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Contents

The covers, front and back, show respectively an expansion joint and gusset plate and bolts on the Volta Bridge, West Africa. The centre spread shows the completed bridge. (Photos: G.Wood)

Who, or why, or where, or what is the Wali of Swat?*

Roger Rigby

I was lucky enough to visit the subject of this schoolboy conundrum some years ago in his remote valley and one of the nicest things about the WALI, to my mind, was that one of his neighbours was the AKOND of AM. Now this, of course, is completely useless information but it has a certain romantic and unworldly charm about it. We need such whimsical snippets to titillate our minds and stimulate our imaginations as a relief from workaday activities.
You may suppose, for instance, that to have to maintain our staff records would be sheer drudgery. On the contrary, from this mass of seemingly dull statistics there is a fallout of knowledge, part useless, part bizarre, part of historical interest, all of it essentially human and this provides the necessary relief from tedium.
For instance, did you know that there are 606 men in this outfit in this country and 122 women and that of the men 339 are married but only 57 of the women, and that one of these ladies has raised eight children, which is a splendid help for the averages?
Are you aware that our oldest colleague was born in 1893, the year in which Cecil Rhodes finally obtained control of the land that is called after him? Our youngest colleague, on the other hand, dates from 1950, so that she will be able, one day, to boast to her grandchildren that she was actually born during the reign of George VI.
Surely there can be few firms in this country with such a multi-racial composition. At this time the British, a heterogeneous mass from many countries, number 585 but there are representatives of 31 other nations besides - Danish, Indian, Chinese, Polish, Nigerian, South African, Australian, Canadian, Italian, Pakistani, Malaysian, Greek, German, Israeli, Hungarian, Yugoslav, Jamaican, Bolivian, French, Japanese, American, Maltese, Spanish, Iraqi, Rhodesian, Lebanese, Zanzibari, Mauritian, Irish Argentinian, Czech, Franco-Turk and New Zealanders.
Many of these people have been educated at Universities, but why is it that so few of them managed to get to Oxford? London, Cambridge, Leeds and Edinburgh, in that order, provide the most popular choices.

THE NAME GAME

There must surely be some political capital to be made out of the fact that out of 420 men who were educated in this country only 14 had the doubtful pleasure of going to a public school. However, we have recently acquired our first Old Etonian.
Guess who has most letters in his name? This is a close thing. Currently ABUL KHAIR MUHAMMED MUSHARRUF HUSSAIN (33) pips PIERRE IGNACE GUY NEMOURS DESJARDINS (32) by a short head and LARS CHRISTIEN FREDERICK INGERSLEV (31) and PHILIPPE PIERRE DE MARIGNY-LAGESSE (30) provide competition.
Surely there can be few enterprises in this country of comparable numbers who have two members with surnames beginning with 'Z' (ZAJAC, ZUNZ) or with so many containing only two letters AU (2), HO (2), IP (1), NG (1), YE (1). This is real collector's material.
Consider the imagination of those of us who are parents. Whilst it is true that Karen figures amongst the dozen most popular first names given to our offspring, appreciate from the following list the wild nativity researches of some of your colleagues, who chose SUNDAY, DOMINIC, CALVIN, ADEN, KATRINA, LOLITA, MIRABELLE, CLINTON, ARLETTE, GILES, KARL, LUCINDA, STACEY, GAVIN, JASON, CATO, ADAM, EVE, DUKE, EMMANUEL, DAVINA, LIZZIE, LUCILLE, RHYS, THAMASIN, SHONA, KENZO, HAMISH, WANDA, NINA-CLARE, LEE, SOPHIE, KERRY, KIERON, IVAN, DREW, BECKY, JARED, AMELIA, MORTEN, CELINA, CRAIG, FELIX, LORRAINE, MAGDALINE, GLORIA, MELISSA, TANYA, MAGNUS, LYAL and try harder next time.

DISTANCE NO OBJECT

Think of the extraordinary things that some of us have got up to before we came here - Colonel of Polish and Adjutant of Indian Cavalry regiments, bank clerk, sculptor, coal miner and who knows what besides.
By far the largest number of us reside within four miles of the London office, so that we could walk here at a fast pace within the hour. Some of us choose to live an extraordinarily long way away, even on a clear day you wouldn't see some of our houses from the top of the radio tower. Living at Rye, Hove and Bognor Regis must provide a great deal of time for finishing the crossword puzzle and plenty of excuse for arriving late, whereas to live, as one of us does, only sixty yards from the office door, is disastrous in that respect.
Our surnames can be indicative of colour - GREEN, BLACK, BROWN (2), WHITE (2) or of character - BRIGHT, MOODY, SAGE, SPEED, SWIFT, GOOD, GOODSIR, JUST, STRANGE, LUCK, KINDER or of physique - LARGE, ARMSTRONG, CRUICKSHANK.
There were the places we were named after, BILLINGHURST and COVENTRY (2), and the boys' names

* The information on which this article is based was culled from our records in February, and so it may be inaccurate in some statistical details when it appears in print.

our forebears were given - John was the most popular with ten named after him - JONES (2), JOHNSON (4), JOHNS (1), JENSEN (1), JENKINSON (1) and JENKINS (1) - followed by Henry with eight - HENRY (1), HARRISON (4), HARRIS (3) - Thomas (7), Robert (6), William, Stephen, Martin, Gibb (Gilbert) and Peter in their various forms five each.
This is all useless information, but there is something to be learned nevertheless from our names. Modern English surnames are so many fragments of medieval conversation crystallized into permanent form. By 1400, surnames, which had been coming into use even before the Conquest, were in general use. We can, therefore, glean a picture of England in the Middle Ages from these names. Consider, for instance, our own building trade. We have WRIGHT (3), MASON (2), STONE (1). 'Wright' was the native English name for a builder, especially one in wood, and this was easily holding its own against the new French name of 'Carpenter' which eventually replaced it. On the other hand the Normans were so distinguished in stone building that it is not surprising their name 'Mason' should outnumber the English 'Stone'. We also have TURNER, WALKER, WOOD(4), WOODS (1) and WOODWARD.
The fighting forces are represented by KNIGHT (2), BOWDEN, BOWYER, CAMP. Metal work of all kinds by SMITH (4), the most common surname, and KEMP, this last comes from the Anglo-Saxon 'Campa' meaning a warrior, and even in Chaucer's day this word must have sounded somewhat archaic.
The Arts have only one representative, a HARPER, but no PLAYER, FIDDLER, or PIPER, which were the commonest titles.

THE SIX TAYLORS

Although we know that 'Smith' was the commonest trade because of his skill - both rich and poor alike depended on him for the tools of husbandry and the weapons of hunting and war - not many may know that 'Clark' and 'Tailor' were the second most numerous occupational names. Surprisingly, we have only one CLARKE but we have no fewer than six TAYLORS. This word is of French origin, the English equivalent is 'Cutter' and we do indeed have our own CUTTING.
It may be surprising to find that there were so many 'Tailors'. One might suppose that only the rich could afford to have clothes made for them in any age. In fact, medieval people loved fine clothes, and as they had no stretching material as we have today, they had to have their strong cloths cut on the cross with great skill to fit their legs and still admit their feet.
So the professional 'Cutters' were kept busy not only in the towns and castles of the rich but also in humble hamlets all over the country.

