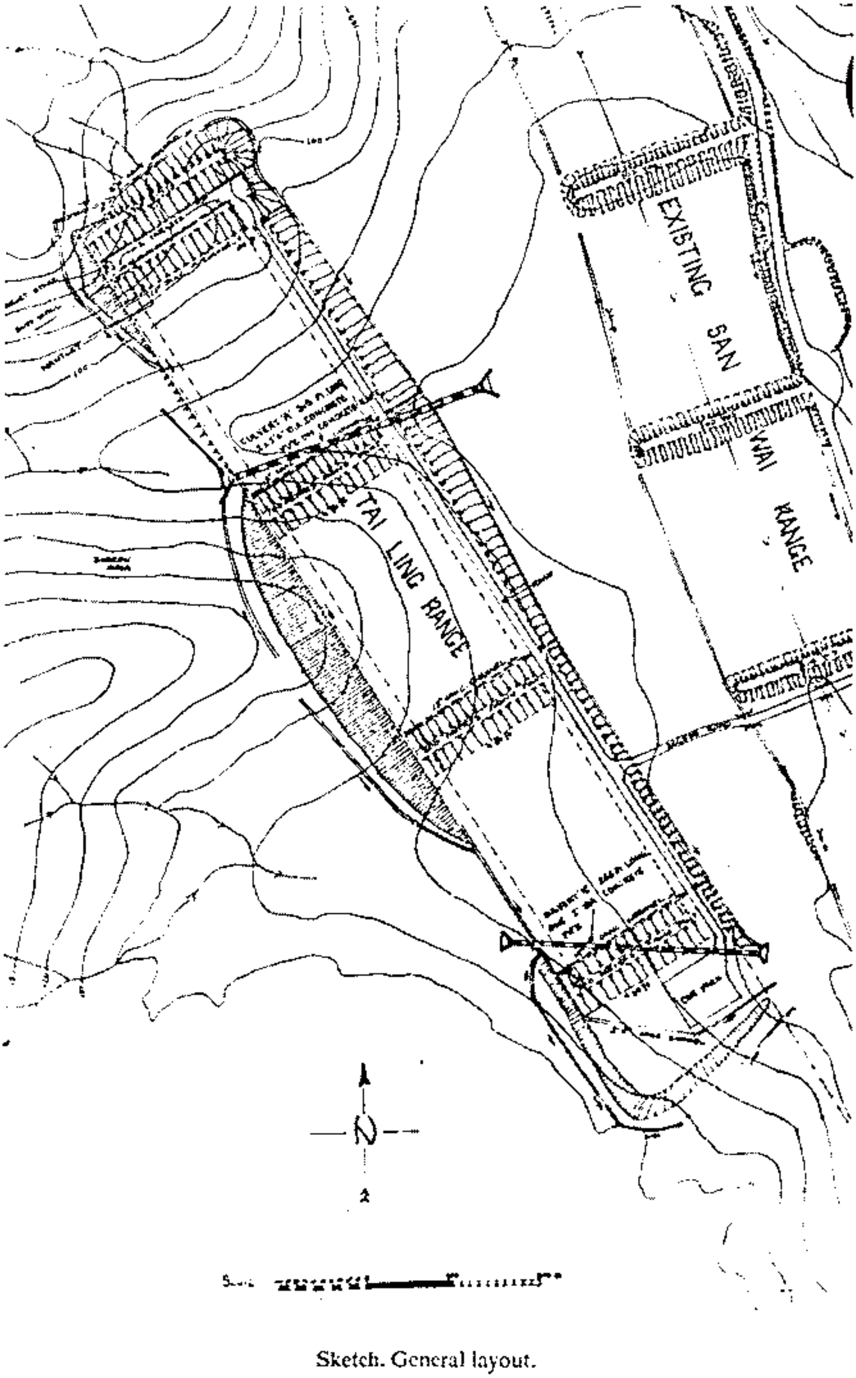
Initially it had been intended that the range should be constructed by PWD, but it had been agreed in principle that military engineers would assist with the earthworks. PWD have great difficulty in finding contractors to work in the New Territories, and in this case, the proximity of another active range was a further discouragement to them. By March 1973 it became clear that PWD would be unable to meet the deadline, and the whole project was handed to the CRE, Lieut-Col J H Edwards, RE, BSc.

PRELIMINARIES

The requirement was for a 300 yd, 12 target, conventional gallery range. £79,000 was available, based on the original plan for military engineer earthworks and PWD construction, but final MOD approval for the expenditure of this money had not been given. As the work was now to be done by military engineers, it seemed likely that money would not be a critical factor. In retrospect this was a major factor in enabling the Squadron to complete the project on time. While wastage had to be avoided we never had to skimp on materials or stores.

HQLF Hong Kong specified that the new range was to be designed so that any firing point on either range could be used without inhibiting firing on the other. Furthermore the existing range at San Wai must remain in use while the new range was being built. It was however accepted that there would be some interference with firing during construction. Our only vehicle access to the construction site, was along our construction road built behind the 300 yd firing point on the existing 600 yd range.

We had decided early on to site our batching area on some hardstanding on the



Sketch. General layout.

"wrong" side of the existing range. The main reason for this was that the sand and aggregate contractors' delivery vehicles could not cope with the sort of muddy conditions we expected on site, and we did not wish to double handle materials. We also had a ready supply of water at the site chosen. We were never short of plant during the whole project and delivery of concrete to site never became a serious problem, even when concreting was taking place simultaneously in three or four different places.

Infantry Training Manuals state that to meet the requirements specified by HQLF, the minimum arc of separation between ranges is 11°, provided the two stop butts are roughly in line, which in this case they were. The 11° arc from the 600 yd firing point of the existing range was the basic design criterion. We were unable to widen the arc of separation, as this would have increased the earthworks unnecessarily.

Throughout the project we had to take great care that our men, and also the various civilians who worked on the site at times, did not stray into the danger area between the ranges. This problem was of course particularly severe when firing took place from behind the 300 yd firing point on the existing range. It was essential to have close liaison with the units using the existing range and to some extent we had to dictate their firing plans. We were given priority over all, but very rarely had to use a big stick to make them do what we wanted.

The fact remains, that when the new batch of Gurkha recruits opened up from 600 yds with GPMG on their first shoot ever, we began to wonder whether 11° was enough! However we had no accidents and became used to the interminable "crack and thump".

The design of the range remained a PWD responsibility. This was partly a matter of politics, as they would have to maintain the range later on, and we did not want to run the risk of their refusing to take it over, because they did not like our design. PWD are not accustomed to working to tight deadlines, and we had constant trouble in extracting designs from them in time to start work on parts of the project. In some cases we could not agree with their designs, but we were usually able to make them change their minds. The level and slope of the range depended on the earthwork calculations, and the height of the hill behind the butts. To complete the job in time, we argued that cut and fill must be balanced as nearly as possible.

SITE INVESTIGATION

In taking on the task, the CRE had obtained agreement from the Staff, that if bedrock were struck, the project would certainly not be completed in time, and that the site should probably be reconsidered.

As OC 67 Squadron I was told to deploy a troop as soon as possible to drill for rock and carry out initial recces and survey. About a week later on 6 April 1973, C Troop, under command of Captain C A Lowe, who later became Project Officer, arrived on site to drill for rock. The only equipment available to us was a curious hydraulic powered earth auger which belonged to the Bomb Disposal equipment with 54 (Hong Kong) Support Squadron. This could drill to 30 or 40 ft provided it did not meet bed rock.

THE SITE

Photo 1 shows the virgin site looking down the range from where we thought one end of the stop butt would be. Photo 2 shows the range almost complete. It can be seen that the range was to be sited across the grain of the land, and that the earthworks must involve considerable cut and fill. We guessed initially that the maximum cut would probably be about 50 ft and we were not far out. The areas requiring filling were all disused paddy fields and very swampy. Most of the hills in Hong Kong are of decomposed granite, which varies from being really quite hard, to a terrible crumbling mess.

The Chinese have a habit of building graves in what to us seem unlikely places.

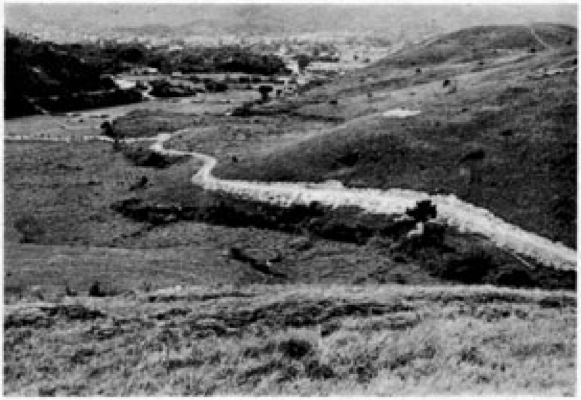


Photo 1. Almost virgin site.

To move these graves, especially when they are twenty or thirty years old, takes considerable time, negotiation and ultimately compensation. There were four graves on the edge of the probable area of the range, and we therefore immediately started the tortuous process of getting them moved.

EARLY STAGES

Using the borrowed drilling rig, C Troop with our MPF, SSgt Perkins, drilled ten boreholes down to about 30 ft, in a couple of weeks in places where we were bound to have cut. At no place was rock met.

It so happened that in early May there was no other major military earthmoving task in Hong Kong. We therefore had *carte blanche* in choosing what plant we wanted from the CRE's pool, held by the Support Squadron. Over a period of three weeks we built up a sizeable plant force for the Squadron to operate. Most of this plant was to remain with us until December 1973, when the earthworks were virtually complete. The major items we drew were:

2 Cat D8H Dozers	1 21/14 Mixer
2 Cat D6C Dozers	1 Grader 12 foot m/b
1 Cat D4C	1 Roller, Motorized 6 ton
1 Hymac	1 Roller Towed Grid 13½ ton

2 Dumpers ¾ cu yard

We also had numerous small items of plant and ECP and our own two Allis Chalmers and three Muirhills.

The summer in Hong Kong runs from May until September and this is the wettest time of the year. 1973 as it happened had the wettest summer on record, and between June and September 120 inches of rain fell. We then had no rain at all for nearly three months. Earthworks are normally avoided during the wet season in Hong Kong, but in this case we had no choice.

CULVERT A

Culvert A can be seen in the foreground of photo 2 and in the sketch. For various reasons we totally disagreed with the PWD design for this culvert. We redesigned it ourselves and subsequently after we had built it, the PWD accepted our design.

Construction Of Tai Ling Rifle Range

In May and early June the weather was quite dry and the plant party were able to bulldoze fill into the paddy area. An attempt was made to excavate the paddy in one place, to try to reach a firm base for the culvert, but having dug down 12 ft the ground was no better. It was decided to build the culvert, which was to be 315 ft long and consisted of two 2 ft 6 in spun concrete pipes, on a concrete raft which sat on a few feet of compacted fill on top of the paddy. Until this culvert was completed, no further plant work could be carried out. The rains came in late June and C troop, joined in June by A Troop, spent nearly two months working on this culvert and its associated head and wing walls and spillways, in appalling conditions of mud and heat.

During this depressing period, another blow struck. Because of the urgency of the project, we had started ordering stores before final approval for the money had been obtained from MOD. In early July, it suddenly seemed possible that we might not be allocated the necessary funds, and we were ordered not to buy any more materials. One troop was sent off to do ten days training on the medium girder bridge, as there was nothing to do on site. This was one more factor to confuse our planning, which was already based on too many unknowns. For example, during the construction of culvert A we did not know the final level of the range, and hence the depth of fill. We had to guess how long to make the culvert, and in fact made it a bit too long.

The Hymac proved to be of immense value in the construction of this and other culverts. It seldom bogged and its long reach enabled us to place the 3 ft long pipe sections with great ease.

CULVERT B

Culvert B's location can be seen on the sketch. This was a 2 ft diameter spun concrete pipe, 266 ft long with its associated head and wing walls and spillway. C Troop built this culvert in about three weeks. It was a much easier task as the pipe lay in cut and the weather was by this time better.

Two months after we started work we were told that the range should be 300 metres and not 300 yd long. Somebody should have thought of this earlier, and the

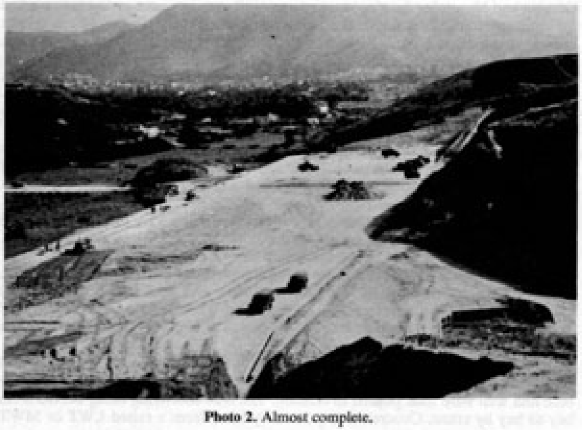


Photo 2. Almost complete.

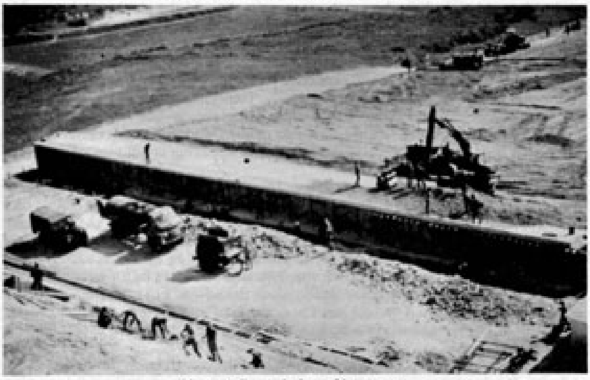


Photo 3. General view of butts area.

implications were quite serious. We had not initially needed culvert B at all, and the extension of the range involved cutting a 30 ft high face into a new spur. In addition to this a large grave lay right on the alignment of culvert B. Further re-planning was necessary at short notice.

GENERAL CONSTRUCTION

By September with Culvert A complete and the weather improving, the plant was able to start the major earthworks. These consisted of cutting out the spur running across the range, and subsequently the excavation of the butt area and construction of the stop-butt, which was cut for ½ of its length and fill for the rest. All through October and November the plant party were at full stretch; at one period they worked for fourteen continuous days. The temperature was always in the 80's and dust became a major problem. We borrowed seven plant operators from 68 Gurkha Field Squadron and for some time worked the plant in shifts of 0700–1300 and 1400–1900 hours. SSgt Reast had by this stage taken over as MPF, and he and Cpl Harising Gurung, who was acting Plant Sergeant, put in many long hours, supervising the operators, and the maintenance and repair of the plant. Cpl Harising Gurung was subsequently awarded the BEM for his efforts.

The serviceability rate of the plant was very high indeed; a tribute to the state in which 54 Squadron keeps the pool. The strain on the squadron plant operators and fitters became intense at this time, and we had a few problems caused by lack of thorough daily maintenance.

Apart from the immediate area of the culvert we did not have major problems on compaction, because a range by its nature is never going to be heavily loaded. Nevertheless we compacted to the maximum that time allowed us.

By late August the PWD had given us the complete design of the butts. The butts were standard, looking exactly like all butts I have ever seen. They consisted of a mass concrete wall on a large mass concrete base, with a reinforced concrete roof cantilevered out. The butt wall was 170 ft long, 8 ft high. The steel target frames were made by a sub-contractor.

In early September A Troop started work on the butt wall and base. They had prefabricated one set of base shuttering and one set of wall shuttering. Bays of the base and wall were then poured in echelon. The wall shuttering being moved from bay to bay by crane. Concrete was poured by hand from a raised LWT or MWT bucket. Photo 3 shows a general view of the butt area with the butt wall complete. Excavation of the target frame trench is under way and the earth mantlet in front of the butt wall is being formed. Photo 4 shows a section of the butt wall with the shuttering for the roof being placed.

A SQUADRON TASK

One of my ambitions on taking over my Squadron in March 1972, had been to have the whole Squadron working together in one place. This is difficult to achieve. In mid October B Troop, having returned from building a 170 ft span suspension bridge in Fiji, arrived on site, thereby achieving my ambition. B Troop's main task was to build a permanent access road across the existing San Wai range, and the road running down the side of the new range. These roads totalled about 500 m in length, 10 ft wide, and consisted of 6 ins of 3-in hardcore retained between 9 in high concrete kerbs, which were poured *in situ*. The plan was that at some later date, the PWD would surface the roads. We felt that as the whole range road lay on many feet of fill on top of paddy, there was likely to be some settlement and therefore surfacing was not wise at this time.

In December A Troop went off to Brunei for a five week jungle training exercise, and we were reduced to two troops once more.

FINISHING OFF

In September it had become apparent that the squadron could not finish the project by January 1974 if it had to construct the 2,000 metres of catchwater drains, of various sizes, required on the range and above the cut faces. I therefore arranged to subcontract the construction of these drains through the PWD. The drains were built incredibly quickly by Chinese labourers, who were very experienced in this work. Supervision was a problem as the Chinese spoke no English at all and we had few Chinese speaking Gurkhas. However we managed to get what we wanted in the end.

The final design level of the range left us short of about 4,000 cu yds of fill. We therefore opened a borrow area near the mouth of culvert A and used an Allis Chalmers, a D6 and our Bedford tippers to produce the fill, which was used in the

Photo 4. Butt wall under construction.

Construction Of Tai Ling Rifle Range 4

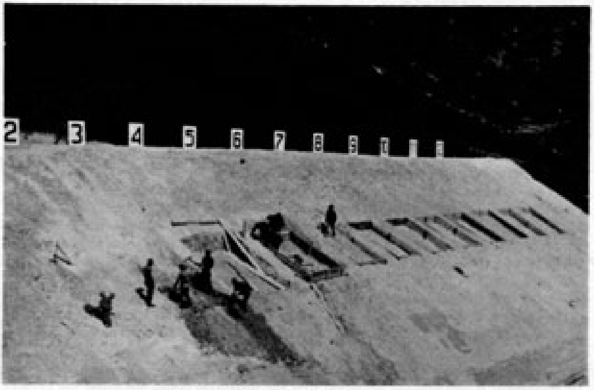


Photo 5. The stop-butt.

main to construct the firing points. The firing points had to be very well compacted to ensure that they did not suffer from rain scour and also because we had to excavate twelve fire trenches on each point. These fire trenches were revetted with precast concrete slabs. The programme of casting these slabs on site had started in May, and we only finished all the casting in January 1974.

By Christmas much work remained to be done. Most of it was really tidying up, but we were behind with the placing of the target frames. This was mainly because we finally struck rock excavating the trench into which the frames were to be mounted. This was the only hard rock we met on the whole project. We soon re-learnt that the hi-cycle tools are simply not powerful or robust enough for continuous rock breaking. We therefore reverted to our old compressor tools which did the job admirably.