SMITHS AND BAKERS

In the London Telephone Directory there are 5750 SMITHS, 2740 CLARKES and 2570 TAYLORS and no other occupational name exceeds 2000 but in the next most numerous group come those who made bread. We are also well represented in this trade with MILLER, BAKER (3), BAXTER - this was the feminine form of the 'Bakester'. We also have a rarity in this trade, a BACCHUS - this is a fanciful version of the word Bakehouse, which was where the Baker worked.
Next most numerous were those who produced the cloth that the 'Tailors' used. In this endeavour we are very well represented. We have WEBB (3), but no WEBSTER, which was the feminine version of the word. 'Webb' is an old word for one who is skilled in the ancient craft of weaving. We have a WEAVER, also we have WALKER (2) and TUCKER (1). Cloth to be finished had to be Walked or Tucked - it was a special function. Consider also the specialists in the clothing trade GLOVER (2) and GLOVE. They were kept busy by the popular sport of falconry. COTTON, a later product, BUNTING, MARKER, MARK and BUCKLE (2) who made buckles, BRADLEY and BRADY and CHAPMAN, a traveller who brought the buttons and buckles and other small wares to the country.
In the brewing industry we have BREWER (2) and BREW, but no 'Coopers' or 'Hoopers' who made the barrels, We are well supplied with servants, however, and this is not surprising for in the Middle Ages many worked in the great households. We have PORTER, BUTLER (3), CHAMBERS (the Chamberlain), FACTOR, KITCHEN and KITCHER and SPENCE (2) who dispensed the stores.
In the field of sport we have HUNTER, BOWLER and FOX(2) but to include BILYARD in this category would be an anachronism.
In the legal profession are BAILLIE and BAYLIS. These were the Norman Bailiffs who presided at courts of justice and who superseded the English REEVE, of whom we have one descendant.

WAY OF LIFE

As the clergy were supposed to be celibate their titles should not have been passed on. Nevertheless, many people seem to have been adherents of the great religious establishments. We have ABBOTT, BLAKE (the Sexton) CAPLE (Chapel), COFFIN (the undertaker).
In the leather industry we have no 'Tanner' but we do have a BARKER, which was the same thing - bark was used in the preparation of skins.
The sea is very badly represented by only one FISHER but this, in fact, reflects exactly the evidence of the London Telephone Directory, which, with more than 800,000 names in it, is a very good guide to the past. The number of Sailors, Shipman, Mariners, Shipwrights is insignificant, this is because in the period in question the English tendency towards seafaring was indeed in abeyance.
In agriculture we have CROFT, PARKER (a Norman official who protected the sporting rights of the Barons), GARDNER (2) and DESJARDINS, the same thing and FORSTER, who was a Forrester.
In music there is HORN, BELL (2) and DOUBELL, but were COLE, COLES, COLLEY, COLLIE and COLLINS really anything to do with Coal? It seems doubtful. Whilst we can appreciate what COX (2), LOCK, BRIDGER and TOOTH (the dentist) got up to, can we say for certain what GATES, SPOONER and BONNER did?
How sad it is that surnames have become fixed long since. Otherwise our own BAKER might be called 'Computer' and our ARMSTRONG would be 'Model'. Our descendants would then be able to learn a great deal more about our way of life, assuming, of course, that they were ever lucky enough to be able to find and study all those personal records that are hidden away on the top floor.

Belts, braces and crutches

K. C. Anthony

We recently completed a job for Michael Scott & Partners which, while small in scope, provided some interesting problems.
The building, now known as Ireland House, in New Bond Street, is something of a hybrid structure. About three years ago, a six-storey reinforced concrete structure designed by Bylander, Waddell & Partners, was built alongside an existing steel-framed building so that now there is a 1 in. Flexcell joint between the two halves from top to bottom.

CONVERSION FOR IRISH GOVERNMENT

Last year the building was leased by the Irish Government and Michael Scott & Partners were to convert the building into offices and showrooms for the promotion of Irish tourism and exports. Apart from the usual problems in such conversions, such as forming holes in walls and slabs for air conditioning ducts, altering staircases, the removal of lateral restraint to columns, etc., our main

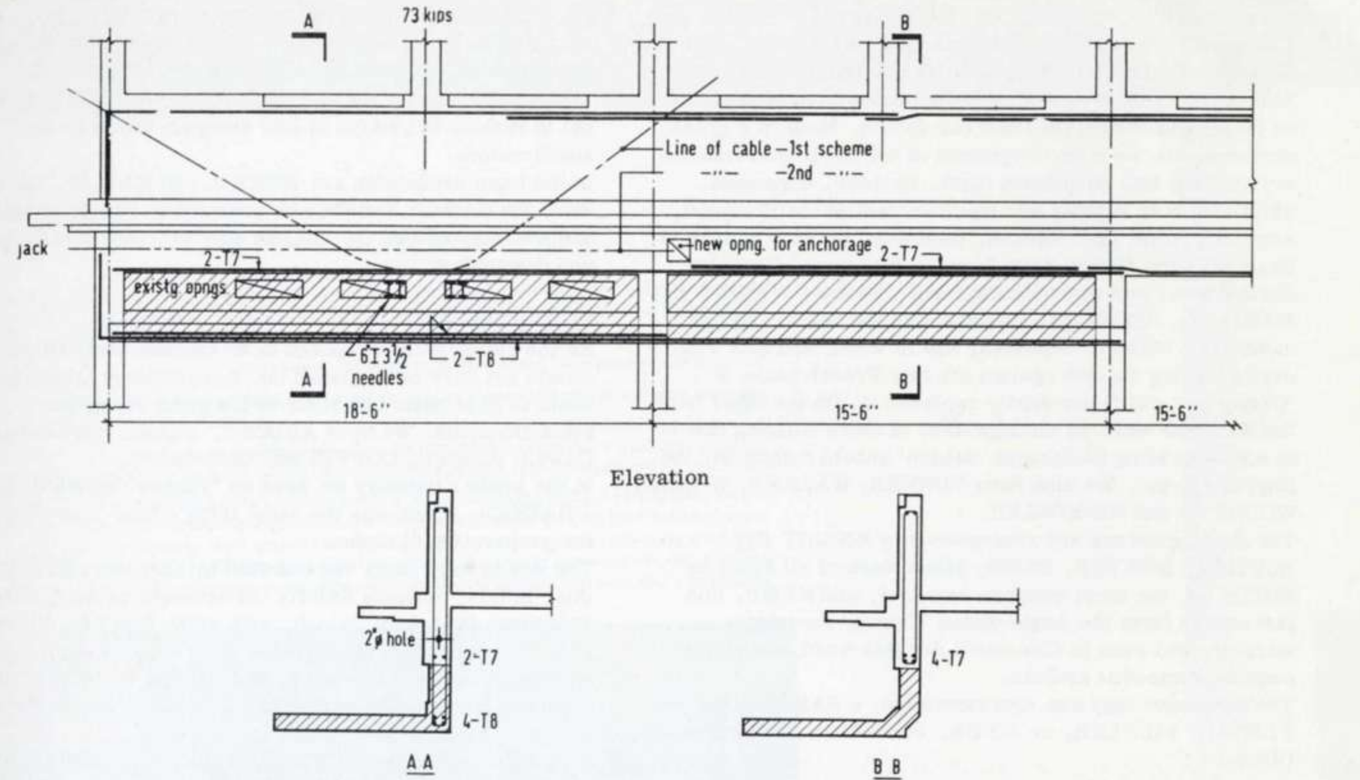


Fig. 1
End two bays of beam - Post-tensioning schemes

Details of end two bays
(main reinforcement only shown) hatched portions removed

concern was with the first floor spandrel beam along Bruton Street.

This beam, as shown in Fig. 1, was continuous over several columns and supported columns up to roof-level at the mid-points of each bay. The two bays at the western end supported a reinforced concrete canopy which projected from the beam soffit at a lower level than the soffits of the other bays. The architects wanted to remove not only the canopy but also the lower part of each of the two end beams so that the soffits of all the beams would be at the same level for the full length of the elevation. Fortunately, the main bottom tensile reinforcement in the penultimate bay was above this new soffit level but that in the end bay was within the portion to be removed.

We did consider briefly the insertion of a rolled steel joist lintel but the problems involved in the operation of propping, cutting away and inserting the joist were considerable. In any case, we felt we should prefer a rather more elegant solution.

THE CHALLENGE

The first idea was John Martin's. It was to drill two 2 in. diameter inclined holes from the top of the beam to meet directly under the central column load, at which point the holes would be joined by a radiussed chase. A cable would then be inserted and stressed from each end simultaneously thus providing an upward reaction in direct opposition to the 73 kip column load. It wasn't necessary that this reaction be equal to the column load since there were two 7/8 in. diameter high tensile bars just above the new soffit level. An upward reaction was calculated such that these bars were stressed to just below 30000 lbs/sq.in. The effect of the cable forces on all other parts of continuous beam system was then checked, all the final stresses being acceptable.

The big question was, of course, whether the holes could be drilled. Each would be some 11 ft. long and would need to be quite accurately positioned both in plan and elevation. We consulted the A.S. Demolition & Construction Co. which specializes in concrete drilling and cutting. Mr. Sabatini, whose firm this is, thought it could be done and was keen to do the job as he believed it was probably unique and he liked the challenge.

A DISAPPOINTING SET-BACK

A start was made by cutting the anchorage pocket in the top of the beam. At this point it became apparent that this scheme would have to be abandoned. Instead of the top bars being 3½ in. apart as the existing drawings indicated, they were bunched together exactly where we wanted to drill the hole. So we went back to the drawing-board.

A HORIZONTAL 20 ft HOLE

As the stressing cable had already been delivered and as Sabatini had modified some of his gear, we thought it a pity to waste all this and came up with the idea of drilling a horizontal hole from the free end to a pocket cut just within the second bay where an anchorage plate would be located. Stressing could then be done from the free end only. This time, the hole was to be over 20 ft. long and even more of a challenge. Both Mr. Sabatini and his drill operator were convinced that they could do it. It was essential that the drill bit should not hit any reinforcement as this would throw the line out, perhaps even out of the beam altogether in this length. Fortunately there was an area shown on the drawings, where the drill could pass through the links and this determined the cable position. The column bars at each end of the bay determined the size of the anchorage plates which had to be recessed into the concrete between the bars.

THE STRESS

Although a core taken from the beam indicated an equivalent cube strength of 6500 lbs/sq.in. it was decided to limit the stress under the anchorage plates to 2000 lb/sq.in. because of the proximity of the column steel. The combined effect of

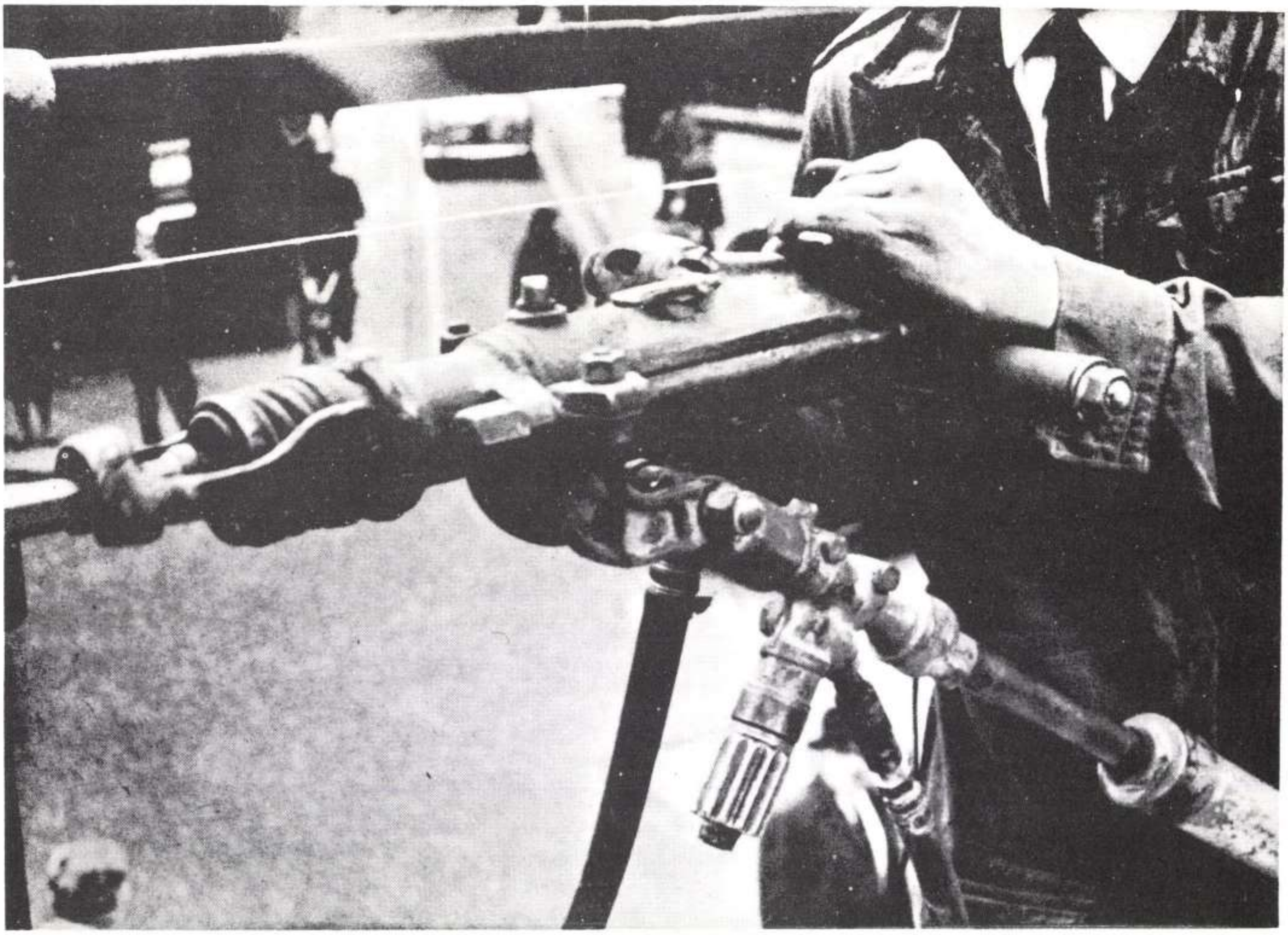


Fig 2. above
The drill with 'air leg'

Fig. 3 below
Drilling in progress

the prestress moment and the existing loads was investigated for the entire beam system and at all points found to be well within acceptable limits.
To avoid the relatively large cable force required and the redistribution of stress that would occur should the cable be stressed before the beam was cut away, it was decided to do the cutting first. But this meant propping. There were four very convenient slots through the beam which had served as vent openings. Through two of these, needles were inserted and supported on 9 in. x 9 in. timber struts down to the top of a retaining wall below, the projection portion of the canopy having already been removed.