To finish in time the whole squadron, clerks and all, worked seven days a week for most of January. In addition, an *ad hoc* section from 54 Squadron spent two weeks with us. They became the experts in placing the concrete revetment in the fire trenches.

The design of the range specified that in the stop-butt there must be a sand box behind each target. The construction of these caused us great trouble. Photo 5 shows work in progress. They had to be dug by hand and should have been filled with sand. In fact we filled them with spoil from the stop butt. These boxes took a lot of labour, at a time when we were under great pressure. We felt all along that they were a waste of time as they would soon be shot to pieces. This has in fact happened. Boxes appear to serve little useful purpose, and I would recommend that they be omitted from any future stop-butt design.

At the beginning of January we started to back load the plant. Most of it was required by 3 Field Squadron, and subsequently 9 Parachute Squadron, who were visiting Hong Kong. The machines therefore went straight from site to site, which meant that some pieces missed the complete overhaul which they needed.

On the 22 January 1974, the CRE was able to report to HQLF that the range was useable. All that remained to be done was spot turfing, which was to be done at the beginning of the next wet season. On the 30 January, the Commander British Forces, Lieut-General Sir Edwin Bramall, KCB, OBE, MC opened the range by firing the first shot. It was incidentally, a very accurate shot, and as he pressed the trigger, two pounds of PE were detonated behind the stop butt.

FINANCE

The costs of the range broke down as follows:

Materials	HK$184,000
Target frames	80,000
Turfing Contractor	95,000
Catchwater Drainage Contractor	130,000
Total	HK$489,000

The Sterling exchange rate dropped from $14.55 to the £1, to around $12 during the project. However £79,000, which was what we were allocated, comes to HK$948,000 at the worst rate.

COMMAND AND CONTROL

Because the project was started in such a hurry, it was not possible to form a proper project team. Captain Lowe, who commanded the troop doing the initial work, naturally became responsible for the day to day supervision of the whole project, and there seemed no point in formalizing this *ad hoc* command and control system into a project team. I was lucky that Captain Lowe was available as project officer throughout the project, although he also commanded his troop at the same time.

If the project had started normally with a period of pre-planning, I would have set up a Project Team within the squadron. Probably the main reason I managed to get by without one was that, within reason, money was no problem, and therefore control of materials used was not of the utmost priority. I was being urged constantly to complete the project somehow within the deadline, and to some extent our motto was "bash on regardless"!

STATISTICS

This is not an engineer project report and I will therefore include only the following very basic statistics on the military part of the project:

Earth moved	—	about 100,000 cu yds
Concrete placed	—	about 1,000 cu yds
Hardcore for road	—	about 700 cu yds
Plant machine hour worked	—	about 4,500 hrs
Military manpower expended	—	about 11,000 man days

LESSONS LEARNT

The major lesson learnt is one that everyone already knows!, it is not good practice to crash into a project without pre-planning. In this case, for good military reasons, we had to do so, and in the end it turned out alright, for the following main reasons:

(1) There was plenty of money.

(2) We had first priority in Hong Kong for plant and stores, and escaped nearly all other engineer commitments.

(3) All concerned with the project worked very long hours for a long time in, at times, very unpleasant conditions.

The last reason was probably the key one. The Squadron was given a challenge, and the men rose to it magnificently. Occasionally they may have wondered why they had to work so hard while the remainder of the Garrison went about its more leisurely business, but in general they understand the importance of what they were doing, and moral remained high.

We also learnt that it would have been better to have set up a proper project team to control the task. However I doubt whether such a team would have succeeded in meeting the deadline.

A number of minor lessons were also learnt on the design of gallery ranges. For example the construction of sandboxes in the stop butts was really a waste of time.

It is normally felt that it is a mistake to have civilian contractors working on the same site as military engineers. In the event we had no trouble with this, because we were completely responsible for the tasking and supervision of the sub-contractors.

One other important lesson learnt was that where possible major earthworks should be avoided in Hong Kong during the wet season. We were unlucky to strike the wettest summer on record, when 120 ins of rain fell in three months.

A last lesson was that life will become simpler when we manage to escape from the mixture of metric and imperial units at present in use in Hong Kong.

CONCLUSION

This project was, for all its problems, of great value to the Squadron. Most men practiced their own trades for long periods, and many learnt the practical aspects of new trades. Our plant operators and fitters in particular benefitted greatly. There is no doubt that the NCOs and Officers of the squadron also gained a great deal of experience. By the time it was completed the range was known by us all as "our range", and it will remain an object of pride for the squadron.

The way in which the project was set up, will probably horrify the experts at RSME, but we were able to provide a much needed facility for other arms to carry out the most important aspect of their training, quickly and at short notice, when there was no other agency able to do so. This surely is what military engineering is all about.

Three Engineers-in-Chief

MAJOR-GENERAL R E ASERAPPA (RETD)

THE accompanying sketch depicts three Engineers-in-Chief with Major-General C de L (Kim) Gaussen, CB, MC in the middle, with Major-General J F D (Tich) Steedman, CMG, CBE, MC tugging at his right arm and Major-General Sir Millis Jefferis, KBE, MC tugging at his left arm. The sketch was drawn by Major-General Gaussen in New Delhi during September 1947, and the accompanying "poem" was written by Major-General Sir Millis Jefferis in reply.

Major-General W F Hasted, CB, CIE, CBE, DSO, MC was the last Engineer-in-Chief of undivided India with Brigadier C E A Browning, CBE, MC as his Brigadier Engineer Staff. Field-Marshal Sir Claude Auchinleck was the Commander-in-Chief of the three Services. From the date of Partition on 15 August 1947 the combined Defence Services Headquarters changed it's title to Supreme Headquarters with Field-Marshal Sir Claude Auchinleck staying on as the Commander Supreme HQ. At the time of Partition Major-General Hasted handed over to Major-General Gaussen, who thus became the first, and only, E-in-C Supreme HQ. Brigadier Browning remained as his BES until towards the end of September when he returned to the UK from which time that appointment remained unfilled.

From the time of Partition India started forming it's own Services Headquarters in New Delhi, and decided to adopt the three Chiefs-of-Staff system instead of the Commander-in-Chief system. Major-General Steedman was appointed the first E-in-C of divided India, but it is interesting to note that, although the three Services were now under their own Chief-of-Staff, Major-General Steedman was also the E-in-C for Airforce and Navy Works. This system has been carried on to date.

Similarly, Pakistan started forming it's own Service HQs in Karachi from the date of Partition with Major-General Sir Millis Jefferis as their first E-in-C.

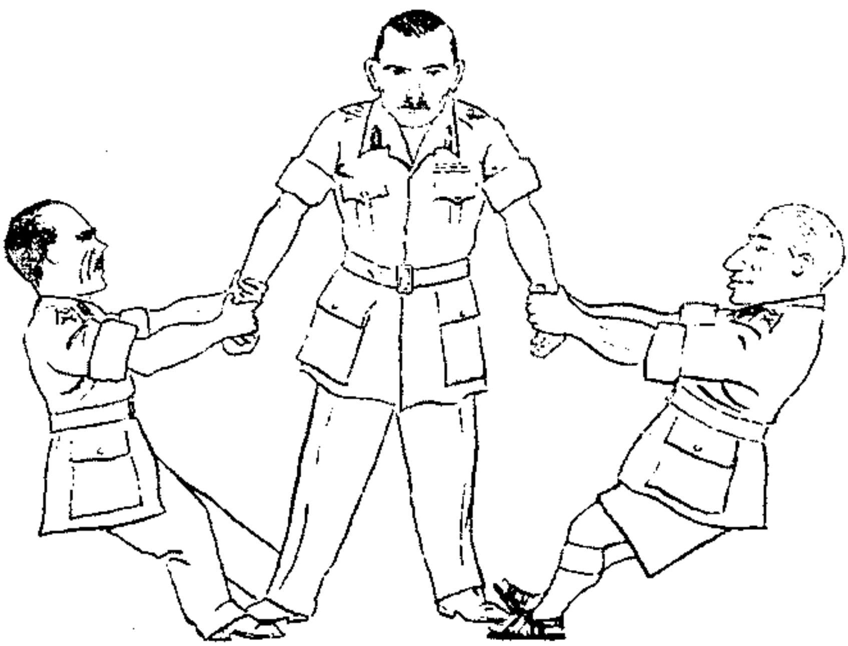
Supreme HQ was supposed to remain in existence for a year, and one of it's functions was to divide the military assets of undivided India in the proportion of two thirds to divided India and one third to Pakistan. The E-in-C Supreme HQ, therefore, was responsible for the division of all Engineer assets (such as Plant, Equipment, Stores, etc from the Engineer Store Depots), between the two countries in the agreed proportion. As these assets were not correctly located at the time of Partition this meant the selection of serviceable and unserviceable items (with spares), from the Depots and then transferring the out of balance items to the other country so as to end up with the correct distribution.

As far as India was concerned other functions of Supreme HQ were to divide the old Indian Army into two Armies, one for India and the other for Pakistan; to run down the Indian Army and establishments to meet post-war requirements; to settle the size, composition and locations of the Indian Army; and finally, to deal with the Gurkhas, some of whom were allotted to the Indian Army and the remainder to the British Army in Malaya.

The E-in-C India, which was an expanding organization, quite logically located his Office in the same buildings, Kashmir House, as that of E-in-C Supreme HQ, which was a fading establishment. Also as both the E's-in-C of Supreme HQ and India were on their own without family they naturally shared the official E-in-C's residence at 3 Dupleix Road, New Delhi.

So much for the background; now for the sketch.

As the selection of engineer assets for distribution was not a simple task, and as there was a certain measure of distrust between the two countries, Major-General Jefferies decided that it would be in the interests of the Pakistan Engineers if he spent a few weeks in New Delhi. Perhaps he may also have felt that being somewhat out of



Centre
Maj-Gen C de L (Kim) Gaussen CB, MC
E-in-C Supreme HQ India
on Field Marshal Sir Claude Auchinleck's Staff

Left
Maj-Gen J F D (Tich) Steedman,
CMG, CBE, MC
E-in-C India

Right
Maj-Gen Sir Millis Jefferies,
KBE, MC
E-in-C Pakistan

Sketch drawn in September 1947 by Kim to depict how the E's-in-C of India and Pakistan were tugging at him for their share of the engineer assets at the time of Partition.

THE INCONSTANT NYMPH

I had a little Sweetheart
She really was Supreme,
She weren't so very beautiful
If you know what I mean.

But Tich and I we loved her
And took her out to tea
For both of us we coveted
Her well kept E S D.

But She was very fickle
And when kisses gave'd She
T'was two She gave to little Tich
And only one to me.

Poem composed by Major-General Sir Millis Jefferis in reply to Kim's sketch.

touch in Karachi that Major-General Steedman had an advantage over him by being on the spot both in the Office and the home!

He arrived in New Delhi during September, and while there he also resided at 3 Dupleix Road. Thus there were three Engineers-in-Chief living in the same house at the same time. It would be interesting to know whether such an event has ever occurred before.

Thus, in trying to make a fair division of the engineer assets the E-in-C Supreme HQ was being pulled in opposite directions by the other two. Hence the sketch and the poem reply.

As a footnote it might be mentioned that for reasons such as the Punjab Border War between India and Pakistan, and the War in Kashmir, hardly any of the military assets were exchanged between the two countries and the situation remained much as it was at the time of Partition. Furthermore, due to the situation then prevailing the Commander of Supreme HQ found it increasingly difficult to carry out his role with the result that he decided to close down Supreme HQ by 1 January 1948 and hand over military control completely to the two new independent countries. The E-in-C's Office Supreme HQ closed down by this date and Major-General Gaussen returned to the UK.

In India an orderly take over by senior Indian Engineer Officers of the appointments of Chief Engineers of the three Commands, and Commandants of the three Corps of Sapper and Miners, Madras, Bengal and Bombay, was arranged to start on 1 January 1948. Only the appointment of Engineer-in-Chief was to be taken by a British Officer acceptable to Army HQ. Major-General Sir Harold (Bill) Williams was appointed and all other British Engineer Officers were repatriated.

In Pakistan, where there were few senior Pakistani Engineer Officers available, a number of British Officers served on for some years under the Pakistan Government. The Pakistan Engineers were formed largely from the Bengal Sappers and Miners together with the Punjabi Mussalmans and Hazara from the Bombay Sappers and Miners.

This, then, brought a final end to British Military control in the Indian sub-Continent.

The Structural Assessment of Buildings Subject to Bomb Damage

PETER S RHODES, C Eng, FI Struct E, FGS

INTRODUCTION

THE bomb damage referred to in this paper is that caused by anarchists in "peace time" conditions. Virtually all of the attacks come from the ground and most of the explosions are on or near ground level, although upper parts of buildings may be damaged. The overall effect differs somewhat from that caused by war-time air raids but much of the immediate damage is similar. It is therefore profitable to refer to war-time and post-war writing on the subject. A useful small booklet is:—

Military Engineering Volume VII, Accommodation and Installation, Part XII Repair of Damaged Buildings, 1948

The Chartered Structural Engineer, by virtue of his profession, may at any time be called upon to give an assessment of the safety of a damaged building and to suggest immediate remedial or precautionary measures. His concern at such a time after bomb damage would be firstly for public safety and secondly to preserve as much as possible of the damaged building. In times of emergency and without the immediate availability of the Specialist Structural Engineer, the Royal Engineer may find himself having to make such an assessment. It was with this thought in mind that the Author gave a series of lectures at the Royal School of Military Engineering in Chatham. This paper is a brief summary of the content of those lectures.

A paper under the same title was published in "The Structural Engineer", Vol 52, No 9, September 1974. Grateful acknowledgment is made to the Institution of Structural Engineers for permission to reprint parts of that paper. Paragraphs in that paper, but omitted from this version, deal with repairs and lessons for designers in the future.

Assessment of Safety

The prime consideration of the Royal Engineer would be the first appraisal of danger and the provision of "first aid" to make the building *safe*. This should not be confused with the work entailed in subsequent repairs to return the building to its original use. This would be the normal function of a Chartered Structural Engineer commissioned by the owner.

Usually, the inspecting Engineer need not concern himself with the strength or stiffness of individual members. It may be assumed that they were adequate for their purpose before the damage occurred and that if they are still intact and working, even though in a greatly deflected state, after the damage has occurred they do not in themselves constitute a danger. However, the inspecting Engineer may have to say that the building would be safe for only a limited time, for example, impending winter weather could cause further damage.

Knowledge of Building Construction

For the work here envisaged a sound knowledge of building construction, both modern and "old fashioned" is absolutely essential and the inspecting Engineer must be able to visualize such things as centres of gravity and lines of force without having to resort to the office and the drawing board. Bomb damage usually presents an urgent problem when time is short and assessment and decision have to be made on the spot and quickly.

Grouping of Building Types

Building types seen today fall into three main categories:—

(1) Wholly compressive
(2) Intermediate
(3) Tensile

This grouping needs some explanation.

Compressive

Tensile stresses, in floors, etc are provided by timber. The main body of the structure is of masonry or brickwork, all designed to use only compressive stresses. It is only in comparatively recent times that man has had a more or less permanent tensile material—steel.

Intermediate

Some tensile material is provided by cast iron, or by the early use of steel plate in combination with other materials such as timber.

Tensile

Large portions, if not the whole structure, are supported by tensile material, either rolled steel or reinforced concrete.

In modern buildings, with skeletons of either rolled steel or reinforced concrete, almost every single member (including columns) is designed using tensile stresses. Another property or virtue that comes with the use of steel, either as rolled sections or as reinforcement in concrete, is that the skeletal structure can be coherent. To a greater or lesser extent the whole frame can be monolithic and it has been seen that this is probably the most important factor in allowing the structure to withstand bomb damage and still be repairable.

The general scene

Unfortunately, from the point of view of bomb damage repair, in almost all of our cities and towns only a small percentage of the buildings are in the fully tensile group. By far the majority are in the compressive or intermediate groups and the assessment of damage to them involves the building construction of yester-year.

BUILDINGS IN COMPRESSION

Walls: mortar and bond

The basic element of this form of construction is the wall, built of separate blocks or bricks. Whether a particular wall has been damaged or not, it may have to be considered in the general assessment of stability and safety. Two important factors are the mortar and the bond. Both should be examined.

Modern mortar, gauged with Portland cement, has a fairly high adhesive property when it is new. Older mortar, relying solely upon lime, has virtually no tensile strength. It is best to regard all mortar as a bedding agent, capable of transmitting compressive stress and of contributing considerable frictional stress if not too badly decayed or disturbed.

The inherent strength of a wall depends very largely upon the type of bond. The bond must also tie the wall together through its thickness. Therefore, "throughs" are needed in masonry, and "headers" in brickwork. Where a wall is built of two materials, for example: facing stone and backing brick, this through bond becomes much more difficult to achieve. A thick and apparently sturdy wall of this compound construction may, because of an insufficiency of through bond, have a stability factor of only about a quarter of that of a solid, well bonded wall of the same thickness. If this stability factor appears to be of importance and is not to be seen it may be necessary to remove, gingerly, some of the external rendering and internal plaster at window or door openings.

In many "prestige" buildings of the commercial type, apparently having walls of solid stone, more than half of the thickness is of brickwork and experience has shown that in many instances the through bond left much to be desired.

In some buildings of heavy, neo-classical style, such as town halls, the real loads are carried on properly-designed brick cores. The ashlar stonework is often quite thin and may be hung on to the core, sometimes with a cavity of as much as 75 mm (3 in) between stone and brick.

In the brickwork construction the general use of the cavity dates from about 1930. Any work of earlier than that date is likely to be in solid brick. A modern cavity wall has no "throughs" passing across the cavity. Instead, wall ties are used. For full stability the two leaves of the wall must act together. If the wall ties are of strip steel and in good condition the wall will be fairly strong; but if the ties are of bent wire and rusted the wall may be no stronger than the two single leaves. A torch shone into the cavity will usually reveal the condition of the ties. Access to the cavity is, alas, usually all too easy after bomb damage.

With traditional bricks, 9 in long and 4½ in wide, the best longitudinal bond to be hoped for is 2¼ in. This will be referred to later under the heading *Corbels*.

The stability of a wall

The general principles of stability of a wall are well known. There are, however, some features arising out of damage that bear mention.

The most obvious horizontal force is wind and in built-up areas this can be dangerously high. The engineer should study any free-standing or imperfectly tied walls in relation to possible wind channels between the surrounding buildings and if in any doubt should call for temporary shores. If it is not practicable to provide shores, on both sides, of such an exposed wall then even though the wall itself may be sound it should be demolished without delay.