FINALLY - SUCCESS

The actual drilling was done with a modified CPT 32 compressed air driven rotary percussion rock drill. The 2 in. tungsten carbide bit was constantly fed with compressed air via hollow extension rods to keep the hole clear of dust. To maintain pressure between the bit and the concrete, the drill was fitted with an 'air leg' which is a pneumatic ram controlled by means of a valve (fig 2).
At intervals during the drilling, holes were made through the face of the beam to check the line of the drill. After about 7 ft. it was found that the drill was falling. If this had been allowed to continue, the drill might have missed the anchorage pocket altogether. Frantic efforts were made to keep the drill bit up by levering it up with steel bars through the face of the beam. Eventually the drill emerged at the pocket with just enough room for the anchorage plates to be inserted. It was to the credit of the drill operator that the hole remained exactly on the centre line of the beam in plan. If such an operation were ever to be repeated, an allowance for the flexibility of the extension rods would be made by drilling at a slight angle of elevation at the beginning.
The rest was quite commonplace by comparison. The anchorage plates were bedded in epoxy mortar, the cable inserted and stressed, the hole grouted and the props removed.
Now it's all over we can sleep at nights.

Fig.4 above
Essential equipment

Fig.5 below
Trying to trace the hole

'By education most have been misled'*

Poul Beckmann

The pukka civil engineer may think that he is directing the great sources of power in nature for the use and convenience of man. What we largely hope to do in Ove Arup & Partners is to create better conditions for our fellow men by helping to produce better buildings. This is what we aim our engineering at and it should be more important to us than membership of established engineering institutions - let alone academic awards for abstruse papers.

The means to this aim is structural design and that is our trade. (There is so much talk about professions these days that it is as well to remember Bernard Shaw's definition - 'A profession is a conspiracy against the layman'). In our trade of structural design, we have a tool which is called structural analysis. It is no more and no less than a tool. To fulfil their purpose, structures must be strong enough and stiff enough. To satisfy the first requirement we must study the strength of materials, to satisfy the second we are led on to the theory of elasticity.

The old master builders may not consciously have studied strength of materials as the scientific subject it is today but they got to know the strengths of their materials all the same by long apprenticeship and the accumulation of experience. When Telford and Stephenson started to use the 'new' materials, cast iron and wrought iron, they studied their strength properties by making experiments. The fact is that strength of materials is an experimental science which cannot be pursued from your armchair without getting your hands dirty.

In the early nineteenth century, the techniques for making more refined experiments in strength of materials were not yet developed. Hooke's Law and Navier's hypothesis of plane sections remaining plane had, however, been well-established and accepted. In addition, an experiment might be subject to varying interpretations but a mathematical calculation could be checked once the basic assumptions were accepted. Elastic analysis, therefore, came in ascendency because it enabled you, in the peace and quiet of your study, remote from the clamour of the practical world, to calculate stresses which could be compared with permissible stresses and thus produce a criterion of adequate strength.

Once you have been indoctrinated and used to that approach it is difficult to see what is wrong with it but let us try and look at a few of the fallacies.

a)'Materials are assumed to follow Hooke's Law.'

This we know in this day and age as being true only for a very limited range of stresses.

b)'Plane sections remain plane even after the member has been subjected to bending moment.'

This does not even apply within the elastic range if the member is subject to shear forces at the same time.

c)'Permissible stresses.'

These are usually determined by a committee of old men. Age is assumed to have given you experience and therefore judgement but your experience may well in parts have been unfortunate and consequently prejudiced your judgment towards playing safe at all costs. Apart from that, your brain has, according to the experts, been decaying since the age of 20 and therefore your grasp of new ideas is likely to be somewhat impaired.

d)'Factor of Safety.' The common idea is that by dividing the ultimate strength with the working stresses you get a factor of safety. That may be so but what is it a factor of safety against? In rolled steel beams you may have an ultimate strength of 30 tons per sq. inch which with the working stress of 10 tons per sq. inch would appear to give you a factor of safety of well over three. This is, however, only the factor of safety against the material failing in tension. We know that the steel will start to yield about 16 tons per sq. inch and that means that at 60% overload you may get such large deflections that your structure may become unusable and even literally fall down. On the other hand, the common criterion for stability of long columns is the Euler load below which the column will straighten itself if accidentally bent. It is also known now that columns can carry loads well in excess of their Euler load but it is much more difficult to calculate how much.

All this adds up to saying that we ought occasionally to discard all our previous ideas and sit down and think about how structures really do behave.

In 1921 Aage Ingerslev presented to the Institution of Structural Engineers his paper, ' The strength of rectangular slabs'. In this paper he stated the sequence of events that were generally observed in tests on slabs - at a certain load the crack appears where the reinforcement yields first. Further loading makes the crack extend as adjacent parts of the slab help to resist the bending moments and, in turn, reach the yield point. The cracks propagate along certain well-defined paths and, at failure, they are eventually distributed along these bands or lines, where the reinforcement has yielded.

Referring to load tests carried out by Bach and Graf 1911-1914, Ingerslev proceeded to develop a yield line theory enabling the moments in rectangular slabs to be calculated by simple equations of equilibrium.

Ingerslev's method was only applicable to certain limited types of slabs and support conditions because he assumed that as on the yield lines the moment was maximum the shear forces along it must be zero. It was left to K.W. Johansen to develop the general application of the yield line principle to reinforced concrete slabs in the 1930's and, being in the forefront of developments, the Cement & Concrete Association published a translation of his thesis in 1962.

* The quotation comes from John Dryden and the paper is based on a talk with which Poul Beckmann electrified the Edinburgh Office last year. It formed the introduction to a summary of the yield line theory and ends where it does because Poul Beckmann tells me that he is not here to rewrite Johansen. (Ed).

Rough concrete on site

A. C. Powell

In the G.L.C. South Bank Development adjoining the Royal Festival Hall extensive use is made of exposed concrete finishes from rough-sawn boarded shuttering, more extensive in both area and variety of application than any other contract to date in this country. The merits, or otherwise, of this type of finish are outside the scope of this article but it is clearly becoming increasingly popular with architects in this country and perhaps a summary of our experiences would be of interest.

Being a prestige job, considerable testing and research into all aspects of the site production of this finish were undertaken at the beginning of the contract at the same time as the work on the main foundations was being done. A number of small trial panels was constructed, principally to test a variety of mixes but also giving opportunities of seeing how our ideas on shutter construction, mould oil application and vibrating would work in practice. As a final test, the contractor was asked to construct a specially designed test piece - about the size of a small room - which incorporated a number of features typical of the final work. This was done successfully to the approval of the architect and this test piece remains on site as a

permanent yardstick of the acceptable standard of workmanship.

CONCRETE

The requirements of the concrete mix were that it should (i) be of uniform consistency and colour, and, obviously, give the required strength (ii) give very good surface definition of the grain of the boards (iii) be as workable as possible so as to flow readily into confined spaces and to avoid segregation (iv) be as dry as possible to avoid shrinkage cracking and (v) have a high early strength to allow reasonably early striking without damaging the surface.

Requirement (i) is dependent on the consistency and cleanliness of the materials used. The cement is rapid-hardening and is all from the same works of the same manufacturer. It was used originally because the Cement and Concrete Association recommended that rapid-hardening cement would give a more uniform concrete colour but it is interesting to note that it became obvious very quickly that an even greater advantage in using it was being derived from its early strength characteristics. Similarly, all the aggregate is supplied from the same pit and is closely inspected for cleanliness. Dirty loads are rejected on the spot and dirty lorries are reported to the pit. At one time we were baffled by the discovery that there were occasional oil patches on the freshly delivered aggregate. After each complaint the supplier would find a new and even more improbable source of the oil and swear that the trouble had been put right. It took us about two months to spot that the hydraulic ram on one particular lorry was leaking when at its fullest extent! Despite all these precautions, the occasional pour turns out to be a slightly different colour to its neighbours and we have found no logical explanation for this. The difference is never very great, however, and is usually unnoticeable after a few months.