Floor joists bearing into a wall offer considerable restraint against overturning. But if a timber, or other, floor has collapsed leaving a remnant hanging out from a wall there will be a considerable moment applied to the wall at that point. This should be studied carefully to decide whether it is aggravating the condition of the wall or, in fact, tending to balance it in its damaged state. If the latter case is true then to remove the remnant floor might bring down the wall.

Roof timbers are a common cause of horizontal or inclined forces at the top of a wall. Normal trusses and common rafters that are trussed or tied by either ceiling joists or collars at a higher level are not likely to transmit much serious thrust. But if the ties are damaged or missing the thrusts can be serious.

The stability of a wall is greatly increased by the buttressing effects of cross walls but these will be efficaceous only if the bond at the joint is good. It is quite common in older domestic type buildings for the cross walls to be block-bonded to the front and rear walls and for the blocks to be very widely spaced. These are very easily displaced by bomb blast but it has been seen on several occasions that in fact the front wall had moved outwards long before the explosion. The cause might have been a failure of the foundations, frost action in the outer joints due to lack of maintenance of the pointing, or vibration caused by heavy traffic. If temporary shores are thought to be desirable, this is the place to put them.

If a bomb explodes inside a brick-built structure it is almost inevitable that many cracks will appear in the walls, both externally and internally. They will be most obvious when the walls are plastered but not papered. In many instances these will not constitute any danger to the stability or the future life of the wall or the building as a whole. There may be no reason to condemn a wall merely because the plaster is cracked. The shock of an explosion tends to shake and to move old cracks that have been there for a long time. There are many ways of discerning that a crack is an old one and the engineer needs to be something of a detective.

Post and lintel

This is one of the earliest and most primitive of building forms. It consists simply of a doorway made of two posts or piers and spanned by a single piece of material—the lintel. It is essentially strong under purely vertical loads and, unlike an arch, of itself produces no inclined thrusts. However, the basic weaknesses of such a simple "four-pinned" portal is that by itself it is not stable and is easily deflected into a dangerous state.

If such a "post and lintel" condition is recognized in a damaged building it should be studied to find any tendency of the posts to move. Shoring in more than one direction may be urgently required. Usually it will be found that the lintel itself is more than adequate. Simply propping it at mid-span is not likely to help and may in fact aggravate the tendency to sway sideways. For the continuing stability of a pier or post it may be necessary to keep vertical weight on its top. See notes on *Buttresses* later.

The simple masonry arch

In almost all practical arches, by the time the thrusts reach the springing there is a considerable horizontal component present. The resultant inclined thrusts must be brought to the ground well within the structure and thus adequate abutments are necessary. See Fig. 1.

In the original design the triangle of forces would have been used to indicate the amount of vertical load that would be required to combine with the inclined thrust from the arch so as to bring the resultant thrust down to the ground well within the abutment and preferably within its "kern".

Bomb blast may damage the arch itself, or the abutment, or both. If the arch is damaged but masonry still remains in position above, then the situation can no longer be considered in terms of an arch but must be regarded as a combination of corbels.

If the arch is intact but the abutment is damaged this may cause a state of impending collapse. This condition can occur anywhere in a wall but has been seen to be fairly common when arched windows or doorways are at the end of an elevation. The damage might be caused, for instance, by a car bomb.

In times of emergency the inspecting engineer usually assumes that originally the structure was designed to be stable and safe, with the resultant thrusts passing probably within the kern of the abutment. He should then try to assess by eye the degree to which this original condition has been altered and should form a mental picture of where the resultant thrusts now pass. If it is apparent that they come outside the remnant abutment then impending collapse must be assumed, although that part of the building may be able to stand for a time due to some tensile value of the mortar.

Unless the abutment is very wide it will be necessary to have a large vertical load to combine with the inclined thrust from the arch. Loss of masonry above the abutment and higher than the springing could present a serious danger. This fact should

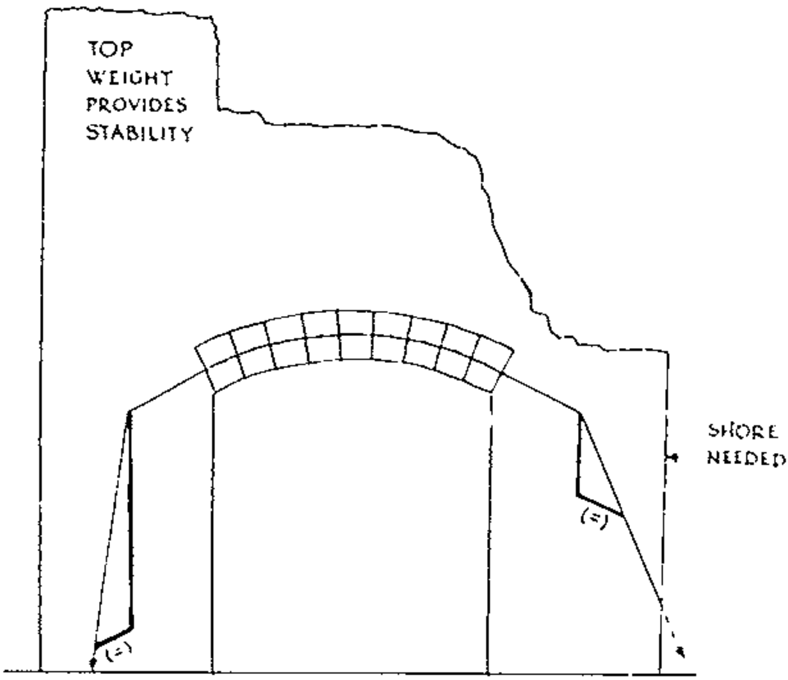


Fig 1. Abutment to an arch

be remembered before deciding to remove top weight which, for other reasons, looks dangerous. It may be better to leave the high level work in place and to prop or shore it against collapse. If it is clear that the abutment is now too narrow, timber shores will be required.

Buttresses

Buttresses do permanently what the timber shores do temporarily. In effect they enlarge the abutment so that the resultant thrust can reach the ground safely within the masonry. It is the outer edge of the abutment and its associated buttress that is the most important part.

It must be remembered, however, that top weight is vital, both in walls and in buttresses. Sometimes the top weight to a buttress is provided by what appears to be pure ornament. The best example of this is the many fancifully carved and crocketed finials that cap and decorate the butresses of a Gothic style cathedral or similar structure. The layman may think that damage to such finials is of minor structural importance but this is not so. Remove a few fancy finials from around a tall and vaulted Gothic cathedral and the whole lot might come down.

In emergency, if such decorative top weight is removed it will be almost impossible to replace it as a temporary repair. Therefore, shores to the buttresses will be needed. Alternatively, if time permits, a new and temporary but massive buttress may be built outside the original abutment.

Vaults

The principle of the vault is generally the same as that of the arch except that another dimension has to be considered. It is unlikely that emergency treatment would be required for a cathedral but this is by no means the only place where vaulting is to be found. Vaults were once fairly common in the larger domestic buildings as well as in many of the "prestige" buildings of commerce, in town halls, law courts, etc. With the advent of cast iron, vaults or "jack arches" were also once very common in warehouse construction.

If a series of vaults lie side by side, the only out of balance thrusts are those on the extreme outsides or flanks. These are taken up by the outside wall that supports and encloses that part of the structure. Usually the wall is sturdy enough in itself to restrain the adjacent vault but one can never be quite sure, in an emergency and without the opportunity to make a proper analysis, of the extent to which the lower wall relies upon the dead weight of the structure above. If an upper wall in such circumstances has been removed, the engineer should examine the lower wall and the vault which it supports to see if there are any signs of distress. Indications of this could be horizontal cracks along bedding joints on the inside of the wall at about a quarter of the way down from the springing. Furthermore the longitudinal joints on the underside of the vault at the crown may show signs of opening. The slightest crack could indicate a movement in the wall.

A hole in a simple barrel vault, of diameter say up to half the span, will probably not cause instability. If there is damage greater than this then sturdy struts should be inserted across the springings. Propping of the damaged vault itself would usually be unnecessary and may even aggravate the general condition.

In domestic buildings, lines of ground floor vaults are usually supported on walls that form the various small rooms of the basement. A hole low down in such a wall would cause little concern but a hole at the top, immediately below the springing, might be dangerous. Vertical propping should be inserted.

Corbels

Given a good bond and a bedding, with or without mortar, that is capable of providing the friction required to resist horizontal sliding at the bedding joints, it is possible to build compound corbels that can project to quite great distances. Emphasizing again the need for good bedding friction, such a compound corbel will stand and be stable so long as the whole of that part of the structure is balanced. See Fig 2.

As with the arch abutments, there will be horizontal or inclined overturning

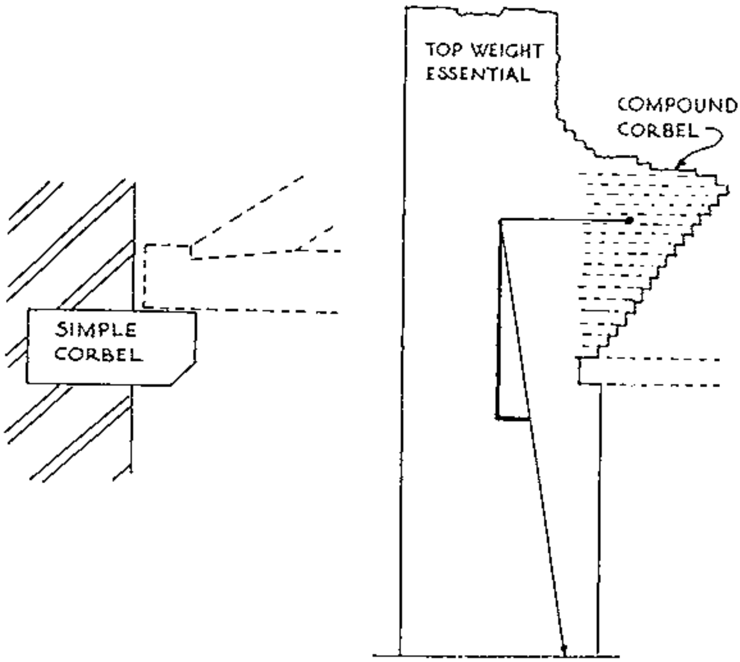


Fig 2. Simple and compound corbels

forces but with the corbel these will be working in a direction opposite to that of the arch. Thus, and for the same reason, top weight above the supporting wall is all important. If there is insufficient top weight to balance a compound corbel it will fall over, but if two such compound corbels meet then their overturning effects can cancel each other and the whole may be reasonably stable. The result will have been to produce a rough kind of arch and the thrust lines will be more or less similar to those of an arch.

This sort of condition is encountered when a large hole is blown in a solid brick or masonry wall, or when a lintel over a door or window opening has been broken or removed. The masonry or brickwork will form a corbel from the head of the opening at each side. With normal traditional brickwork the angle of the corbel line will be at about 60° from the horizontal; with masonry the angle would depend upon the bond. Provided that there are fairly wide remnant abutments at each side of such an opening its condition may be considered as stable. Had there been a lintel in the original state of the building the actual load on it would not have been more than that of the triangle of wall below the soffit lines of the natural compound corbels.

If after damage there are any bricks or stones remaining below the lines of the natural corbels it is best to remove them as they will certainly fall sooner or later.

If the natural corbel lines, when projected upwards from the extreme ends of the original lintel, cannot meet in solid masonry because of another opening such as a window on the floor above, then that part of the wall cannot act as a pair of balanced corbels. Bricks or stones will tend to drop away from below the corbel lines as the mortar joints fail and that part of the wall will be left as two independent stacks. Each stack must then be considered separately for stability. See Fig 3.

Overall stability

In the loadbearing brick or masonry buildings, overall stability is obtained by a careful arrangement of walls at right-angles to one another. To be effective they must be well bonded to each other. When a building is damaged, the first thing to inspect is the overall stability. If it has been impaired so that any wall or part of a wall is left without good lateral restraint then an overall collapse may occur.

Often it is possible, using timber shores or a modest amount of temporary brick or blockwork, to restore a fair measure of stability, sufficient to save the building but if this is impossible total demolition may be the only answer.

It may be assumed that when a building was erected the general stability was provided for by an adequate number and arrangement of linking walls, but often at some later date walls have been removed to facilitate a change of use. This is a frequent occurrence where buildings that once were domestic houses have been converted into shops or, often worse from the point of view of stability, into public houses or places of entertainment. It is, alas, quite common for almost all of the inner walls, particularly on the ground floor, to be removed and for steel joists to be inserted to carry their original vertical loads. Unfortunately, these beams do nothing to replace the diaphragm duties of the original wall and so the overall stability of the building is seriously reduced.

Under normal peaceful conditions the outside walls of a detached building, acting as a big box, may be sufficient to withstand safely the overturning effects of wind, etc, but under the action of bomb blast it is more than likely that the whole edifice will collapse like a house of cards.

A similar condition that has produced a tendency to progressive collapse occurs in terraces of old houses that have been converted into shops. The internal walls that run parallel to the street are removed, usually only on the ground floor, to produce a double-sized room suitable as a shop. The terrace is then further weakened by the removal of the front wall, again only on the ground floor, to provide large shop windows. Generally, so long as the whole of the original terrace is intact and undisturbed there is sufficient mutual support for the whole to stand. But if one house,

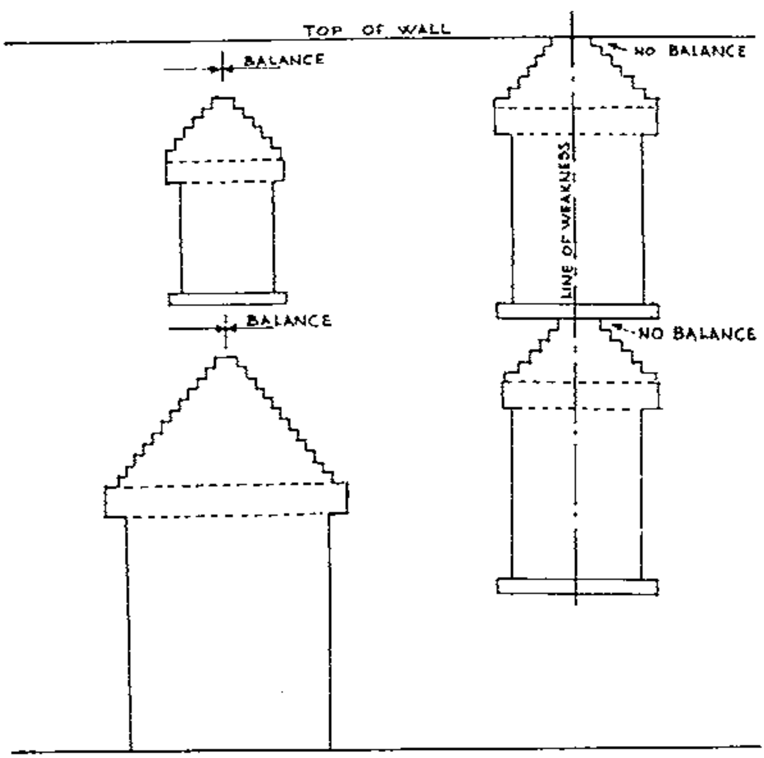


Fig 3. Compound corbels over openings

anywhere in the terrace, is removed it leaves its rather shaken neighbours in a very perilous state. Progressive collapse into the gap is almost certain and this could take place at any time after the original damage. Modern traffic causes far more vibration than was ever expected when the terrace was built and this could provide the triggering force.

The overall stability is the first thing to be checked when a bomb-damaged building is inspected.

Auxiliary parts

Chimney breasts normally rise from the foundations, commonly on cross walls. The hearth stones may be of real stone or of mass concrete and are partially cantilevered from the brickwork of the breast but usually have their outer edges supported by floor timbers.

When floor timbers are damaged by blast it is common for the hearth stone to be dislodged. As it falls it often brings with it one or two courses of the breastwork that rises above. This leaves a large portion of the breast hanging off the wall as a complex corbel. The condition is quite common when a single house in a terrace is removed. As immediate first aid some propping should be provided under the overhanging breastwork but it may be desirable to remove the remnant corbel as soon as the opportunity arrives.

Flues in domestic work are usually one brick (9 in) square and the facing walls and dividing brickwork are usually only a half brick (4½ in) thick. In better class work the ends of the breasts are usually one brick thick but in cheaper work may be only of half brick thickness. Party walls in better class work are at least one brick thick but in much of the poorer work are only of half brick and, even in the better work, it is quite common for the party brickwork between neighbours' flues to be only half a brick thick. Bearing those dimensions in mind, care is needed in demolishing remnant flues and breastwork lest a gaping hole should be made into the adjoining property. Even in the best of work, with or without flue liners, the construction of the "feathers", the curving half-brick thick partitions between the flues as they gather near the roof space, leave lines of weakness in the wall. This means that such walls are very prone to cracking, induced by the effects of the heat in the flue. Cracks seen in the vicinity of flues, notably on exposed walls and gables, are likely to have been there for a long time but bomb blast may have widened them. The wall should be judged on its overall merits and not condemned out of hand because of such cracks.

Stone stairs built to project without separate support at their outer ends are held up partly by being cantilevered and partly by bearing on the back of the step immediately below. This latter support is expected only to provide a measure of stiffness to the flight; the real support comes from the cantilever. This can only work with full safety if there is a considerable amount of solid brickwork above the step. Normally the minimum amount of height of wall above the step would be some 1½ m (5 ft). If there is less than this remaining, the stair should be considered as unsafe. When metal balusters are well grouted into the outer ends of the steps and there is a fairly sturdy baluster rail, the whole adds considerably to the overall strength of a stair and, as a temporary condition, may allow a damaged flight to be used.

INTERMEDIATE CONSTRUCTION

General

This class of buildings includes a wide variety of structures between those that are fully compressive and those that are fully tensile. It includes a very high percentage of all the buildings seen in the British Isles today. Typical of this class are the older warehouses and mills, many multi-storey factories and also many large shops. The significant feature in all of these buildings is the preservation of an external shell of load-bearing brick or stonework, as in the compressive construction previously described, but with the introduction of cast iron or, later, of steel. The cast iron may be used for columns only, with the beams in timber, or both columns and beams may be of cast iron.

Apart from the properties conferred by the use of the cast iron, the structure will behave very much as those of buildings in compression. Therefore, for all buildings in this category the earlier remarks apply.

Properties of cast iron

Cast iron is strong when in compression but is not so strong in tension. Beams were therefore constructed with comparatively small top or compression flanges but with much larger bottom flanges where the iron would be in tension. Cast iron is hard and brittle, and is not a good material in fire. If it is heated by a fire and is then chilled by the water from the firemens' hoses it tends to crack and fly to pieces.

Wrought iron was used to some extent instead of the cheaper cast iron because it is malleable and therefore comparatively fire-resistant. However, its use in buildings was limited and in any case it is almost impossible to identify it by cursory visual inspection. Therefore, in cases of emergency it should be assumed that the metal is cast iron.

Forms of cast iron members

Beams are usually parallel-sided, with a large thick rectangular bottom flange and a much smaller top flange. Sometimes, on deeper beams, there is a third flange as a stiffening rib about a third of the way down from the top. This third flange may be used as a support for the secondary construction of the floor. After the advent of rolled steel beams the same methods of floor construction were continued, with ledger angles riveted on.

In some of the older civil engineering works "fish-bellied" beams were used, for example, for roofing over railway cuttings in cut-and-cover work, but not normally in buildings unless they have been imported second-hand during alterations.

Columns are most commonly circular and hollow, with a wall thickness varying from 12 or 15 mm (½ or ⅝ in) up to 40 or 50 mm (1½ or 2 in), depending upon the diameter, often tapering slightly to the top. Bases and caps were usually cast integrally with the shaft. Sometimes columns intended for use in public places such as hotels or shops had their caps cast to imitate the carving of classical Greek or Roman stone columns. On almost all cast iron columns the caps are rather ornamental and massive. Occasionally cross or star-shaped columns are seen, with rib thicknesses varying but averaging about 25 mm (1 in). The caps were designed to receive the ends of the beams which usually were simply laid on. Bolting was quite rare and even when bolt holes were provided it was quite common for them to be unused. Even when bolts were used their value as a means of joining the members was very limited.

When considering the building as damaged, this lack of positive connection between the beams and columns is a series weakness. The engineer will understand that lack of catenary action, together with dragging from one column to another could cause a progressive collapse.

Sometimes the column continues beyond the cap and between the ends of the incoming beams, to terminate in a flat or shaped end designed to receive the base of the column on the floor above. On other occasions the upper column merely sits on the top of the incoming beams even if these are of timber. In many of the earliest buildings only the columns were of cast iron while the beams were of timber, usually pitch pine.

Jack arches

The heaviest form of construction, used for warehouses and factories, is with jack arches of brickwork spanning between the supported by cast iron beams. The beams are usually seen at between 2·5 and 3 m (8 and 10 ft) centres, when their depth will be about 600 mm (24 in). With shallower beams of say, 300 mm (12 in) depth their centres would be about 2 m (6 ft 6 in). The jack arches are only a half-brick thick and the space between their tops and the underside of the floor finish is filled either with well compacted brick rubble or with weak mass concrete. The floor finish above may be a thin layer of stronger concrete, or asphalt, or paving flags of York stone or similar. This construction is very heavy, loading the beams with about twice what is available for super-load.

Resistance to spreading of the arches is provided by the balancing of the horizontal thrusts from adjacent vaults. As a further safety measure and as a necessary provision during erection, tie bars are bolted through the web of the cast iron beam at about the centre of gravity of the section. They are arranged in lines across the building, at centres of about 3 m (10 ft) or a little more.

The end vault of a series has one side not balanced by an adjoining vault, so that all its horizontal thrust must be taken by the side wall. If tie bars are seen to be passing into the wall these will be anchored into iron plates. They were useful during erection but offer no restraint if the wall has been damaged. In such an instance, if the wall shows any outward movement or if horizontal cracks appear on its inner face, shoring may be needed on the outside, applied at the springing level of the jack arch.

This form of construction looks sturdy, and indeed is so, but a great deal of the carrying capacity of the cast iron beams is taken up with the dead weight of the jack arches and the floor construction above. Therefore, if an upper floor of such heavy construction should collapse, the weight of its rubble could progressively bring down the floors below. The cast iron beams rather than the jack arches would fail. This condition was seen as the result of wartime aerial bombing, but the whole system is tough and resistant to damage because of its very massiveness, and progressive collapse was rare.

Patent fire-resistant floors

There are several alternatives to the jack arch that were offered by individual firms as a fire-resisting but lighter form of construction. One of these, called Doulton's system, used secondary iron beams at about 1 m (3 ft) centres, spanning between the main cast iron beams. Hollow firebrick "pots" shaped like the voussoirs of a flat arch then spanned between the secondary beams and were shaped so as to cover the undersides of the secondary beams. Specially-shaped pots were provided to encase the otherwise exposed lower part of the main beams. The whole of the underside was then plastered and the floor surface was either wood block or floor boards laid on timber battens. This type of floor is quite strong, gives a much better live-to-dead load ratio, and is unlikely to collapse under rubble.

Another method was to use much smaller secondary beams, about 100 mm (4 in) deep, and to fill the spaces between them with coke breeze concrete thick enough to give about 25 mm (1 in) of cover below the secondary "filler" beams to provide fire resistance. There are several varieties of this, depending upon the firm that produced the system or erected the building. They are all fairly strong but the material between the filler joists may be broken or displaced, either upward or downward. Damage is likely to be local.

Plank floors

A lighter form of construction, also used for warehouses and mills, particularly old flour mills, is to use cast iron columns and beams inside a sturdy brick shell. Over the beams is laid a timber floor comprising planks only, of about 300 mm (12 in) wide and 75 mm (3 in) deep. It is common for the planks to be joined together with separate tongues of hardwood fitted into grooves in each side of the plank. These plank floors are very strong and are also very good in case of fire, because they are sealed and the air and flames cannot pass through and round them. The underside becomes charred but then the charcoal insulates them against further damage. Many old flour mills are so constructed even though a flour mill is considered to be a high fire risk and prone to explosion. In a fire the most vulnerable members are the cast iron beams. This may be one reason why the old flour mills appeared to favour pitch pine beams, although the author has noticed that the millwright was not above using a saw if a main beam appeared to be in the way of a new feed pipe. If an explosion occurs in such a building, the floor or floors above may be lifted and displaced. There is little or nothing to hold them down.

Joist floors

A still lighter construction, much used in old buildings especially those designed as shops, was to build all as for the plank floor but to use normal timber floor joists at about 300 mm (12 in) centres, covered with floor boards of about 20 mm (¾ in) thickness. The ceiling may be either of riven laths and plaster or, as often seen in old shop buildings, of tongued and grooved pitch pine sheeting, fixed diagonally or arranged to form patterns.

In some of the older buildings of this joisted construction "deadening" was inserted between the joists. Unjointed and rough match-boarding was fixed between the joists, supported by, but rarely nailed to, rough timber battens nailed to the sides of the joists some 50 to 75 mm (2 to 3 in) from the bottom. The space between the match-boarding and the top of the joists was then filled with a rather dirty looking mixture of cinders and sawdust. This added some extra weight to the floor construction; its purpose being to act as sound deadening by reducing the effects of reverberation of the rather light floor construction. Often when such an old building was wired for electricity or fitted with pneumatic tubes etc, the cinders and sawdust were removed. However, the engineer must be aware of the possible existence of deadening when measuring the depth of a joist, and match-boarding must not be mistaken for the ceiling.

When a deadened floor is damaged the dusty and dirty filling tends to fall at unexpected times. The engineer should guard his eyes.

Timber beams replaced by steel

Very early buildings of the mill, warehouse and shop type were constructed using timber beams, and sometimes timber columns. With the passage of time the timber has decayed and there are still some of the old brick shells wherein the timber members have been replaced by steel. Although steel beams, and possibly steel columns, have been inserted it is only rarely that they are properly bolted together. The connections are therefore weak and the general vulnerability remains. No catenary action can be expected and dragging from one column to another can occur. The assessment of this particular kind of building depends upon a careful scrutiny of the joints at the column heads. The trained eye should have no difficulty in assessing the capability of the joint to take up horizontal shearing forces.

Partial steel frame

In mills, warehouses etc, as a final stage before the adoption of the full steel frame, the heavy brick outer shell was retained and framed inside with steel in the modern manner. The floors may have been of timber or concrete. Concrete floors may have been reinforced, with bars or expanded metal, or may have had small filler joists at about 600 mm (24 in) centres. When expanded metal was used it was generally laid as one sheet in the bottom of the slab over the middle of the span, but rose to the top as it passed over the beams. Sometimes the beams were cased but it was common for the slab to be supported on ledger angles.

This specially designed internal steel framing can be recognized because the joints are all bolted or riveted together, usually in strict "textbook" fashion. If this is the case, then some catenary action can be expected from the internal framing, but it is important to be sure that the "frame" is not as described in the previous section. It is not always easy to decide whether such a building has a partial frame or whether in fact it has a complete frame with columns concealed within the external walls. If there are columns it may be possible to see them on the uppermost floor or floors where the brick wall is not thick enough to conceal them, but even this may not be possible if they have been covered by brick pilasters looking like piers. In tall buildings, if the lowest storey has a very thick wall it is almost certain that there are no external columns. If padstones can be seen almost certainly there are no columns in the wall. If there is a wall column the thickness of the wall may be only 1½ bricks through all floors. It may be possible to see a small space between the underside of the beam and the top of the brickwork, thus indicating that the brickwork is not supporting the beam and almost certainly was built after the steel frame was erected. The absence of padstones indicates the possible presence of wall columns but unfortunately this is not positive evidence.

If there are no wall columns then the external shell of this type of building will behave just like any other loadbearing structure.

Shop front construction

Big shop buildings may have been designed for the purpose or may have started life as industrial structures and have been converted later. The important feature to consider is the line of large display windows that occupy the whole of the ground floor wall to the street. Their presence reduces or nullifies the diaphragm or shear-wall effect of that wall. In some of the buildings actually designed as shops this condition was recognized and so fairly large panels of brickwork were provided between the big windows. In others there are large panels at each end of the facade, but unfortunately there are many buildings without such large panels of solid wall.

The heavy wall above the display windows is carried by wide beams which may be of solid timber or may be flitch beams consisting of two, three or four timber beams between which are sandwiched steel plates, all tightly bolted together. In other instances there may be two or three cast iron beams side by side, or a single box-girder made of two beams or two channels with flat plates bolted or riveted top and bottom. Sometimes the beams are supported by brick piers between the windows. In other buildings cast iron columns are used but commonly these do not continue up to the floors above.

In all of these constructions there is usually a very poor connection between the ends of the beams and between them and the caps of the columns if these are used. There is usually only a very poor tie between this front line of beams and the construction within the building, so that the whole facade is prone to movement under the effect of abnormal horizontal forces. Temporary shoring may be required, or at least desirable, but modern facings and the widespread use by the original designers of string courses and other projecting ornamental details may make it difficult to obtain a good and effective bearing against the damaged wall.

A failure of the beams over the windows could leave the upper storeys, which usually have smaller windows, in a dangerous condition. It must also be remembered that the piers of brickwork or masonry between the first floor windows rely only upon friction to hold them to the "post and lintel" construction over the big windows. Direct stress from the masonry above would normally far exceed any bending stresses arising from wind pressure but in certain circumstances this condition can be reversed.

MODERN TENSILE CONSTRUCTION

This general class of structures includes almost all of the larger modern buildings and also some that date from the turn of the century. The various building types may be listed as:

(1) *In situ* monolithic reinforced concrete.
(2) Steel frame of stanchions and beams, all cased in concrete.
(3) Steel frame of stanchions and beams, uncased.
(4) Precast concrete frame.
(5) Precast concrete cross-wall construction.
(6) Single storey sheds, factories etc, with steel frame.
(7) Prestressed concrete (although damage to this has not been seen by the author).

The significant difference between this class of buildings and the two already described is that, with the exception of precast concrete cross-wall construction, the building has a frame, a skeletal shape of permanent tensile material. The presence of such a frame enables the building to withstand damage from explosion much better than can the earlier buildings without a frame. However, while all behave well as regards the immediate safety of the public, repairability depends almost entirely upon the degree of coherence of the frame and its ability to remain undistorted. Individual members of all kinds can be repaired fairly quickly but if the joints fail so that the frame becomes distorted then repair involves partial demolition and a much greater time. This point will be enlarged upon later.

As regards the stability of a damaged building in this general class, the principles of corbelling and the retention of top weight, needed for buildings in compression, do not apply. Instead the engineer must consider the frame in terms of its coherence and its capability to offer bridging effects, either by a form of multi-directional Vierendeel action of the whole or by catenary action of the separate parts. Both of these conditions can prevent collapse but it is only when the former condition is present by virtue of stiff and coherent joints, that a reasonably quick repair is possible.

In situ monolithic reinforced concrete

This is one of the strongest and most resistant forms of construction. The fairly massive and monolithic nature of the concrete and generally the two-directional reinforcement in the walls, floors and roof, make all the parts very resistant to damage that would cause a collapse. An explosion might sever beams or columns or blow holes in walls or floors but still the frame as a whole would stand. The carefully placed diaphragm walls, which are called for under normal design conditions, add greatly to the overall stability of the damaged structure. Because of their massiveness and two-way reinforcement they also act as useful blast screens and tend to localize the effects of an explosion. This applies particularly if the building is well fenestrated, but without adequate outlet for the blast such walls may direct the blast or its secondary effects into more remote areas of the building. The structural engineer will readily understand that certain stability cores may have this effect.

A considerable degree of overall stability and resistance to deformation or collapse derives from the fact that the joints are monolithic and rigid. Frequently even though a fairly large or apparently salient portion of the supporting frame is damaged or removed the remainder of the building, including the part above the damaged area, is well capable of standing and of suffering little or no distortion. The reason for this durability appears to be that the portion of the building above the damaged area acts like a multi-directional stiff jointed girder or space frame. In-fill panels of brickwork or similar material appear to add to the general stiffness. It would also seem that the more storeys there are above the damage the better is the building able to bridge or to cantilever over any gap or lack of support.

As a first thought it would appear that a corner column would be very vulnerable and that the removal of a lower length would cause damage. However, it has been seen that this is not so, provided that there is a fair amount of frame above the damage and that the joints are stiff.

Possible damage

Bomb blast produces some strange effects. Quite apart from the freakishness of the blast itself the effects vary according to the type of building. An explosion exerts hammer-like blows on the various parts of the structure, bringing into play strong, albeit short-lived, forces that act in almost any direction *except* that catered for by the designer. Massive thrusts acting sideways as well as upwards can be expected. As the result of many observations the following conclusions have been reached as regards damage to monolithic reinforced concrete structures.

It is quite common for individual members to be unharmed although they have been displaced. The reason for this is that the concrete which tends to fail first is that which is common to two members where they join. With the normal methods of arranging reinforcement, intended to withstand and resist normal strains from dead and live loading, wind pressure, and the effects of fixity, if the concrete fails in the joint itself this permits relative movement between the joining members. For instance, where a floor slab joins into a wall the concrete that is common to the two members is most likely to be reduced to small rubble while the members themselves are not damaged. Movement can take place and it is likely that as the result of blast the wall may move outwards and the end of the slab may droop slightly. The result of this is that while the members themselves may be intact and undamaged nevertheless that part of the building may not be repairable without complete demolition. This can be a very costly process, particularly in terms of time.

If a bomb explodes on a suspended floor it will probably blow a hole in the slab. The size of the hole and of the aureole of damaged concrete around it will depend upon the size and nature of the bomb and upon the thickness of the slab. The damage to the floor above is likely to be different. Because floor slabs are reinforced only to withstand downward pressure they have but little resistance against upward blast. Holes such as those in the lower slab are unlikely to occur but the whole slab may be bowed upwards and may be torn away from any supporting beams in the immediate vicinity. When this occurs it is once again the concrete that is common to the two members that crumbles. The general habit of setting the beam binders with their laps at the top permits them to be opened, thus allowing the floor reinforcement to be displaced upwards.

Flat slab floors have been seen to fail by shearing closely around the column, both downwards *and* upwards.

Damage to columns would appear to be quite unpredictable. In one instance a large portion of a sturdy column was removed by a bomb placed close by. In another instance a bomb known to have been of about the same size and at almost exactly the same distance from a similar column did not even harm the plaster cover. In yet another building a bomb known to be appreciably smaller than the two just described damaged six columns.

Steel frame, cased in concrete

The behaviour of this type of structure is very much the same as that of the monolithic reinforced concrete frame but with one or two minor differences. The joints are less likely to fail and, if the floors are of *in situ* concrete, the overall strength is generally better than that of the reinforced concrete frame. Stanchions generally are less likely to suffer serious damage. On the other hand, if a beam or other member is seriously damaged its replacement may be a more complicated process.

If precast concrete units have been used for the floors, these present some weakness as they do not contribute so well to the overall "space frame" effect as does monolithic concrete. They are also liable to be blown up and displaced or they may fall on to the floor below and cause some consequential damage. Precast floors using slip tiles are more vulnerable against uplift blast than are the more common hollow-box type units.

Steel frame, uncased

The behaviour of the uncased steel frame is rather different from that which has been fully cased. The joints are not so stiff and so distortion can occur more readily. Chances of a complete collapse are remote but this kind of frame may not be capable of bridging over a large gap without some sagging. With a greater use of precast concrete flooring the chances are that the building as a whole is not so stiff as its fully cased counterpart.

Undoubtedly the biggest risk to unclad steel is from fire rather than damage from blast. If fire has occurred the steelwork must be given the closest scrutiny and, if necessary, portions must be removed for testing. A convenient way to do this is to prop the beam and to remove a short length of the bottom flange, later replacing this with a piece of steel plate welded on like a cover plate. The small extra depth of 25 mm (1 in) or so should cause little inconvenience when the building is reinstated and redecorated.

Precast concrete frame

The problem with a precast concrete frame is the assessment of the coherence and rigidity of the joints. If these have been well designed and well made there should be little difference between the behaviour of the precast frame and the *in situ* monolithic one. However, when the construction joints occur at the effective joints of the members they tend to rely upon gravity and the use of dowels, looped bars, etc so that the frame is likely to have very little coherence and tends to distort badly under the effect of blast. Such joints at some distance from the explosion have been seen to disintegrate completely.

With precast concrete it is possible to have two sets of joints: those where the actual members such as beams and columns come together, and those where the separate portions of precast work are joined during construction. These latter joints may occur in the middle of actual members.

Precast concrete cross-wall construction

There are very few examples in Northern Ireland of this kind of construction and no damage has been seen or indeed suffered. *The Building Regulations* stipulate that the various parts should be tied so that progressive collapse cannot occur, but it is interesting to speculate about the repairability of such a building after bomb damage.

Single-storey steel sheds, factories, etc.

There are many variations within this broad class of structures. The basic intention is to provide a weatherproof roof and walls over a large and open working space. The roof and walls are commonly sheeted with corrugated steel, aluminium or asbestos-cement sheets supported on purlins or sheeting rails. The supporting steelwork may consist of stanchions and roof trusses, or of steel portals, or of stanchions supporting steel space-frames. In a very general sense all behave in much the same way under bomb blast.