Requirement (ii) was met by increasing the fine aggregate content of the mix until we have what is basically a 1:2:4 by weight with 30% increase in sand. This gives excellent definition and an attractive colour but has the disadvantage of lowering the workability, and this, in conjunction with requirement (iv), which limited the water/cement ratio to a maximum of 0.52, produced a concrete with practically no slump. These problems were overcome and requirement (iii) met by using a plasticiser. A compaction factor of 90% was attained - equivalent to an average slump of 1 in.

Requirement (v) is obviously fulfilled by using rapid-hardening cement. Striking of rough-sawn boarded shuttering is much more difficult than conventional plywood sheets because of the combined pull of countless wood fibres or whiskers. Added to this is the suction effect produced by having alternate boards standing 1/8 in. proud of the shutter face. Shutter striking is usually carried out by carpenter labourers, a species not noted for its lightness of hand and it is at this time that the most damage is likely to be done to the concrete. Therefore, unless a contractor can be persuaded to leave the shutters undisturbed for what he will undoubtedly consider an unreasonable length of time it is essential to achieve a high early concrete strength. Failure to do this will result in patches of the surface being torn off and the small arrisses of individual board marks being damaged.

The South Bank specification forbids any form of making-good on a boarded finish and states that any sub-standard work must be cut down and recast. This ideal state of affairs would not be practicable on the normal run of contracts and, to be honest, we permit a limited amount of repair work to be carried out, subject to the result being acceptable. Under the shadow of a demolition order, great care is taken with making-good and this is carried out by a few hand-picked men who have become very skilful in matching colour and grain. Results are sometimes disappointing, however, and under less ideal conditions the results of haphazard making-good could well be disastrous. It cannot be over-emphasized that no amount of time or effort spent in avoiding surface defects is wasted.

REINFORCEMENT

Imaginative detailing of the reinforcement can do much to assist the placing and vibration of the concrete. What appears to be a straightforward detail on the drawing can turn out to be a tangle of small diameter bars when fixed, a number of which are unnecessary. Such a situation in, say, a complex of 6 in. walls makes it difficult to inspect, difficult to fill with anything stiffer than grout and impossible to vibrate satisfactorily. The end result is usually one or more patches of serious segregation. Adequate spacing of reinforcement is most important and in a tight spot consideration should be given to the use of a smaller number of larger diameter bars.

Our final concrete is slightly porous because of the aggregate grading and to avoid rust staining, and eventual spalling, we have tried to maintain a minimum concrete cover of $1\frac{1}{2}$ in. in parts of the structure exposed to the elements and 1 in. elsewhere. These covers have been difficult to achieve in a number of cases for two reasons. The straightforward one, that adjacent reinforcement on separate drawings - and on separate walls on the same drawing - clashes, and the more subtle but common one that bending yards tend to exceed overall bending dimensions. This is a nuisance with 'U' bars and even more so with straight bars bobbed at each end. Whenever possible, the reinforcement should be detailed to allow some small adjustment during fixing and it should be impressed upon the steel fixers at an early stage that, if they are ever unable to fix to the correct cover, they should immediately refer the problem elsewhere. Reinforcement to a lift shaft fixed with only $\frac{1}{4}$ in. cover can never be satisfactorily adjusted without taking the outside shutters down.

A final point on reinforcement is our use of high tensile steel for all horizontal lacer bars. This has been done solely to utilize the increased bond property of such bars to prevent shrinkage cracking.

SPACERS

The type of spacer block to be used to maintain concrete cover has been a controversial subject. The architects decided that only grey plastic spacers were to be used on exposed surfaces and then only sparsely and this has led to some difficulty on soffits. We have found that heavy reinforcement supported on a small number of spacers tends to press the spacers into the boards, particularly when a spacer has rocked sideways, resulting in their standing proud of the finished surface by up to $\frac{1}{4}$ in. The choice lies between a large number of spacers which can only be seen after close inspection, or a small number which immediately catches the eye.

In walls we have found it easiest to maintain cover by using loose battens of appropriate thickness which are slowly withdrawn during concreting.

A method used very successfully on an adjacent site was the use of a concrete block shaped like a truncated pyramid, and having a slightly domed head and two tie wires cast into the base. Their only drawback was their small extra cost and during my visits I was only ever able to find one block showing in a surface.

SHUTTERING

The architectural pattern of the boards was worked out after close consultation with us to agree where construction joints should go. The majority of walls have a vertical board marking and a pair of horizontal boards was introduced at each horizontal construction joint to enable a watertight joint to be formed between these boards, using a polyurethane foam gasket. To get maximum surface effect, adjacent boards differ in thickness by an accurate 1/8 in. and this difference has proved to be the minimum to give a satisfactory appearance with boards which are approximately 6 in. wide. The original idea was to use boards of slightly different thickness at random but this chance variation proved to be most unreliable and was replaced by the present planned variation. The joint between two adjacent boards is sealed by a $\frac{1}{4}$ in. x 1 in.

hardwood ply tongue slotted loosely into a groove in the edge of each board. This system has proved to be very watertight provided that only internal vibrators are used. Boards are delivered to site $1\frac{1}{2}$ in. or 1.3/8 in. thick and are rough band sawn on the front face, wrought on the back and grooved on each edge. The wrought face makes it easier to machine the grooves accurately and to assemble the shutter panels in the site workshop.

All boards are screwed to framing timbers from the back and all holes, conduits, fittings and other features are incorporated in the shutters before casting. No cutting away or drilling of the final boarded surface is permitted.

The architect supplies $\frac{1}{4}$ in. scale scheme drawings of surface finishes and from them the contractor produces the final shop drawing for each shutter. These drawings combine all the available relevant information and sub-contractors' requirements, and are finally submitted to the architect and me for approval before going to the workshop.

Apart from columns, there is almost no repetition and therefore scarcely any second use of any complete shutters on the job. After striking, each shutter goes back to the shop to be dismantled and the undamaged boards are cleaned and sorted for re-use. Maximum average expectation of life per board is about two uses under these conditions. Column shutters average about four uses but even these sometimes need to have a board replaced because of damage sustained during striking. Minor blemishes in board surfaces are repaired with Polyfilla, and before leaving the shop, each shutter is given two coats of Duckham's Z2 shutter oil.

PROTECTION

Protection of special surfaces is a problem which defies complete solution when such surfaces are extensively used throughout a large contract. Principal damage is caused by rust staining from starter bars, scaffolding and a multitude of assorted small objects, such as nails, which lie about everywhere. The contractor began by covering finished surfaces and starter bars with heavy polythene sheet but this proved very expensive and it was easily torn. He then began the present system of grout washing starter bars, which has been fairly successful. The fundamental weakness of this system lies in the fact that this work is carried out by the lowest grade of site operative. He probably regards it simply as a means of filling in time between weekends, and, to be fair, it is a soul-destroying job. With the best will in the world it would be impossible not to miss small areas of bars and intersections and these are our main source of trouble. If anyone can think of a reasonably cheap, practical alternative - of which he has had experience, we would be pleased to hear of it.

The scaffolding problem can be partly solved by using alloy tubing but the couplings, which seem to have been specially designed to drip rust, must have a fresh coat of paint after fixing, particularly on their threads.