Unless cutting charges are carefully placed at the correct positions it is unlikely that an explosion would directly damage much of the basic frame of one of these single-storey sheds. A column might be bent so as to make it unsuitable for the continuing life of the building but an immediate collapse would be most unlikely. Removal of any one or more of the various devices used to provide overall stability would weaken the building but would not cause an immediate collapse.

A bomb in a lightly sheeted shed usually has very little effect upon the frame because its pressure is vented rapidly by the removal of large areas of sheeting. As with the uncased steel frame the steelwork is likely to be more vulnerable to fire than to explosions.

CONCLUSIONS

Several general thoughts arise out of the whole sickening business of bomb damage. Caused by anarchists who have no regard whatsoever for the good or the safety of the country and its people, it leaves unsightly scars and hurts a great many innocent and peaceful people. Its main purpose is to cause disruption to the normal working and way of life of the community. The disruption can be minimized by being able to clear away the rubble and to reinstate the town as quickly and painlessly as possible. This is where the structural engineer can help. However, the young structural engineer is trained in modern methods of construction, in steel and reinforced concrete; and the examinations for which he must sit concentrate upon these modern techniques. Yet, a very high percentage of our environment consists of much older buildings.

To deal adequately with this unfortunate problem one must dig out dusty old textbooks on building construction and be prepared to devote some time to the study of the supposedly outdated methods of building and of the older buildings themselves. The behaviour of loadbearing brick and masonry structures has been well demonstrated in recent times and the author is convinced that this form of construction must be understood by all who call themselves chartered structural engineers.

The writer spent some time after the Second World War in repairing and modernizing bomb-damaged buildings, mostly flour mills and warehouses. He also had the doubtful pleasure but most memorable experience of seeing Nagasaki after the atom bomb. It was an unforgettable sight and must have been very near to the ultimate of bomb damage. Fortunately for us that war time damage is a long way removed from the conditions that are met in our towns today but even so, tramping over seemingly endless broken glass that cuts the shoes to ribbons is very depressing.

Bomb damage, by any standards, is a messy business.

Fortifications and Works

PART TWO—WORKS

BRIGADIER H E HOPTHROW, CBE, ERD, CEng, FI MechE

ORGANISATION

THE previous article, *RE Journal* June 1974, dealt with Fortifications; of military and technical interest and vitally important during the early years of the 1939-45 War, their importance decreased as the allies turned to the offensive. The very much larger engineering tasks were those covered by the all embracing yet inexplicit title of Works. This article is concerned with those Works under the aegis of the Director of Fortifications and Works (DFW) in the War Office, that is to say all Works Services in the United Kingdom and in places abroad where there was no field army.

The writer's predecessor as DFW, Major-General A G B Buchanan wrote a history which covers in considerable detail the organization and statistics of the period.[1] This article attempts to add personal recollections which would be inappropriate in an official History but which may have human interest and some historical value.

Due to intense financial stringency between the wars the Works Services, which then included the Engineer Stores organization, were in a depressed condition. The depth of financial parsimony reached was such that for example it was not unknown for the timing of limewashing in barracks to be linked with availability of "RASC Lime" because it was fractionally cheaper than the same product obtained from Ordnance. Older readers of the Journal may recall limiting water lines painted on baths in officers quarters at Chatham not because of a shortage of water but to economize on water rates. The Works Services had lapsed into "barrack plumbing" and a routine of often meaningless red tape. Ledgers, vouchers and tally cards for engineer stores were meticulously kept and audited but often bore no relation to stores held. In 1942 when central accounting was introduced all old records in Eastern Command had to be scrapped and a new stocktaking organized.[2]

An outcome of this depression was the loss of interest by senior officers and junior officers tried to avoid home postings to the Works Services. It is credibly reported that one young officer, more interested in bridles and bits than in Bills of Quantities and Term Contracts, told an inspecting general officer that it was no job for a gentleman!

The situation was further exacerbated when early in 1939 the Government decided to raise a Militia (not to be confused with the pre-1914 Militia). Due to haste, secrecy and strong political pressures contracts for militia camps valued at £21 million were placed without competition on a cost plus fixed fee basis. The contractors were given specifications and type plans but it was left to the contractors to adapt them including all the services to the sites allocated to them.[3] Progress varied, costs rocketed and by the end of the war in 1945 some final accounts were still not settled.

The rapid expansion of the Army and the unexpected return of the BEF from France imposed a strain on the organization of the Works Services well beyond its capacity. Some strange and impracticable devices were hastily adopted. The Militia camp contracts have already been mentioned. Another was the abandonment, with Treasury approval, of cost accounting (Construction Account) with results which any engineer reading these words will readily imagine.

In May 1941 Major-General C J S King (later Lieut-General Sir Charles King) was appointed Controller General of Military Works Services (CGMWS) where he was joined by Colonel Desmond Harrison, DSO (later Major-General D Harrison) and the writer of this article as Ds CMWS (known later in some quarters as the "monarch and the king makers"). Not only were they concerned with the Works Services but were required by the Army Council to report on the whole of the Royal Engineer organization in the War Office, Commands and the field armies. One of the CGMWS's first actions was to restore cost accounting. His memorandum recommending it, or more accurately insisting on it, included a quotation from the Third Gospel "For which of you intending to build a tower sitteth not down first and counteth the cost, whether he have sufficient to finish it? Lest haply after he hath laid the foundation, and is not able to finish it, all that behold it begin to mock him".[4]

Following recommendations in the report the appointment of an Engineer-in-Chief in the War Office was approved. On 4 September 1941 Major-General King was appointed E-in-C (the first time there had been such a post in the War Office), combining the duties of a Director General under CIGS and being responsible to the QMG for the Works Services and Engineer Stores organizations. Other notable changes were the setting up of a separate Directorate of Engineer Stores, the appointment of District Chief Engineers in Home Commands and Assistant DCREs to relieve DCREs of much of their administrative work.

Pen and ink cost accounting in DCRE's offices was too laborious for the growing works commitment. Store Keeping and accounting had deteriorated to such an extent that DCREs having lost faith in the service over-ordered materials on each specific job and built up unofficial unaccounted and unaudited storehouses. Pilferage and misuse became rife. One officer deflected sufficient stores to build an extension to his chosen place of worship. When discovery and discipline overtook him the cost of the stores was stopped from his pay. It would be interesting to know whether a grateful congregation recorded his munificence by a plaque and what was inscribed on it.

A committee was appointed with DDFW as chairman to investigate alternative methods of accounting. Mechanization and some centralization of Cost Accounting and its reconciliation with RAPC Cash Accounting was recommended. The machines for the new systems were imported from USA with some difficulty owing to enemy submarine activity in the Atlantic. Installation commenced in 1942 and all Commands except Southern were fully mechanized by 1944.[5]

ACCOMMODATION

Mallory and Ottar in "Architecture of Aggression" devote interesting chapters to hutting design.[6] Relying on published material they have been misled to some extent about the huts and sheds used by the Army. For example the *Tarran Hut* although used for a time in quantity, particularly in Northern Command, developed many, faults in bad weather and its use abandoned. Mr Tarran was a contractor in Hull; a substantial and vigorous "character". The hut he designed and produced was parabolic in cross section, consisting of pre-cast panels made of "Lignocrete", a mixture of cement and chemically treated sawdust cast on wires running between two arched timber ribs.[7] Basically the design had merit but, like the Inglis Bridge in another field of military engineering, when quantity produced could not match the more carefully fabricated prototype. The principle defects were in the joints between the sections which leaked in bad weather bringing misery to the occupants. Following a survey and report by Lieut-Colonel G Perry RE its use was abandoned notwithstanding the vociferous protestations of Mr Tarran.

Of the many other designs submitted to the War Office, and not accepted for general use, was the design of Major J H de W Waller, RE (retd) the *Ctesiphon Hut*.[8] Again basically parabolic, its name is derived from the great brick arch of the palace at a place of that name, built by the Persians in the third century AD and which still stands in what is now part of Iraq. Waller's design may have been used by the Air Ministry or directly by the US forces but it was not standard in the Army.

The *Iris Hut*, or shed, was in a different category. Sometime, probably in 1940, the Inspectorate of Royal Engineer and Signal Stores (Telegraphic code *Iris*) at Chislehurst had a delivery of stores that could not be put in their already overcrowded accommodation. As a temporary measure an arched shed built from tubular scaffolding was hastily erected. At that time the Army had no quickly erected shed. Someone borrowed the drawings, duplication and unofficial dissemination followed, and *Iris Sheds* were erected in most home commands. The first snowfalls in the winter of 1940–41 brought about the collapse of most of them.

Between the wars some standard designs of huts and sheds had been made in the War Office. Unfortunately they were profligate of materials that became scarce and the standard shed proved to be difficult to erect with plant then available in the field.

The sudden demand in 1939 by the BEF for hutting for winter accommodation precipitated a reversion to the hut designed by Captain Nissen, RCE during the 1914–18 War. In its simplest and most used form its dimensions were 27 ft × 16 ft. Owing to shortages of timber some details were varied. Concrete floors, corrugated steel sheet lining and brick ends were introduced. Black light gauge corrugated sheets replaced the heavier galvanized sheets. Some huts were improved for office use, by adding dormer windows. A larger version 60 ft × 20 ft, sometimes known as the Hospital Hut, was used but not extensively.

The pressing need for sheds for stores and workshops led to the design by FW4 (Lieut-Colonel E F Brawn, RE of the Directorate) of the *Romney* and *Marston Sheds*. The *Romney* (from Romney House, DFW's offices in Westminster during the War), consisted of a semicircular vault built from three different components, a curved tubular segment of Bessemer Steel, an angle iron purlin and a standard bolt. The external covering consisted of 24 gauge corrugated steel sheets. The standard shed was 96 ft × 35 ft, the steel content 6.65lbs per square foot of floor area. It was extensively used at home and in most theatres of war. A variation known as the *Semi-Romney*, which could be erected more quickly, used the same vault but had a canvas covering which when time permitted could be replaced by steel sheets. Major-General A G B Buchanan described the *Romney Shed* as "one of the outstanding successes of World War II".[9]

Improved designs for personnel huts were also made, the *Abbey* 24 ft span and the *Tufton* 16 ft span. They showed great promise and prototypes were erected in Hyde Park but the end of the war being hopefully in sight it was considered unwise to change the production line from *Nissens*.

There was still need for a shed suitable for workshops and the use of overhead travelling cranes capable of lifting the turret of a Churchill Tank. The design adopted was of more conventional civilian style and known as the *Marston*.

These brief descriptions mask the many problems and the amount of work involved in reaching satisfactory designs. There are hours of consultation with potential users about their functional requirements, for example, living and sleeping quarters for all ranks, messes and offices, a large variety of technical needs for the Ordnance, REME and Medical Services and many others. War time scarcity of materials severely limit choice and shipping space for transport overseas is always a restricting design factor. Nevertheless most of the war time accommodation requirements for the British, US, and allied armies were met by two modified forms of the *Nissen Hut*, two versions of the *Romney* and two of the *Marston* sheds.

STANDARDIZATION

In addition to the standardization of the designs for huts and sheds, standard requirements for complete installations and designs for E and M services including a range of standardized squirrel cage motors and various sizes of sewage treatment plants were prepared. In support of these the Chief Surveyor of Works (CSW) Colonel J B Marks, OBE, FRICS and his staff prepared standard specifications, bills of quantities and conditions of contract; CREs being left to deal with layouts and local variations. For example, basic designs, quantities and specifications were prepared for a storage depot for the US Army, from which six were constructed in various parts of

England. Each had 450,000 sq ft of covered and about 1,400,000 sq ft of open storage, accommodation for 1,250 officers and men and all supporting services.

The CSW's branch (FW6 later E9) were also active in other directions. The Term Contract procedure was maintained throughout the war and the War Office Schedule of Prices completely rewritten, repriced and published. In preparation for invasion of the continent documents for use with foreign contractors were prepared and translated into all European languages.

SPECIAL PROJECTS

There were many special and unusual projects, a few examples will illustrate their variety. The largest purpose designed project was the Bicester Ordnance Depot, with a total storage space of 12 million sq ft and accommodation for 19,000 staff. Covered storage was in permanent buildings, personnel in hutted accommodation. There were sixty miles of new rail track and twenty-four miles of roads. Eighty per cent of all the work was done by Artisan Works Companies RE and a Quarrying Company RE, supported by Pioneer Corps, and at one time 1,000 Italian Prisoners of War. The site work was supervised by a CRE (Lieut-Colonel J P Haugh, RE and later Colonel J C P Tosh, MC) and specially selected staff.

There were AFV ranges and extensive Ammunition Depots some road served, two served by rail only. One rail served ammunition depot was constructed entirely underground involving extensive mining operations. All were situated in sparsely populated parts of Britain, a sparseness due basically to lack of water and in consequence posing difficult water supply problems.

Another water supply problem arose at the Faslane military port and the Admiralty establishment at Rosneath on the Gareloch. A dam under construction but only just commenced was taken over from a water supply authority in Dunbartonshire. The dam was of no great length but was about 100 ft high. Located at Auchengaich in wild unpopulated country civil labour and contractors could not be employed. The work fell to a number of Royal Engineer Companies and prisoner of war labour. The Italians had to be withdrawn because of the severe climate; towards the end good work was done by Germans.

The Northern Line of the London Underground between Mornington Crescent and Euston Station was penetrated by a bomb which also fractured a large sewer above it. What was left of the Tube became the sewer; the mess was indescribable. Following an appeal from London Transport, Tunnelling Companies RE were moved in, establishing their headquarters and accommodation in waiting rooms on Euston Station. After many weeks of arduous work in unpleasant conditions the Tube was repaired and the line restored.

OVERSEAS

DFW was responsible for the Works Services at places abroad where there was no field army. This description could be misleading. For example for quite long periods it included Gibraltar and even Malta during the siege. At the former, memory recalls particularly water supply, quarrying for the runway, ventilation of the tunnels, precautions against blast and accommodation for the apes. The garrison had requisitioned the apes quarters for other uses which resulted in desultory and seemingly endless correspondence about who should be debited with the cost of the alternative accommodation. At last the finance branch in the War Office relented and agreed to pay. The telegram announcing the decision reached the Rock the day following the Governor's decision that the civil government would pay. Perhaps the successors of the War Office and the Colonial Office are still writing to each other about that! In Iceland, the Faroes, the Azores, the Carribbean and the Falkland Islands, climate was a prevailing factor. In the Azores so benign that work was finished well ahead of time. In the Carribbean, where work was by civil contract, so enervating that one got the impression that little was ever completed notwithstanding the enthusiasm of the two CREs who found travel between the islands, sometimes by sailing schooner, slow and uncertain. Climatic conditions in the Faroes and Iceland although quite different from each other could both be described as dreadful.

The Falkland Islands expedition deserves special comment. The force of 2,000 men and 727 Artisan Works Company RE (Major J D Beresford, MC, RE) left for for the Falklands in August 1942, their object to deter the Japanese from using the islands as a base for naval operations in the Atlantic. Engineer intelligence was sparse. It was known that snow falls every month in the year but January, and that there were adequate supplies of sand and aggregate but little else. By a curious coincidence the writer of this article acquired a valuable piece of intelligence spending a few hours one Sunday, standing as godfather at a christening in Grantham Parish Church, when he met a member of the staff of Aveling Barford. He of course knew nothing of the expedition, but recounted with some pride how his company had supplied four steam rollers to the government of the Falkland Isles with fire boxes modified to burn sheeps' hooves.

The Commander of the Force learning that there were foxes on the Islands proposed to provide recreation by taking hounds with him. Hearing of this the Governor sent a peremptory telegram forecasting that the fierce breed of sheep dogs on the islands would tear the hounds to pieces on their first day out!

The work consisted of erecting 325 × 16 ft *Nissen Huts* and 700 bays of 24 ft span *Nissen*, a great deal of land drainage, and the provision of the usual services including a 185 kW power station.

Their work finished, 727 AW Coy RE, less a cadre left behind for maintenance, returned by sea to the UK. The ship put into Montevideo with strict orders that no soldiers were allowed ashore. Major Beresford obtained permission to see the Ambassador and on the strength of his pleading and assurances of good behaviour the order was rescinded. Long before the Company arrived home the E-in-C received an eulogistic letter from the Ambassador praising the conduct of the Company and saying how much they had impressed the Uraguayans.

STATISTICS

Statistics make dull reading but a few are necessary to give perspective to this account. From 1939 to 1945 the expenditure on Works Services at home (excluding Fortifications and Engineer Stores) amounted to £313 million. Civil building labour employed varied from 52,800 in 1942 to a peak of 77,800 in 1943 falling away steadily to 17,400 in 1945.[10] There are no figures available for military labour which was extensively used consisting mainly of Artisan Works and General Construction Companies RE supported by Pioneer Corps and Italian and German prisoners of war. Military and civilian staffs in Commands rose from 8,000 to 15,800. Figures for DFW's staff are not available but except for a small reduction in 1942 they varied very little from then onwards. This happy situation derived partly from intensive standardization already mentioned coupled with the maximum delegation to Commands permitted by the financial authorities.[11] It was also due to the splendid performance of the Policy Planning Branch (FW2 later E6) of the Directorate so ably established and developed by Lieut-Colonel E S de Brett (later Brigadier E S de Brett) and his staff[11] supported by a completely new Branch E Stats (Major A G Woods) responsible for the collection and dissemination of statistics.

UNITED STATES ARMY

More than half the work organized and executed was for the United States Army. Variations in professional practices, different outlooks of an expeditionary force on foreign soil from those of an army in its home territory, different standards of living, confusing differences in nomenclature were always apparent and could have been the seeds of discord. That there was none of longstanding was due to the tact and forebearance of those concerned in both armies and particularly to Colonel (now Brigadier-General) Paul Berrigan C E of the United States Army who was in charge of the works organization of the US Forces. His high professional competence and sound judgement coupled with a placid and friendly disposition removed innumerable potential difficulties.

CONCLUSION

During the War the Works Services were subjected to dramatic, drastic, and unforseen impacts. In 1940 the sudden return of the BEF from France, then the complete reorganization of the Works Services which was barely started when in December 1941, following the Japanese attack on Pearl Harbour, it was decided that the Works Services should be responsible for all the works needed to accommodate an American expeditionary force of more than a million; this in addition to the two million UK and allied forces already in the country. Finally the massive preparations for the assembly and embarkation of the allied forces for the assault and landings in Normandy. Notwithstanding these impacts, expenditure was controlled, conventional competitive tendering maintained, technical standards were high, completion was on time and overall costs were within estimates.[12]

With all this proof of ability behind us it is sad to think that the Works Services as we knew them are no more. There may have been good reason or strong pressure for the change but it could not be due to lack of achievement. From 1941 to 1945 the Works Services carried out "the biggest works undertaking ever launched in this country".[13] There were no national scandals, no public enquiries; a proud record for the Corps.