The complete solution to the whole problem is to induce an intense feeling of pride in the job in everyone on site but failing this, the only alternative is to constantly watch for signs of staining and make sure that they are dealt with quickly.

A certain amount of accidental damage is inevitable but accident-prone features, such as door jambs, are wrapped with ply off-cuts and walls get a temporary draping of polythene to protect them while sub-contractors are working nearby.

Fortunately, the rough surfaces discourage pencil artistry and slogans done with chalk are easily dealt with but we have not been able to remove completely the efforts of the man who used an oil gun.

In the last few weeks another serious problem has emerged connected with oil and grease marks, this time from the tower cranes. A large amount of the exposed aggregate precast cladding has recently been fixed close to one particular crane. This has developed leaks in its hydraulic ram circuits and is also dropping graphite grease from its cables. The results are spectacular and I particularly mention this problem to draw attention to the large amount of oily filth that tower cranes drop over the whole of their area. Sites are naturally dirty places and these 'droppings' go unnoticed until everything has been cleaned up and the finishing trades start working underneath. Cranes with luffing jibs give more trouble in this respect than the others but whichever type is used, it will probably be painted at least once during the contract. This will be done over a weekend with soft brushes and the results below are always colourful. They will cover either a large area or a very large area depending on the strength of the wind.

SIZE OF POURS

To minimize the effects of shrinkage, the contractor has been limited to pour-lengths of 30 ft. on surfaces which are exposed to the elements, and 35 ft. on internal surfaces. This rule has applied even when changes of direction have been involved - a safe but somewhat controversial decision. Heights of pour have been increasingly left to the contractor's discretion. He argued that turning two lifts of a wall into one pour cut out the risk of a visible construction joint, lined the wall up perfectly and saved a lot of time. Even if as many as one wall in ten had to be cut down and recast, the risk was still worth taking. In view of the contractor's general performance and integrity, he was given the chance to prove his point and there have been no failures so far. Under less ideal contract conditions, however, it would be strongly recommended that heights of pour be restricted to the minimum until the contractor's performance and potential have been accurately gauged.

SUPERVISION

An important aspect of site work, again dependent on individual circumstances, is the amount of supervision necessary of the actual production of the concrete. A first-class mixer driver is an invaluable asset and we are fortunate in having such a man. Apart from regular checks of the accuracy of his weighing equipment, he is left fairly well alone to produce a consistent mix. At the beginning of the contract the concrete was tested continuously and after a few weeks it became possible to tell by appearance and feel whether a mix was satisfactory or not. With a conventional mixer set-up and aggregate heaps which are being added to continually by fresh lorry-loads throughout the day, determination of the moisture content becomes most unreliable. The mixer driver who sticks rigidly to the amount of water calculated in his daily design sheet will find his mix varying alarmingly. A good driver will be constantly watching his aggregate and his mixing drum and will make adjustments as necessary. This play it by ear technique may sound rather unscientific, but we have found that it works very well in practice.

VIBRATING

Good vibrating is even more important than good concrete because it can make up for small deficiencies in the concrete whilst the reverse is not true. The first layer of concrete in the formwork should not be more than 1 ft. deep and must be particularly well vibrated, because this is where segregation mainly occurs. We tried starting a pour with a layer of grout but this showed afterwards as a band of a different colour. Subsequent layers should never be deeper than the length of the vibrator being used.

It is an unfortunate fact that if the operator cannot easily get his vibrator into all parts of the formwork, then he won't waste time by trying too hard, so suggestions for detailers would be:

(i) Decide what size of vibrator is needed to vibrate any section of work adequately, and then make sure that there are large enough gaps between the bars to drop it through.

(ii) Actual diameters of vibrators in common use are 1 in., $1\frac{1}{2}$ in., 2 in. and 2.3/8 in. Effectiveness, for purposes of comparison, varies with roughly the cube of the diameter, and a 1 in. vibrator is normally used only for the very smallest sections of work, for example, lintels.

(iii) Ribbed bars are 10% bigger than they sound.

(iv) Provide a minimum $\frac{1}{4}$ in. clearance all round.

GENERAL

This discussion would not be complete without briefly mentioning the problem of the attitude to tolerances and standards of workmanship currently prevailing in the industry. All specifications nowadays lay down roughly similar tolerances in concrete construction and, unfortunately, these are not taken too seriously on site. Shuttering carpenters have become so used to contracts where 'to the nearest $\frac{1}{2}$ in.' - or worse - is tolerated, that this is now taken for granted. There is a malicious rumour that these inaccuracies have crept in due to the widespread use on site of the 'Irish metric system' - ten shamrocks to the foot - but, whatever the cause, it is difficult to get a job working to the close tolerances necessary for good exposed concrete work.

This attitude has flourished because of poor supervision. Contracts rarely have a resident engineer and often there is no clerk of works, and the current wage system means that a good proportion of a carpenter's weekly wage is related, through bonuses, to the area of shuttering he fixes per hour. We have four clerks of works and have been able to insist that tolerances are strictly observed but consequently the rate of fixing is low and so is the bonus. This has brought in the trade unions hot-foot with cries of 'exhibition work standards' and 'minimum guaranteed bonuses' and the contractor has been faced with the choice of paying exorbitant rates or continuing without carpenters. It is to the credit of the directors of Higgs & Hill Ltd. that they have insisted on maintaining the same high standards, regardless.

To conclude - visitors have asked a variety of questions about our work, some of which could be summarized in the form: 'How can we get a finish like yours from a small contractor of unknown ability and with normal site supervision, on a small job which hasn't any money to spare?' Without trying to discourage anyone, I hope that I have given some of the answers to that question. A good finish is not difficult to achieve and should follow automatically provided that every stage of the construction is carried out properly. The snag with this particular chain of operations is that one weak link is quite sufficient to spoil the result.

Research bulletins and research reports issued by Ove Arup & Partners

RESEARCH BULLETIN No.1

Progress report on product investigations from October 1964 to January 1965, by T. O'Brien, 1965.

Interim statements on concrete additives including anti-freeze, structural adhesives for concrete and timber, cements, timber preservations and varnishes and sealants and priming paints for steel. Is, or will shortly be, superseded as far as concrete additives, cements, sealants and priming paints for steel are concerned. (Refer to Technical Notes Nos. 37, 38, 40)

RESEARCH BULLETIN No.2

Stress plugs and their uses, by D. Michael, 1965. Self-explanatory.

RESEARCH BULLETIN No.3

Report of Conference on plastics in building industry, held in London 14-16 June 1965, by T.O'Brien, 1965. Self-explanatory.

RESEARCH BULLETIN No.4

Report on the Conference on the structure of concrete and its behaviour under load, held at Imperial College, London 28-30 September 1965, by R. Finkelstein and T. O'Brien, 1965.

Self-explanatory.

RESEARCH REPORT No.1

Resume of information on stress corrosion cracking of metals most commonly used in structural engineering, by V.G. Towson, 1965.

Summarizes in an abbreviated form, information from several sources on the problem of stress corrosion cracking and is a most useful introduction to the subject.

RESEARCH REPORT No.2

Summary of report on the failure of three brass holding-down bolts for portable window-cleaning cradles and the general safety of similar bolts in existing installations, by P. Beckmann and D. Michael, 1964. Summary of report of 21 July 1965 made for Palmer's Travelling Cradles Ltd. (Job 2039).

Establishes that, despite weighty expert opinion, the material of the bolts was highly susceptible to stress corrosion. This was not the reason for the failures which were caused by gross mechanical abuse of the fixings.

RESEARCH REPORT No.3A

The effect of local wall deformations on the elastic interaction of cross walls coupled by beams, by D.Michael, 1965.

Investigates the reduction in the shear transfer between the walls due to local deformations in the wall at the intersections with the beams and states reduction factors which can be used in design.

RESEARCH REPORT No.4(a)

Investigation of reduced bond in retaining walls cast under Bentonite, by K.Cole and P.Beckmann, 1964.

Describes site measurements and tests on replicas and samples cut from the ICOS wall at Moorfields. The results, which indicate a very substantial loss of bond, have, so far, been substantiated by tests carried out by the Civil Engineering Research Association following their hearing about our report.

RESEARCH REPORT No.5(a)

Membrane theory in general co-ordinates by matrix-tensor methods, by R.S. Jenkins, 1964.

RESEARCH REPORT No.5(b)

Application (of membrane theory) to shell roof of new Shire Hall, Salop (Job 1391), by R.S.Jenkins, 1965.

Both these Research Reports are of very limited interest as they were used to produce a programme for this job.

RESEARCH REPORT No.6

The nature, behaviour and properties of organic polymers (plastics, adhesives, sealants, etc), by T.O'Brien, 1965.

Or what every young man (and woman) in the building trade ought to know about plastics before he starts using them (used in Sydney for 'do-it-yourself' investigation of chemical grouting for prestressing ducts).

RESEARCH REPORT No.7

Mastics, sealants and gaskets for jointing, by T.O'Brien, 196

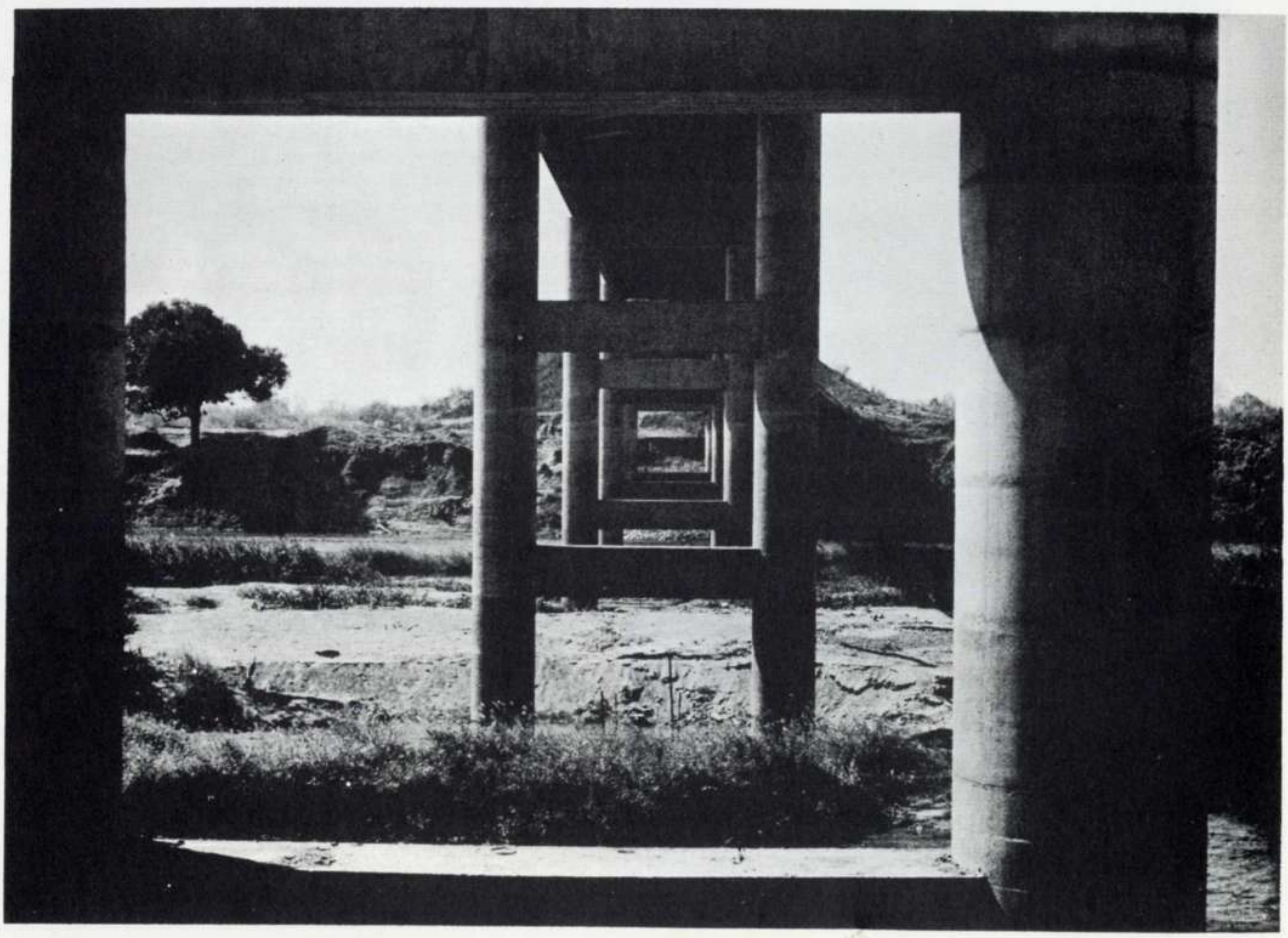
A complete summary of 'the state of the art' of keeping out weather.