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2 Ibid, p 26

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6 Mallory and Ottar, *Architecture of Aggression*, published by Architectural Press 1973

7 Ibid, pp 190, 191

8 Ibid, p 197

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10 Buchanan p 95

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Explosive Welding

CAPTAIN D M ADAMSON, MA, C ENG, MICE, MIHE

INTRODUCTION

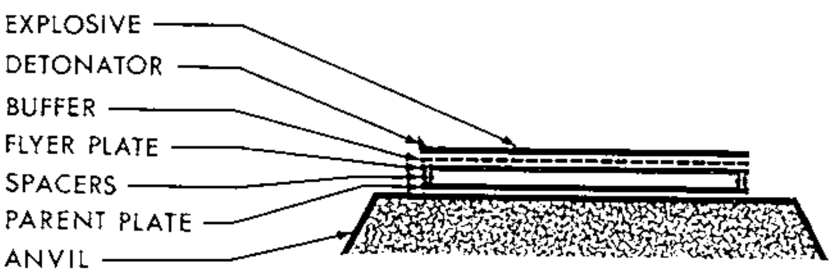
MAN'S use of metals has been a measure of his capacity for destruction on the battlefield. Armies have demanded more and better metals and utilization of those metals to improve their protection, mobility and fire power. For centuries the metals used were limited to iron and steel, but the last three decades have seen a new and greatly improved range of metals and metal alloys. Unfortunately, these improved qualities have been offset by serious problems in achieving good metal joints.

JOINING METALS

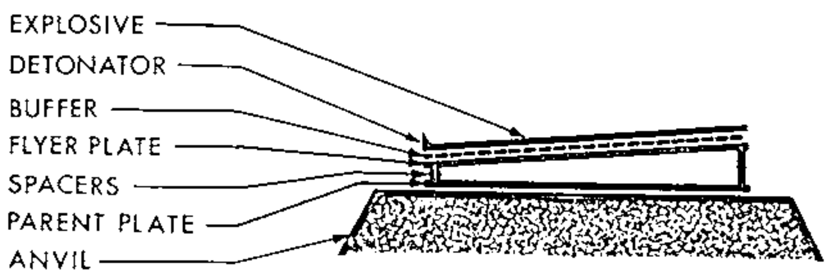
Mechanical and Metallurgical Joints. In their early days iron and steel weapons, such as cannon, were cast in one piece. Later, separate castings were joined together mechanically, using rivets or bolts. Fusion welding, which made possible continuous metallurgical joints, has now almost replaced mechanical joints in military weapons. During fusion welding there is a rapid infusion of heat to melt the metal surfaces which are to be joined. In many of the recently developed metal alloys, such severe heat cycles can reduce both strength and toughness; in a spring steel, for example, fusion welding may reduce its tensile strength by 90 per cent. Further, fusion welding is unsuitable for welding metals of substantially different boiling points and for joining large surface areas.

Solid State Welding. The earliest welding techniques of 5000 years ago did not involve fusion. The surfaces to be joined were thoroughly cleaned and then hammered together until there was sufficient diffusion of atoms to produce an effective bond between the surfaces. This is a solid state welding process. It fell from fashion when fusion welding became popular. However, the art has recently been recalled because it can be used for many metals unsuitable for fusion welding. One of the most promising forms of solid state welding, known as explosive welding, uses a sheet of explosive instead of the blacksmith's hammer to bring the metals into close contact.

Applications of Explosive Welding. Following intermittent research during the last twelve years, industry has been developing several explosive welding techniques, notably the plating of metal sheets and tubes.



a. PARALLEL PLATES



b. ANGLED FLYER PLATE

Photo 1. Arrangements For Explosive Welding of Plates.

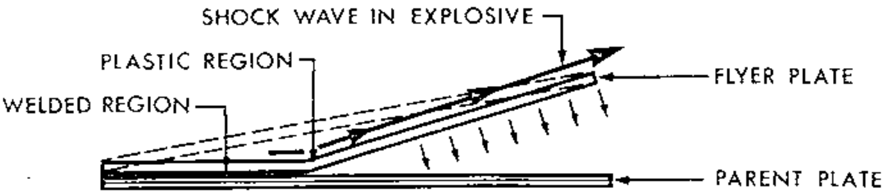


Photo 2. Geometry of Flyer Plate Movement During Weld.

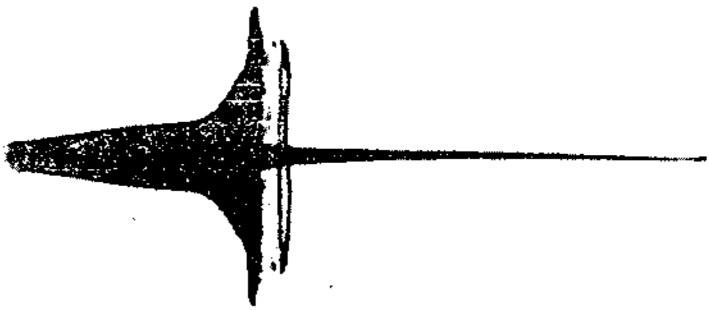


Photo 3. Metal Jet from a Shaped Charge.

AIM

The aim of this article is to describe the process of explosive welding and its possible military application to the welding of the zinc/aluminium alloy known as Zam.

THE MECHANISM OF EXPLOSIVE WELDING

The Development of Explosive Welding. It is not clear who first discovered that metal surfaces could join metallurgically if brought into contact during an explosion. During the First World War it was noticed that shell fragments sometimes stuck surprisingly well to steel plate. The first technical reference appears to be that in the journal *Metal Progress* of 1944 in which L R Carl describes how an exploding detonator caused the fusion of two nearby metal discs. In 1957, explosive welding was again achieved accidentally, in this case by an American called Philipchuk who noticed a wave pattern at the interface of the welded metals. Interest in this wave pattern led to considerable research into explosive welding in America and in some European universities. This research was related to the similar detonation mechanism of conical shaped charges.

The Solid State Bond. When two perfectly clean and atomically flat metal surfaces are brought into close contact then the inter-atomic repulsive and attractive forces will reach equilibrium at such an atomic spacing that the energy of the system is minimized. The interaction between the crystal lattices will bond the surfaces together. The strength of the bond will depend on the crystal lattice structures, and on diffusion and recrystalization: these are functions of temperature and pressure.

Explosive Welding Techniques. (See Photos 1, 2 and 3.) In its simplest form the two plates to be welded are placed horizontally with the lower plate (the parent plate) sitting on a large base (the anvil) and the second plate (the flyer plate) held a few millimetres above it. Alternatively, the flyer plate may be held at an angle to the parent plate. A sheet of explosive is laid on top of the flyer plate and then detonated from one edge (the leading edge). The advancing shock wave progressively thrusts the flyer plate down on to the parent plate. Simultaneously, a high velocity jet of what is thought to be either molten or particulate metal is shot from the junction of the plates among the approaching surfaces. (This mechanism is a two dimensional form of that produced by the collapse of the cone in a hollow charge, see Photo 3.) The jet so cleans the surfaces of the plates that they weld together under the high pressure and temperature caused by the shock wave of the explosive. The metal near the joining surfaces acts as a fluid and takes up a wave form by a mechanism not yet fully understood. The amplitude and frequency of the wave increase in the direction of the shock wave (within limits defined by its velocity and the nature of the metals). Thermodynamically, the shock wave front can be considered as an adiabatic compression lasting about 10^{-7} seconds over a width of about 5×10^{-9} metres.

Types of Explosive Used. Research workers differ widely in their selection of high explosive, some using a modified form of hexamine (RDX) with high detonation rates and others recommending explosives which produce slower shock waves. The explosive must have enough energy to stress the flyer plate beyond its yield point, but an excess of energy causes melting, distortion and fragmentation. Some excess energy can be absorbed by a buffer between the explosive and the flyer plate or by holding the flyer plate at an angle of up to 30° to the parent plate. As a general rule, the flyer plate should be angled if the detonation velocity of the explosive is appreciably higher than the sonic velocity in the metal plates being welded.

CIVILIAN APPLICATIONS OF EXPLOSIVE WELDING

Because of the economic potential of explosive welding many details of its practical applications have been considered to be commercial secrets and have not been published.

Cladding of Plates. There has long been a demand for sheet metals, usually steel, to be clad with another metal such as brass or stainless steel. Cladding by fusion welding is unsatisfactory and very difficult, but successful cladding by explosive welding has been reported from many western and communist countries. For example plates 5 × 2 m have been clad with up to 5 mm of stainless steel. In most cases, low explosives have been used, with the flyer plate parallel to the parent plate. Separation of the flyer plate has been achieved by suspending it by threads or by sitting it on polystyrene spacers or on a jet of air.

Cladding and Joining Pipes. (See Photo 4.) The cladding of tubes by explosive or implosive welding is achieved by detonating a tube of explosive against a flyer tube of the cladding material. It is necessary to position a stiff anvil tube on the opposite side of the parent tube. One case reported involved patching a perforated heat exchange pipe buried some 10 m deep in some reinforced concrete in a nuclear power station. A copper tube with a tiny explosive charge inside was lowered down the pipe by a thread. The charge was then detonated so that the copper tube was welded out on to the perforated pipe, thereby sealing it.

In joining up pipes into a pipeline it is difficult to get access to the joint area for fusion welding if the pipeline is buried. The British Gas Corporation has reported successful explosive welding of pipes carrying fluid at pressures up to 0·7 MN m^2. The pipes being joined are welded together inside a sleeve.

Joining Cables. Successful explosive welding of a broken cable inside a sleeve has been demonstrated: this technique has been of interest to those responsible for repairing broken power cables or steel wire ropes.

Welding of Layered Aluminium and High Tensile Steel Mesh. Research is being carried out in Belfast University on the explosive welding of alternate layers of aluminium and high tensile steel mesh. The material is strong, tough and relatively light.

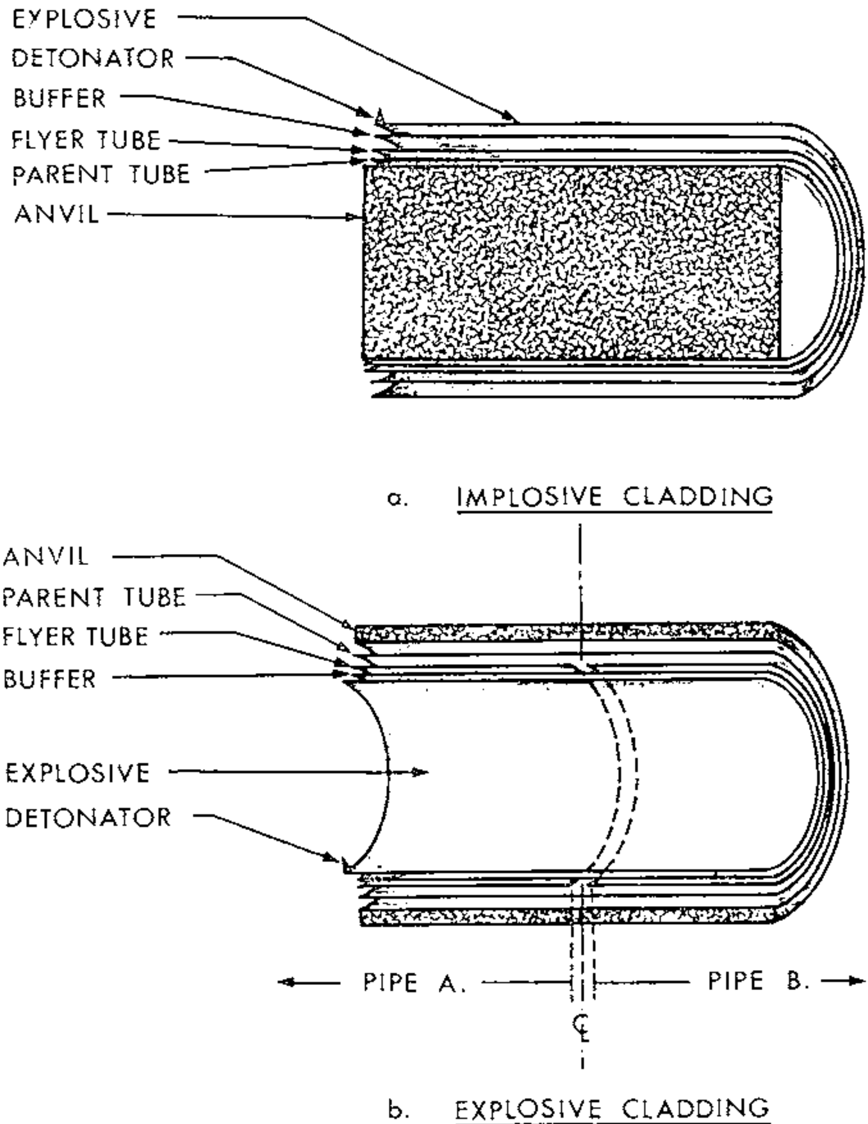


Photo 4. Cladding and Joining of Tubes and Pipes.

THE REQUIREMENT FOR EXPLOSIVELY WELDED ZAM

Zam is a superplastic alloy of zinc and aluminium, with some copper and magnesium as alloying metals. It contains equal proportions by volume of face centred cubic and close packed hexagonal structures, each in equinoxed grains of about 1×10^{-6} metres. At room temperatures and a strain rate of $3{\cdot}3 \times 10^{-3}\ S^{-1}$, Zam has a tensile strength of between 290–500 N/mm² depending on its previous heat treatment, with elongation between 12–18%. The corresponding fatigue strengths at 10^7 hertz are 105–135 N/mm². The modulus of elasticity, E, varied within the range 70–100 GN/m². At room temperature, ductility is about 8% and is about 1,000% at 250°C. A shock wave will propagate at a velocity of c_{el} m/s, where

$$c_{el} \doteq \frac{E}{\rho} \qquad \text{where } \rho = \text{density} = 5{\cdot}29\ \text{g/cm}^3$$

$$\doteq 4\ \text{km/s}$$

The value of c_{pl}, the velocity through plastic Zam may be derived from the relationship:

$$c_{pl} = c_{el} \frac{1 + \mu}{3(1-\mu)} \text{ where } \mu = \text{ Poisson's Ratio}$$

Typically $c_{el} = 1{\cdot}3\, c_{pl}$. Because elastic waves are propagated much more quickly than plastic waves, a shock wave is an ideal elastic-plastic material will not be stable at the elastic/plastic interface but will degenerate into two shock waves. This effect could affect the thermodynamics of a phase change in the weld region of explosively welded Zam.

It has been required to develop a technique for welding Zam to itself and to aluminium alloy. After completing a contract in Nov 73, the Welding Institute reported that Zam could be butt and fillet welded by closely controlled conventional MIG and TIG methods, but that shallow bonding and inclusions were noted. No attempt was made to weld large surfaces together.

EXPERIMENTAL EXPLOSIVE WELDING OF ZAM

Experimental explosive welding of Zam was carried out at RMCS Shrivenham, during October and November 1974 and the results were reasonably successful (see Photos 5–9). Intimate wave-pattern welds were achieved between Zam and Zam and between Zam and an aluminium alloy using two types of explosive. Detonation rates probably as slow as 2·5 km/s were achieved using a 1·5 mm thick layer of 8:1 ammonium nitrate:diesel (AFNO). Fast rates of detonation, 8·2 km/s, were achieved using SX2 service explosive. Both parallel and angled flyer plate arrangements were used, with different forms of buffer between the explosive and the flyer plate. The strongest welds were achieved using ANFO in the parallel plate, but there were even fewer inclusions using SX2 with the flyer plate angled. (When this angle exceeded 1:5 the plates were blown to pieces, the optimum angle being related to the relative velocities of detonation and the shock waves through the plates.) There were very narrow pressure/heat affected zones, these could probably be eliminated by reducing the explosive energy, and in any case the welds appeared to be very strong. The welds could be seen clearly under magnification of × 70 to × 1100, especially under cross polarized light using Nital as etchant. In only one weld was there evidence of shear cracking. It is possible that a phase change occurred near the weld.

In many tests there was unacceptable plate buckling, but this was reduced in the later tests. There was little buckling when the parent plate was thicker than a few millimetres or when a buffer of 4 cm of water in polythene bags was used. Variables such as explosive and buffer thickness and flyer plate angle were fixed pragmatically, as they have been in civilian research.

Attempts were made to weld a patch of Zam to an aluminium alloy by an annular weld. Little success was achieved because, in spite of multiple initiation, converging shock waves around the annulus blew the flyer plate off the parent plate and also deposited inclusions.

CONCLUSIONS

The need for solid state welding is already considerable and will increase with greater use of high performance alloys. Explosive welding is a convenient form of solid state welding and has proved itself to be successful for industrial tasks such as cladding plates and joining or cladding pipes. There is likely to be a military requirement for welding sheets of Zam to itself and to an aluminium alloy. This has been achieved with reasonable success using the technique of explosive welding. Strength testing of explosive welds of Zam—Zam and Zam—aluminium alloy have shown the welds to be strong and tough, although no evaluation has yet been made of whether the shock loading of Zam during the explosive weld degrades its fatigue strength nor of any phase changes that may occur in the weld region.

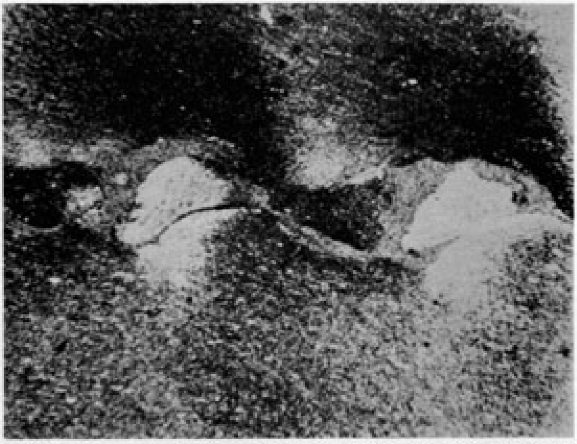


Photo 5. DETAIL OF WELD OF ZAM TO ZAM using AFNO with cardboard buffer and parallel flyer plate. This weld contained inclusions but was nevertheless strong because of the large amplitude of the interface wave.

Magnification × 70 approx

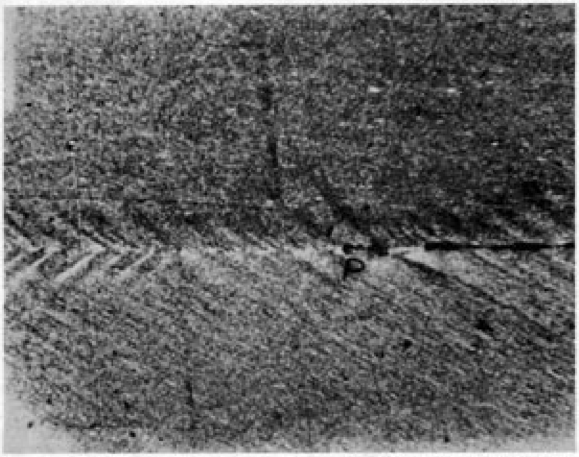


Photo 6. PART DETAIL OF WELD OF ZAM TO ZAM using SX2 explosive with timber buffer and flyer plate angled at 1:6. The weld extends as far to the right as point P.

Magnification × 70 approx

Explosive Welding (5 & 6)

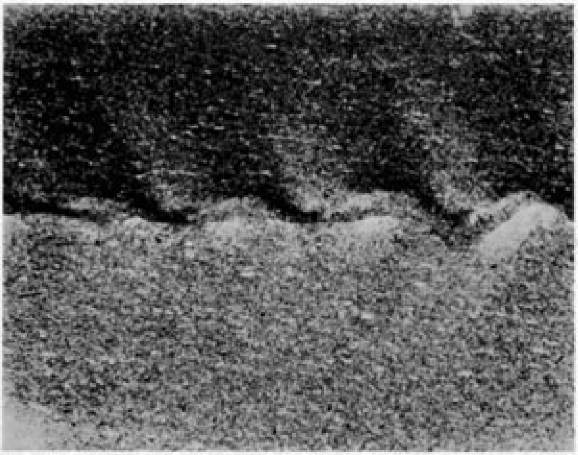


Photo 7. DETAIL OF WELD OF ZAM TO ZAM using SX2 explosive, 26 mm buffer of timber plus cardboard, and a flyer plate angled at 1:6. Note that the amplitude of the interface wave increases in the direction of the weld from left to right.

Magnification × 70

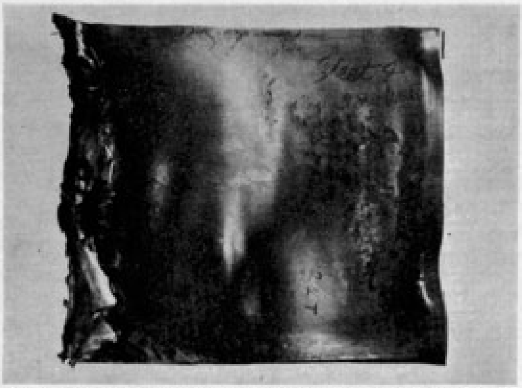


Photo 8. WELDED ZAM PLATES, 150 mm × 150 mm × 1·5 mm using SX2 explosive with 4 cm of water as buffer and flyer plate angled at 1:10. Initiation using No 6 detonator and a lump of PE was from the left.

Magnification × 0·3

Explosive Welding (7 & 8)

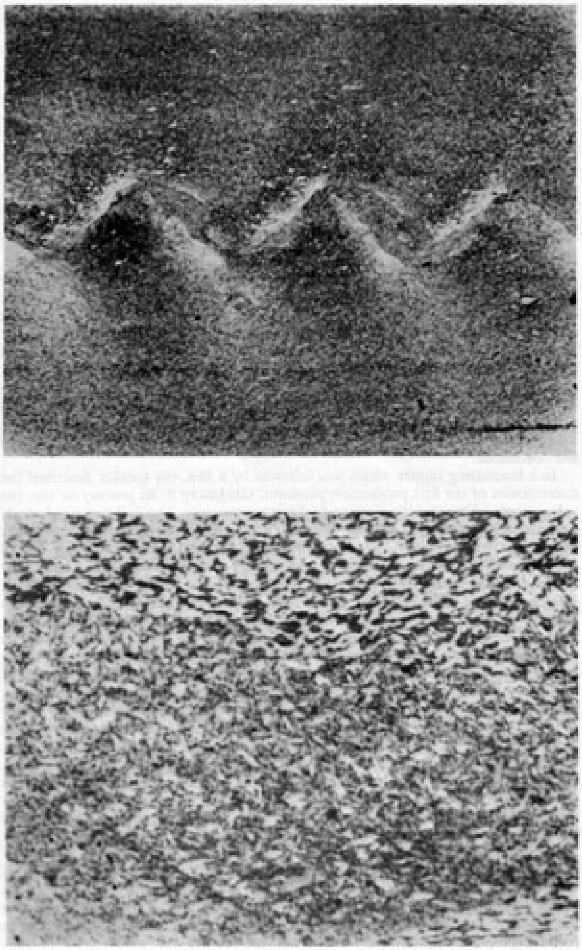


Photo 9 (a) and (b). DETAIL OF WELD IN PLATES SHOWN IN PHOTO 8. Note the area in the interface area in which the presence of a phase change is suspected.
Magnification (a) × 70 and (b) × 1100

Explosive Welding (9a & 9b)

Joint Professional Meeting
The Development of a North Sea Oilfield

COLONEL T G L INGRAM, ERD, BSc, C Eng, MICE, MIMech E, a member of the Engineer Specialist Pool, T and AVR, and British Petroleum's Project Manager for the Development of the Forties Field, presented a paper on the development of the Field to a Joint Professional Meeting of the Institution of Royal Engineers, the SE Branch of the Institution of Mechanical Engineers and the Society for Underwater Technology, at Chattenden Study Centre on 6 February 1975. A number of members of the Southern Association of the Institution of Civil Engineers also attended.

Major-General J C Woollett, CBE, MC, President of the Institution of Royal Engineers, was in the Chair.

Colonel Ingram traced the exploration and development in the North Sea since 1960 and, having set the scene, described how oil was discovered in the Forties Field in 1970. Further exploratory drilling in 1971 confirmed the presence of a field with a potential of at least 400,000 barrels a day, equivalent to 20M tons a year, or almost a fifth of the present UK demand. The field is some 110 miles ENE of Aberdeen and the water depth averages 400 ft. The sea bottom consists of a very soft material, about 70 ft thick, overlying stiff clay. Oil is found in the sedimentary beds some 8,000 ft below sea bed level. To meet the production potential some 100 or so wells will be required, these will be directionally drilled and operated from four platforms. The engineering techniques of the project have been dictated to a large extent by the site conditions.

In a fascinating lecture which was followed by a film, the speaker described the construction of the first production platform, Graythorp 1, its journey to site, the subsequent sinking and the erection of the superstructure. The first two rigs frames, each some 20,000 tons in weight, were manufactured in improvised graving docks adjacent to the sea, one on Teesside near Hartlepool, and the other at Nigg Bay in Scotland; the heavily braced structures were built up from exceptionally large tube sections of high yield steel, up to 2½ in thickness and 14 ft in diameter; the design was changed on later platforms to use steel up to 5 in thick at node points, thus allowing the omission of internal stiffening. Built on their sides, with 30 ft diameter flotation tanks fitted on the lower members, the rigs were eventually floated out to sea after flooding the graving docks and removing their concrete gates. Having waited for suitable weather conditions the rigs were towed out to their predetermined locations on the Forties Field, and were then tipped to a vertical mode and sunk; this was achieved by computer controlled and radio transmitted operation of valves to flood the flotation tanks and legs according to a specially arranged sequence. The tanks were then returned to the graving docks to be used again for later platforms. Once resting on the bottom, the rigs were pinned to the sea bed by driving piles, 325 ft long and 54 in diameter, down from the bottom of the legs. The superstructures on top of the rig frames were built on land in a number of modules; these modules were later shipped out to the site and lifted into position using a specially constructed heavy lift crane ship, the *Thor*. The heaviest module was over 1,900 tons, a clear record for an over-water lift.

When finished, the platforms (some 175 ft by 170 ft in plan) will have three floors with drilling and gas separation equipment, accommodation for 100 personnel, a power station with three 4 MW gas turbine generators, gas turbine pumps to pump the crude oil ashore, all the necessary control equipment, a helicopter deck and so forth. Each platform will have 27 wells.

The laying of the 32 in diameter submarine pipeline between the oilfield and the shore cost some £640,000 per mile. The pipes which were precoated with concrete, 2½ in thick, were laid from special lay barges, working from both ends at once;

many problems were encountered in this work on account of the great water depths, far deeper than those in which pipes had been laid before. The pipe had to be tensioned during laying to keep the stresses within acceptable limits; this requires the barge to be continually pulling against its anchors. Particular problems occurred with buckling and the propagation of a buckle wave along the line; steel collars had to be fitted in the deeper sections to limit this effect.

At the time of the meeting it was expected that the first platform would be completed, allowing drilling to be started, by August this year (1975); once the first four wells have been drilled, pumping ashore of the crude oil can begin. Everything else should by then be ready for the oil to flow straight on to Grangemouth. On the costing side, the estimate for platforms and pipelines totals £535M with an additional £100M for drilling of the production wells; the vast majority of the cost will have been incurred offshore. Expectation is that the commercial life of the field will be about twenty five years, but this may later be increased by improved extraction methods.

The discussions which followed included a number of wide ranging questions, indicative of the interest of the audience; (some 220 attended). In answer to a question of the "national" aspects of offshire oil technology, Colonel Ingram said that it was now truly international; in the early stages there had been a preponderance of US experience and know-how, except for submarine pipeline construction which was mainly a British area of development. The question of possible wells in deeper water had been raised; Colonel Ingram was of the opinion that at this stage, and indeed in the foreseeable future, depths greater than about 1,000 ft were not really practical. On the subject of pipeline problems underwater, he said that the pipeline had been laid from both ends and was joined by an above-water weld; excess length to and from the surface had then been lowered to the sea bed to form an S bend. A 32 in line encased in concrete can only be raised if empty; the line had in fact been accidently flooded twice during construction; the first time it took twelve weeks and the second time eight weeks at £3M each time to carry out repairs and empty it again. A questioner asked about the advisability of using floating production rigs; it appeared that although viable they were not very satisfactory for multi-well operation, since storm conditions made the difficult operation of "closing off" the wells even more hazardous at a critical time. Corrosion and possible damage to the laid lines was not really a problem; shot blasting and painting, impressed current cathodic protection, and burying of the pipe line were all applied to protect the lines; in this area technology was ahead of the problems. Asked to say more about the pinning down of the platforms, Colonel Ingram explained that each was anchored by thirty-six driven piles; twelve of these were floated out (in the guides) with the structure and were released when the platform was correctly positioned; the piles were steam driven through a long chaser; the average driving time was twenty-four hours for each pile cycle. The question of valves on the submarine lines was raised; without valves there would be a considerable line fill volume of oil which could in theory be leaked. Colonel Ingram suggested that this was an over-simplification of the problem; each and every valve was a potential source of leaks in itself; the line would be buried, and was by any standard well protected from physical damage. If however a major leak did occur, the instrumentation was such that the lines would be closed very quickly at both ends; the head of sea water would minimize leakage as the line pressure would quickly drop until it was equal to that of the "sea head"; no valves had therefore been fitted on the submarine line.

Admiral Sir Edmund Irving, founder member and Vice-President of the SUT, in proposing the vote of thanks to the speaker and to the Institution of Royal Engineers, pointed out that the development of oilfields underwater was a vast subject, and that although of necessity parts of the presentation had had to be abridged because of the short time available, the subject had been deepened in the discussion, and all must have been impressed by the challenge accepted by engineers to combat the massive forces of nature.

After the meeting the bar and buffet supper attracted the attention of the majority of those who attended. In the very late hours Colonel Ingram was still answering detailed questions on some of the "specialized fields" of welding, stress relieving, gas regeneration, rich and lean gas refrigeration, tension devices on crane lifting tackle, fire precautions on double purpose (drilling and operating) platforms, connections, contractural liabilities, skirt piling and sledge burying of pipe lines.

Correspondence

Lieut-Colonel R F H Cole RE
STRE (Malta)
BFPO 51

GARRISON ENGINEERS

Sir,—Surely the title "Garrison Engineer" is outdated? Can we not find a more appropriate title? I have heard a number of suggestions but so far all have had some snag—unfortunate abbreviation is the most usual. Perhaps we don't even need a distinctive title?—Yours sincerely, R F H Cole.

L J Cardew Wood
Oatlands Park Hotel
Weybridge, Surrey
16 March 1975

CENTENARY OF THE INSTITUTION OF ROYAL ENGINEERS

Sir,—The spirited article by Brigadier Lacey in our March *Journal*, encourages me to send you the following true story which you may care to print.

My uncle, the late C Whitcombe was, I understand, when he died, the senior member of the Institute of Civil Engineers. He was a formidable little man with bushy white eyebrows and a shock of white hair. He was not much over 5 ft in height; I am over 6 ft but always felt about 4 ft when I went, by command, to dine with him. He retired as Chief Engineer of the Madras and Southern Mahratta Railway, before I was born, and came back to the UK to become Chairman of several Companies.

When I returned from India in 1929, at the age of thirty, he sent for me and gave me the necessary papers to apply for membership of the Civils. When I protested, "But, Uncle, although I took my ACGI in Civil and Mechanical Engineering—my occupation is now that of a Mechanical Engineer, should I not join their Institution?" Quoth my uncle, "If there *is* such an Institution, I have never heard of it. There are only two Engineering Institutions—the Military and the Civil. Since you are not a Regular Army Officer, you will join the Civils and they will give you all the technical information that you are ever likely to require."

So I joined the Civils—and *then* the Mechanicals!—Yours sincerely, L J Cardew Wood.

Brigadier S E M Goodall OBE ME
Tumpy Green Farmhouse
Gossington
Slimbridge, Glos

REORGANIZATION OF ENGINEERS IN BAOR

Sir,—I hesitate, as a retread, to comment on the two excellent papers by David Seekings and Captain MacArthur in your March issue.

Every time however that I read or hear anything on reorganizing the Engineers in BAOR I am reminded of the gunner who said to me: "The trouble with you sappers is that you are always reorganizing. By the time the rest of us have worked out the last one you are at it again!"

Now we sappers know that gunners are not always right but I suspect that this one did have a point. Since 1949 we have concentrated, regimented, dispersed, upranked and performed every act of reorganization possible. Each time it happens we have to seek out and cement new affiliations with other arms, revise our communications and train to a new pattern.

The early battles are going to be the ones which decide the issue, should war ever come. If they don't then the graduated response will have failed (or is it now The Tripwire?). The three fundamental factors which will make engineer support fully effective in these early stages are just those three things which we unsettle on reorganization, namely good and swift communications, close links with other arms and headquarters and a well trained team.

Although, at the time, I much regretted the move to uprank the sapper at Brigade HQ, and still think that our rank to appointment structure in the Army is too rigid, I am now sure that it was right and that any new organization should preserve this.

I am now too much out of touch to attempt further comment except to say that with modern communications, well trained troops and a sound, but not necessarily the best organization, the Engineers in the Division should be able to adapt to any situation.—Yours sincerely, Steve Goodall.

Major W M Crawshaw RE, C Eng, MI Mun E
4 Amherst Redoubt
Brompton
Gillingham
Kent

FUTURE ENGINEER ORGANIZATIONS IN 1 (BR) CORPS

Sir,—It is a little unfair to comment post—Defence Review on the Seekings and MacArthur articles in the March *Journal*. Whatever engineer organization emerges to support the four divisions of the Review is going to appear very different from today's, and the time remaining to us before its implementation is too short to permit anything other than minor re-organization within the existing order of battle. However, both articles remain very relevant to both the short and long term situations. In the short term, there remains scope for some stream-lining of the present organization. In the long term, the articles and the discussion arising from them must have some effect on the shape of the future 1 (BR) Corps Engineer Organization. Regrettably, security still forbids the open discussion of the more intriguing aspects of the Review. I believe that the following principles should guide our approach to the problem:

(a) Leave well alone if possible (Petronius Arbiter).
(b) Go for the simplest command structure (*KISS* principle).
(c) Establishments and organizations must be dictated by the tasks we have to perform, and optimized for the primary task.

On Leaving Well Alone

The APC field squadron and its sub units are about right for their tasks. Taking into account the realities of BAOR life there is no scope whatsoever for any reduction in establishment of the F echelon. Loss of bodies for the demands of courses, trickle leave, centrally employed and so on means that even on today's establishment it is, to frequently, difficult for a field troop to deploy on exercise a full MGB build team. Any proposed reduction, particularly at field troop level, will produce a sickly sub-unit incapable of training as an entity. If Captain MacArthur's slimmed down squadron were adopted, I fear it would be compelled to train on a two-troop basis. However, I agree that there is scope for a re-appraisal of the field squadron echelon organization. While not wishing to be dogmatic about who should actually own the men and vehicles making up the administrative support for the field squadron, at least in the field, the regiment should be responsible for combat supplies as well as engineer stores and control of squadron A2 should be centralized.

"Leave Well Alone" also applies to the present system of the RHQ co-located with brigade HQ. It makes efficient liaison and advice possible at two levels—Commander to CO, and Staff to Staff, and above all produces an engineer advisor to the Commander of the right rank. Parity with the Royal Regiment is not to be dismissed lightly! A squadron HQ unless reinforced, does not have the resources to give the continuous service required by the brigade.

On Simplicity

The present system has particular merits, in that all engineers in a brigade area are under the command of the CO of that brigade regiment. The potential exception is the armoured squadron, which has the unfortunate habit of developing into a "private army" if not kept on a tight rein. Both authors have seized upon its anomalous position in the present command structure. Having a previous vested interest, I entirely agree that the present organization is wrong, particularly in so far as the role of the squadron HQ is concerned. I believe that the right solution in the short term, i.e. that period during which some of the Centurion equipments run on, and the squadron remains at or about its present size, is a half squadron organization. Each half squadron can then operate under full command of a brigade engineer regiment. This is consistent with a principle which applies both for the short and long term; whatever command structure is adopted the CO should be able to control his armoured sub-unit direct, and not through an intermediate HQ.

The problems experienced with the armoured squadron today sound a note of warning for any proposals involving layering, of having two sorts of engineers—brigade and divisional—within the division. Major Seekings's proposal for a divisional regiment is excellent so long as its field squadron works behind the brigade rear boundaries; once it begins to undertake tasks in the brigade areas, bits of it must come under command of the brigade field squadron and we are back to the pre-1969 situation.

On Tailoring Organizations to Tasks

The primary task of the divisional engineers in 1 (BR) Corps is the execution of the obstacle plan. Tasks in direct support of battlegroups take second priority to this. It therefore follows that our organization should be geared to the requirements of the obstacle plan, and that arrangements for direct support may require a measure of *ad-hoccery*. The present organization reflects these priorities.