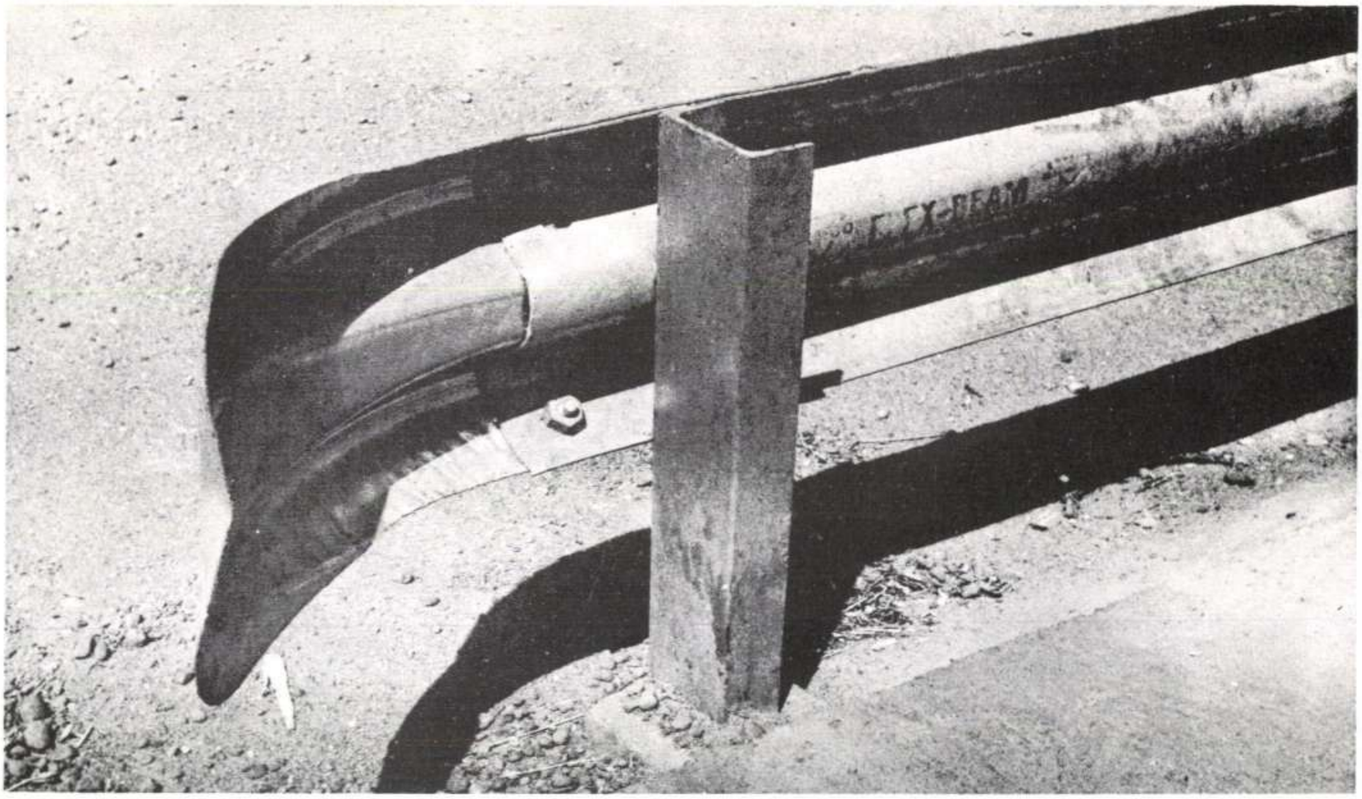
RESEARCH REPORT No.8

Adhesives for structural jointing, by T.O'Brien. (To appear late in 1966)

A comprehensive survey of the state of knowledge and experience in the use of resin adhesives for structural applications.

THE VOLTA BRIDGES
Above is an internal view looking along the inside of one of the bridges showing the structural system,
And below is the supporting frame of twin circular columns





Above: Corner detail of the crash barriers

Far right: The present approach road
to the Yapei ferry which the bridge replaces

Below: General view from the underside

THE VOLTA BRIDGES
PHOTOSTORY BY G. WOOD

The Akosombo dam will transform the Volta River and its various tributaries into a long straggling lake stretched over half of Ghana. It will drown the main lines of communications to the North and to anticipate this, two bridges have been built - one over the Black Volta at Morno and the other crossing the White Volta at Yapei.

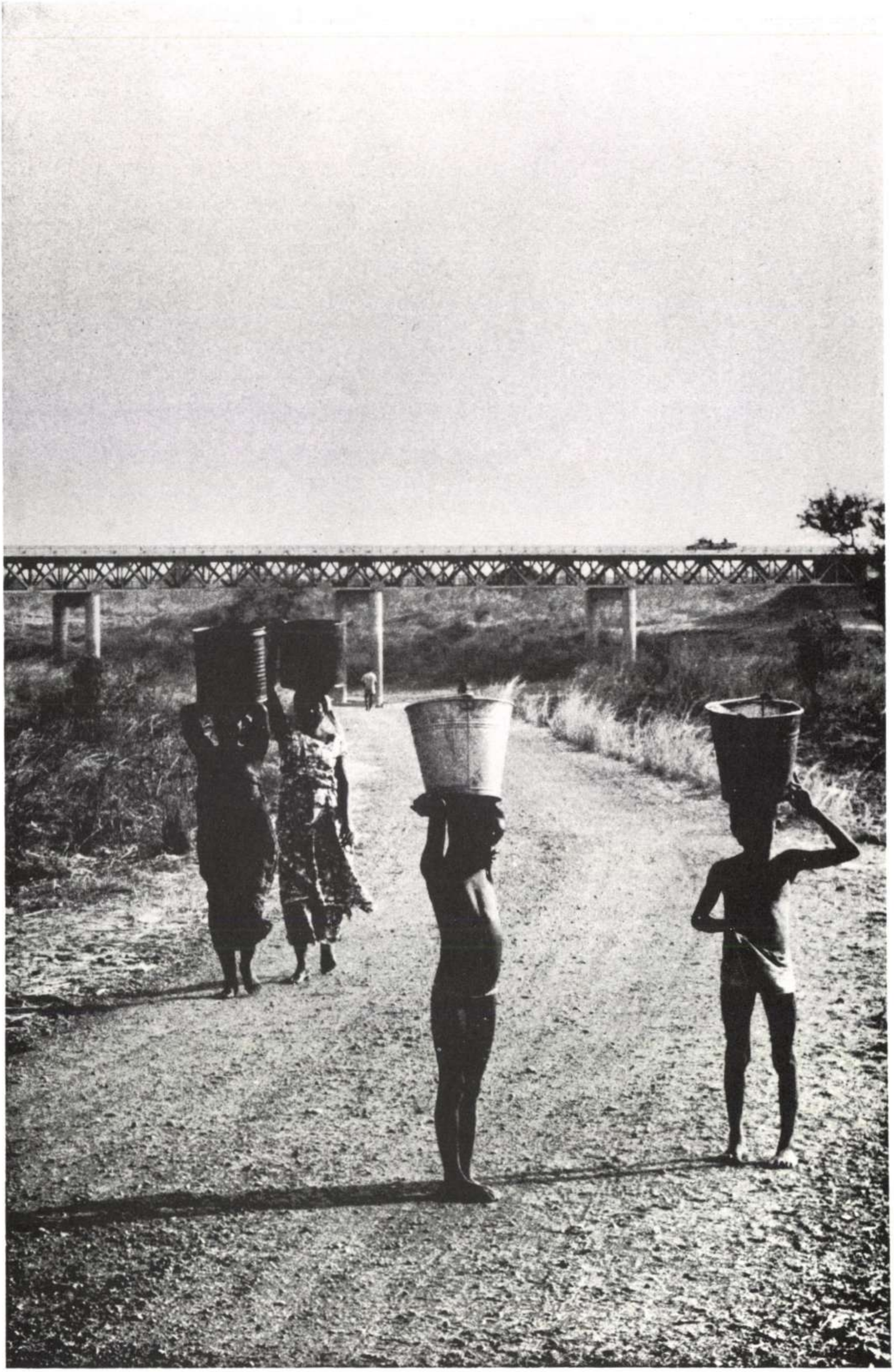
The choice of design was governed by considerations other than purely technical ones. The bridges were built by Cementation by contractor finance with payments guaranteed by the Export Credit Guarantee Department. To fulfil the requirements of such a loan 60% of the cost of the scheme must be in exported material. Steel was therefore the only possible choice.

The next question to decide was what kind of steel bridge? They are each 750 ft. long and we started off with the idea of continuous plate girders as at Sapele in Nigeria. To get to the site, however, the road from Kumasi has to scale the Mampong Escarpment and the bends in the road are such that the maximum length of girder that can be transported is 40 ft. The natural choice was therefore an open latticed girder with piece-small construction bolted together with high tensile steel bolts.

We next tackled the problem of piers. We first thought of having narrow cross walls, again as in Sapele where they are necessary to ward off floating logs, but we found that the current approached some of them at an acute angle and caused overturning problems. The twin circular columns were evolved to overcome this difficulty and have proved not only easy to build but elegant in appearance.

The Volta area is a vast plain of geologically recent deposits overlying very ancient pre-Cambrian rocks. The rivers have cut their way through the overburden and the piers are founded direct into the old rocks of slate and shale.

We sometimes think that to achieve a goodlooking structure we must produce something really breathtaking. These bridges show that straight-forward engineering design can sometimes have very pleasing results.



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