Perhaps we should take a long hard look at the classical grouping of a field troop in support of a battlegroup. Certainly the grouping is right for the advance and provides an adequate force for the immediate clearance of obstacles; but I would question its suitability for mobile defence. The capability of a single troop, with limited time available, and on its collective needs after completion of the obstacle plan to produce effective work is limited. The requirements of battlegroups for engineer support must inevitably differ; one may require a full field squadron, another a section of bridgelayers at one specific time, a third nothing at all. It follows that to dole out a field troop to each must result in uneconomic use of resources. There is nothing new in this point; control of engineers must be centralized at the highest convenient level, in this case brigade. I therefore declare myself firmly against the Seekings solution. There may be a false lesson emerging from the BAOR FTX scene here, in that the best way to ensure that engineers get a slice of the action on exercises has been to allocate an intergral sub-unit to each battlegroup. For real, with less running about (to avoid concentrated damage) and less of the notional about engineer tasks, a different picture might develop.

If we take away the concept of the permanently affiliated field troop, there remains the problem of channelling engineer support to the battlegroups. In particular engineer RHQ needs to know the requirements of the battlegroups sufficiently far in advance for engineer battle procedure to produce the men and the stores. This poses a requirement for engineer liaison, with, desirably, the capability of providing advice, and, ideally a command and planning function. An essential is that these facilities are available from the time of deployment and not merely after the completion of the obstacle plan. Since any command and planning capability will have to come from the field squadron HQs, the last essential rules out the permanent provision of this ideal.

The requirement for liaison and desirably advice remains. In the absence of officer LOs, the role could be filled (and has been—acknowledgements to Lieut-Colonel John Hill) by warrant officers or good quality senior NCOs. The LO would act as link man to engineer RHQ, give such advice as lay within his competence, and on tasking of a sub-unit in support of his battlegroup, would step down as the local engineer in favour of the sub-unit commander. There is a strong parallel with gunner support here; just as artillery fire is applied from outside the battlegroup at the call from a small party with the battlegroup so sapper effort does not have to live within battlegroup boundaries to be effective. The gains are in better use of manpower, better co-ordination of engineer tasks between battlegroups, fewer tasks half-completed, and an improved ability to hold and deploy an engineer reserve.

Conclusion

I believe that if we leave the field squadron alone (allowing for CET coming in) as the work unit, keep the present regimental structure with the armoured engineers embodied, centralize the echelons, and provide battlegroup liaison parties instead of affiliated troops, then we have the potential for short term stream-lining and a good steer for the long term.

Remember that one element must always be right and that is the customer. If a change does not improve the service, then it's not worth the effort.—Yours faithfully, Michael Crawshaw.

Memoirs

BRIGADIER K B S CRAWFORD

Born 23 May 1892, died 7 October 1973, at age of 81

KENNETH BREDIN SHAKESPEAR CRAWFORD was born in Madras the eldest son of Lieut-Colonel F J Crawford, IMS and Henrietta, elder daughter of Surgeon-General W S Murray.

He travelled widely in the course of his duties and all speak of his complete professionalism. He made time to become an Interpreter 1st Class in Italian and also learned to fly (he was equal first in the RE Flying Competition in 1938). Probably the biggest influences on his life were his two periods as a prisoner-of-war. He came through both of these severe and prolonged physical and mental tests with an even deeper understanding of people.

F H M writes:

"Calamitas virtutis occasio est"—Seneca

"I first met Ken Crawford in 1927 when he was my Company Commander in 33 Fortress Company RE at Fort Camden, Queenstown Harbour. An impressive figure, nearly 6 ft 4 in tall, dark and good-looking, he was respected and liked because he obviously knew his job, set high standards, and encouraged his subordinates to develop as soldiers, engineers and social animals.

Like most admirable men he was reticent about his own misfortunes, of which at that time the worst must have been participation in the siege and fall of Kut-el-Amara and the terrible four month 1,200 mile journey to a Turkish POW camp at Afyon, while still recovering from a bullet wound in both thighs.

When, quite by chance one day, I remarked on the horrors of a galley slave's life, his comment, made eleven years after Kut, was 'Oh, man can get used to anything.' He was to need that philosophy even more fifteen years later in his second captivity, this time under the Japanese.

That, after spending six years in two long stretches as a POW, he should remain mellow, mentally alert and physically fit until the last few months of his long life seems to have proved his point, though, as he would have been the first to admit, in this he was greatly helped by a remarkably happy family life."

THFF writes:

"It is from my school holidays at Catterick that I first remember Ken Crawford as a tall, impressive and friendly young officer, and still recall my disquiet when I heard that he had been a prisoner of the Turks, wounded withal in both legs.

When this quiet major arrived at Kirkee about ten years later, I had no inkling of what he must have been feeling at being once more with the Indian Sappers whom he had led so long and bravely in sand, heat and swamp—Crawford the first man to reach the Turkish parapet as his Sappers carry the redoubt with the bayonet. (Sandes).

Only much later did I come to see that the touching faith with which our men used to accept us all on first arrival was due to so many of our predecessors, typified by Crawford, who had led them till they fell, whether in France or Mesopotamia, or on many another field.

His old age was graced by the same dignity, kindness and courtesy as ever, without bitterness at his even more horrible captivity under the Japanese. He read and pondered, and published an anthology of other mens' flowers of wisdom, in the hope of sowing a seed or two in the minds of the young, and called it 'The Aspirant'.

Nothing less than extraordinary physical qualities could have brought him through alive; and seldom can an aspiring soldier of such great promise have had to draw so heavily on the strength of his own, unfailing, philosophy."

COLONEL D R CRONE, CIE, OBE, MSc, FRSA

Born 24 September 1900, died 23 November 1974, at the age of 74

(We are indebted to the Photogrammetric Society for their permission to utilize material from a Memoir, written by RCAE, and published in their *Photogrammetric Record.*)

Desmond Roe Crone, one of Britain's most eminent soldier-surveyors and a pioneer in the application of air survey to the mapping of large areas, died only four days after he had been honoured by election to Life Membership of the Photogrammetric Society.

Commissioned from "The Shop" in July 1920, he was appointed to the Survey of India after his Sapper training. His interest in air survey was excited by a period as official observer of the experimental air survey of Malda District in Bengal; and, whilst on UK leave 1928–29, he made a study of British practice in this field. In 1930 he was given charge of No 18 (Air Survey) Party at Peshawar, a unit whose responsibilities included mapping the North West Frontier for operations and intelligence. Crone worked energetically to improve the methods employed. He found that those he had studied under Hotine in England had limited application in this largely inaccessible country, with its sparse ground control, and he evolved an entirely original method of surveying using horizon oblique air photographs, later to become known as the "Indian Method". It was used to provide contoured mapping of much of the Frontier area. During this period Crone took part in the Khajuri Plain operations of 1930 and the Mohmand operations of 1933 and was a member of the Indo-Afghan Boundary Commission of 1932. He was also responsible for the air survey and military survey training of the officers of the Department.

During the Second World War he moved from the Frontier to the centre of the Survey of India's wartime activities at Dehra Dun, with Departmental responsibility for all air survey matters. He concurrently held the military post of DD Survey (Air) at GHQ with similar responsibilities towards India Command. In spite of this dual role, he still found time and energy to design the new base map reproduction plant of the Survey of India which, built in record time, became the principal source of map supplies to the Far Eastern and much of the Middle Eastern theatres of war.

In 1948 he retired from the Active List. He lectured in surveying at Witwatersrand and Queen's Belfast and was, for a time, in Ethiopia and then Aden on surveying duties. In 1969 he moved to Australia and more lecturing, returning in 1972 to settle at Carnforth in Lancashire.

Crone was a most versatile man with wide-ranging military and professional interests. In the late 1930s he was a strong opponent of the adoption of rectangular grids for military maps of India. He held that, for large continental areas, the resulting complications of multiple origins and overlapping grids outweighed the apparent simplification of computation in a rectangular coordinate system. In this rearguard action he demonstrated the flair for controversy which was a powerful element in his character. But contentious and irascible though he was, Desmond Crone was the kindest of men and the best and most generous of friends.

Outside his professional sphere he had many interests, especially gardening (at one time he cultivated a croft in Angus) and sailing. In 1928 he was navigator when *Ilex* came fifth in the Fastnet race and in 1934 he skippered her into third place in the Heligoland race.

To his wife Margaret ("Meg") and his three sons we extend our deepest sympathy.

RCAE

* * * * *

"SALLY" DEWAR

On 28 December 1974, peacefully, ELSIE, widow of Sandy, beloved of all who knew her in India and Britain

SUCH a brief announcement in the *Daily Telegraph* is indeed an inadequate obituary for one who will be remembered with affection and gratitude by many a Sapper, both British and Indian, and who, in the war years, did so much for members of the Corps.

Apart from coming "home" to England for school Mrs Dewar lived nearly her whole life in India, much of it at Monghyr in Bihar where, prior to the German innovation of the synthetic dyes, she knew that fabulous era of the indigo planters.

It was also at Monghyr on the Ganges, a hitherto "Passage to India" type of civil station, that there was established the war-time Eastern Army (later Command) Bridging School, an organization that Mrs Dewar, by then a widow, joined as its one and only WAC(I)—the Indian equivalent of the ATS. As her clerical ability entitled her to an immediate three stripes she was promptly christened "Sergeant Sally" by the small British community, and it was as "Sally" Dewar that she was known to the many Sapper officers who came to the school on courses or postings and to whom she dispensed unending hospitality, many of its recipients enjoying the peace of a "home" or the luxury of a long bath for the first time after months in the Burma *jangal*. There were also those who, after spells of sickness in the hot, moist, fever-ridden climate, spent a convalescent period in the comfort of her bungalow, ministered to by her excellent servants.

British other ranks enjoyed equal hospitality while the Indian Sappers, who formed the bulk of the staff, tended to discuss all their problems with her prior to approaching their own officers. In the town, where she ran a clinic, she was respected by all and it was never known just how many families she helped financially. Congress riots or the later post-partition troubles were no danger to Sally for, as it was always said in Monghyr, "no one would want to, or be allowed to, harm Dewar *mem sahibah*."

Many of the other local civilians were also extremely kind and hospitable to the staff and students of the school but it was always Sally who seemed to do the most and it was she who became something of a legend. Numerous Sappers will identify their war-time memories of Monghyr with evenings spent sitting in the peace and tranquility of her lovely garden or Sunday drinks in the cool of her bungalow, a bungalow built by she and her husband to replace the one that had collapsed, killing her aunt, in the great earthquake of 1934. To commemorate their Scottish ancestry the new bungalow had a thistle embossed on the concrete of the verandah canopy, and Sally used to tell how in order to enable the *mistri*, who of course had never seen a thistle, to get it right they had told him to make a leechi surmounted by a shaving brush. An instruction that he had regarded as just another example of the *Sahib's* well known madness. But it was indeed an excellent thistle.

Sally stayed on in Monghyr long after the war, but circumstances finally forced her to return to England and the eventual peace and kindness of a nursing convent. Here a few Sapper friends would visit her to talk over old times, and she could be assured that her kindnesses to so many members of the Corps, both British and Indian, was still remembered.

Last October a small gathering celebrated, with her, her eightieth and final birthday.

GH

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COLONEL SIR ALISTER J RANSFORD, KT, CIE

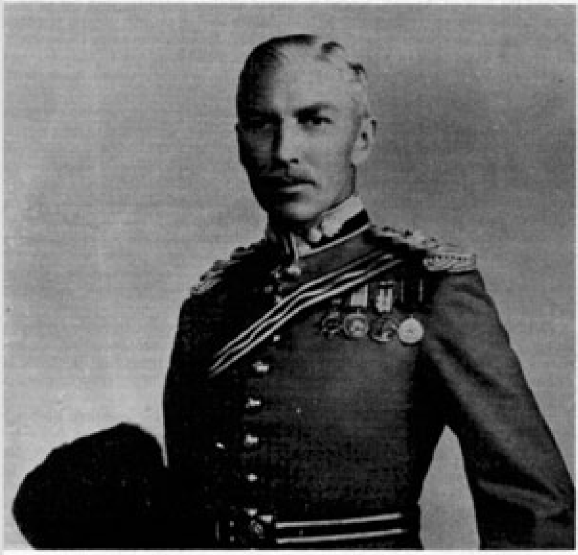
Born 5 January 1895, died 25 November 1974, aged 79

ALISTER JOHN RANSFORD was the second son and youngest child of a family of six born in Bath, to Dr T D Ransford, FRCS, LRCP, and his wife Florence Macalister. From his father he inherited perfectionism and concern for under-privileged people; from his mother his sparkling blue eyes, charm and wit. In 1912 he left Fettes, where he was an open scholar and entered "The Shop". He passed out 6th and became a "Sapper", just at the right time to assist in the training of "Kitchener's Army", at the outbreak of World War I.

A year later he entrained with "The First Hundred Thousand" (he remembered Ian Hay writing his novels while teaching English at Fettes). He joined the 9th Division Signal Service. He was appalled at seeing "the Jocks" digging trenches to bury cables in the mud, their kilts flapping on raw red knees. He served in France and Belgium throughout the War and was Mentioned in Despatches for the excellence of communications during the rapid retreat and advance in 1918. He finished with the temporary rank of Major. Most of his friends were killed.

In 1922, having been to Chatham and trained in electrical and mechanical engineering, he was appointed Garrison Engineer (E & M) Southern Command in India with Headquarters at Poona. There he threw himself into his work, but still enjoyed games in his spare time. In 1924 he was selected as Deputy Mint Master of HM Mints in Bombay and Calcutta—a post which had been held by Sapper officers since East India Company days.

In 1929 he was promoted Master of the Mints and he and his wife moved into



Colonel Sir Alister J Ransford KT CIE

Mint House near Ballard Pier, a building which had originally been part of the Royal Mint and used for stamping gold coins during the war. The huge whitewashed walls and concrete floors were soon camouflaged and the house was known as "No 1 India" for it became "a haven to many in transit with its ever open door, the kindly welcome and comforts for tired travellers arriving any time of day or night". Thousands have happy memories of visits during the years between 1929 and 1947.

The variety of the Mint work was fascinating—especially the building of an electrolytic refinery designed to extract silver from surplus rupees minted during World War I. It was the largest refinery in the world and recovered 20 million ounces of silver annually for twelve years. Alister was awarded the CIE in 1936 for meritious service.

In 1939, World War II brought tremendous pressure on the Mints to provide currency for Expeditionary Forces in all parts of the world east of Suez. The eighty-year-old equipment had to be replaced by more modern efficient machines and these were made in the Mint as those ordered from England did not arrive until 1944. Eventually the miraculous total of 5,200,000 pieces of coins of all denominations was achieved daily. Among other achievements Alister designed the security edge on rupees to prevent counterfeiting. Special machinery was made for this. He also prepared for the introduction of decimal coinage in India. He was knighted in 1946.

During his twenty-five years in the Mint a harmonious atmosphere prevailed throughout. "He was held in great esteem by his labour force of 3,500 workmen, 50 supervisors and 120 clerical staff" and one who had travelled described him as "the best Mint Master in all the world; a born leader who brought the best out of all of us".

A year after returning to Britain in 1947 he became Bursar at Loretto School in Musselburgh, near Edinburgh, where he stayed until 1959. Here he had the problem of repairing buildings whose upkeep had been neglected during the war. Floods in 1948 did not help. Fish were swimming in the gym! Wet and dry rot were a headache for years. At that time only a meagre sum was allotted for such work; the groundsmen's pay was little over £3 a week; rationed food was still in force. "Nothing daunted him; his efficiency was the admiration of all. He was easy to work with and had the gift of putting school matters in their true perspective. He did everything well from a wedding speech to playing golf" . . . wrote the Headmaster.

Alister joined the Catholic Church in 1967. The Abbot of Belmont, near Hereford, said: "I formed an abiding impression of his great charm, his kindness and steadfast faith and above all of his quiet courage which enabled him to look death in the face for six long years without crumbling, knowing he had an incurable disease."

"Few were such good company".

Alister had an ideal married life for forty-seven years with Torfrida (Walford) and left happy memories to all who knew and loved him. He set a high standard to follow for his son and daughter and nine grandchildren. His ashes lie with his family in Freshford Cemetery, near Bath.

LTR

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Book Reviews

THE NUCLEAR TRAP: AN ESCAPE ROUTE

ROBERT E WALTERS

(Published by Penguin Books Ltd, Pelican Series. Price 60p)

In this stimulating "paperback", the author, an American, claims that the development of the nuclear-powered "underseas ship", and in particular the navigation of the Polar Sea in 1958 by *Nautilus*, heralds a new era of strategic thinking.

The start point of the discussion, indeed the whole of the first part of the book, is the "Heartland Theory" which the author argues has been the basis of the Western concept of the nuclear deterrent. He then examines the main premises of the Theory and concludes that it is now mistaken and that other factors are more significant. Consideration of the new significant factors provides the foundation for the latter part of the book, "A New World Outlook". The central element is that the world is entering a new maritime era in which the oceans of the world will play an increasingly important role. The author looks to nuclear powered undersea ships, virtually immune from air attack, to provide the key to the future.

The arguments are imaginative and well presented, and the material is well referenced.

EEP

METRIC CONVERSION TABLES

(Published by Technical Press Ltd, Oxford. Price 50p)

These imperial to metric tables permit almost instantaneous conversion. The layout of the tables in a matrix form, rather like conventional logarithm tables, is excellent. This combined with a sensible grouping and seven digit accuracy makes the book a most useful addition to any engineers personal library.

EEP

MILITARY TRACTION ENGINES AND LORRIES 1858-1918

R W KIDNER

(Published by the Oakwood Press, Locomotion Papers No 82, price 90p)

It is regretted that this book contains a number of printing errors and omits much of the military *use* of steam traction engines. This is particularly irritating to Sappers who were the main users. In fairness the author has concentrated on the vehicles and their development, and not on the application, and he tells a fascinating story. He refers to Cugnot (1769), Gurney (1829) and Boydell (1839) but really begins in 1858 with the setting up of the Ordnance Select Committee. The book makes the point that, in the time scale covered, it was the military need which dominated development. It mentions the contribution of Lieut-Colonel R B Crompton, RE, of 45 Company RE and the struggle for vehicular supremacy in World War I. The thirty well chosen photographs, grouped in the middle pages, bring the book to life. This is the tenth book by this author in the series. It is a pity about those omissions!

EEP

FLUID MECHANICS, THERMODYNAMICS OF TURBOMACHINERY

S L DIXON

(Published by Pergamon Press Ltd. Price £3·50)

In the Second Edition this successful book, one of the Thermodynamics and Fluid Mechanics Series, has been completely revised and brought up to date with the inclusion of some new material and the use of SI Units throughout. As with all books of the series it is well indexed and referenced and each chapter concludes with problems (and the answers!) to confirm the understanding of the reader. The worked solutions in the text are of inestimable value to the student of the subject. (A companion volume of more worked solutions is due to be published in the near future.)

The book will only interest a limited number of members but it should be on the book shelves of all who profess to the E & M disciplines.

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Articles may be submitted at any time and correspondence is always welcome. However, the following dates are normally the latest for inclusion in the issues shown:

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