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REINFORCED CONCRETE CONSTRUCTION.

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It has been the author's privilege to hear many papers read at different times on reinforced concrete, written both from the theoretical and the practical standpoints, and whilst stating at once that it was impossible to fully grasp the question under discussion without some amount of definite theoretical knowledge, he had found that papers purely theoretical were apt to become wearisome unless very ably explained, and he, therefore, proposed to deal that night with the subject under discussion more from a general engineering, than from a specialist's point of view.

The range of application of reinforced concrete in engineering was practically unlimited, and it had been applied to practically every form of structural work. Its possibilities were very wide indeed, and every month saw new inventions produced with a view to furthering the simplicity of its use. These inventions covered the whole field of mixing and grading the materials which formed the concrete, to improvements in the manufacture of cement; to the use of patented moulds in place of the customary wooden frames used for moulding the concrete, and to the production of various patented reinforcements designed to possess some particular advantage over those already in use.

The use of concrete was rapidly spreading all over the world. Concrete was usually composed of three materials, the aggregates—which formed the bulk of the materials; the cement—which joined them together; and the water—which produced the setting of the cement.

The very simplicity of the manufacture of the material had led to its abuse, and, unfortunately, it was still very often considered that the things nearest to hand, such as any kind of pit gravel, brick bats, broken stone mixed with any kind of rubbish, any sort of sand, and the cheapest cement upon the market, would "do for" the concrete; and that the cleanliness of the water required no consideration.

This was altogether wrong.

Concrete was primarily dependent for its strength upon the accuracy of its proportioning. Usually stone of some description was selected to form the bulk of the aggregate. The voids or air spaces between these stones should be filled with sand, and the cement should coat over the whole surface of every particle of sand or stone with a film of mortar, and thus bind the mass into one compact whole. The voids in ordinary ¾in. stone, such as would be used for reinforced work, and in sand, varied between 40 per cent. and 50 per cent. of the bulk of these constituents, and for this reason a mixture of 4 parts stone, 2 parts sand, and 1 part cement would be seen to cover the requirements of most ordinary cases, since these amounts of sand and cement would, under ordinary conditions, fill the voids.

It was of the first importance that no more sand should be used in the concrete than was necessary, for the addition of unnecessary sand simply meant reduction in the strength of the mortar.

A series of nearly 1000 experiments had been made to determine the precise effect of the addition of various quantities of sand to a cement, and it was found that after a year neat cement withstood a tensile stress of 500 lbs. per sq. inch of sectional area; 1 cement : 1 sand, 310 lbs. per sq. inch; 1 cement : 2 sand, 204 lbs. per sq.

inch; 1 cement : 3 sand, 140 lbs. per sq. inch; 1 cement : 4 sand, 98 lbs. per sq. inch; 1 cement : 5 sand, 55 lbs. per sq. inch. From these figures the damaging effects of an excess of sand in the concrete would readily be seen, and this point could not be insisted upon too much, as an extra amount of sand in the concrete enabled it to be more easily worked, permitted a good face to be easily obtained, and, therefore, was preferred by some contractors and by certain clerks of the works.

The stone used in the work should not all be of one size, but should be graded down so that the smallest might adapt itself to fit in with the next larger and so on. If the stones were all of the same size a great deal of the mortar was of no use whatever, as it simply filled the vacancies between the pieces of the aggregate.

Coming now to the question of cement. It was well known that concrete increased in strength with the degree of fineness to which the cement was ground. In the early days of its manufacture Portland Cement was, comparatively speaking, coarsely ground, and required aeration before use. This aeration was effected by spreading it out in layers of about 12in. thickness in a shed, and turning it over at intervals for a fortnight or so. This air slaking had the effect of cooling hot cement by converting the free lime, which it contained, into hydrated lime, and preventing it from blowing or cracking the concrete, and was a necessary operation. As cement could, however, with the present improved methods of production, be relied upon to be fit for use as soon as it left the mill, and as the aeration of modern cement had been many times proved to be an expensive operation, the only apparent result of which to-day was a reduction in strength of the concrete, it was difficult to see why certain engineers continued to specify that this aeration process should be carried out.

No cement should be used which did not reach the standard of the N.S.W. Government test, or the British Standard Specification. All high class modern cements considerably exceeded these standards, and there had been several suggestions made lately with a view to raising the demands for qualification under the British Standard.

Amongst other aggregates, clinker and cinders appeared to be very much used in Sydney, probably very largely for the reason that it appeared to be very difficult to obtain deliveries of crushed blue metal. The use of these materials was not unattended by certain advantages, as they were of very light weight and from their nature, eminently fire resisting; but it was impossible to obtain waterproof concrete with them, and their low crushing strength necessitated the use of much thicker sections than were required with blue metal aggregates. This latter point, of course, reduced the first advantage claimed, viz., that of lightness of construction, and the extra quantity of concrete required because of the increased thickness increased the number of cubic yards of concrete required for a given piece of work when compared with the smaller scantlings which could be used with a blue metal concrete.

With a view to showing the comparative crushing values of concrete made from different materials, the results of various tests made by the author, were given below, and samples of the actual materials from which the test pieces were made might be seen upon the table.

	Crushing Values in lbs. per Square inch.
(1) Clinker 3 parts, sharp sand 2 parts, cement 1 part (5 : 1)	1250
(2) Clinker 4 parts, sand 2 parts, cement 1 part (6 : 1)	1450
(3) $\frac{3}{4}$ inch Bluemetal 4 parts, ordinary builders' white sand 2 parts, cement 1 part (6 : 1)	1750
(4) $\frac{3}{4}$ inch Bluemetal 4 parts, Nepean sand 2 parts, cement 1 part (6 : 1)...	2200

These tests showed that for the same factor of safety against crushing, in each case very much higher compressive stresses might be used with blue metal concrete with good sand, than with the other aggregate tested. Further, as a concrete that was strong in compression was also strong in tension, adhesion and shear, the advantages of the use of first class materials in reinforced concrete work would be obvious.

Concrete attained its strength quickest when it was mixed with a minimum amount of water. For this reason a dry mixture was once thought to be the best for reinforced concrete work, and the materials were mixed with only the least possible amount of water required to set the cement. As it was, however, extremely hard to get such concrete to thoroughly surround the reinforcement, and to get a thoroughly dense non-porous concrete, the use of the dry mixtures was displaced by wetter ones, until to-day we have reached the stage when concrete was often mixed so wet that on being hoisted to the tower of a wooden frame and tipped into a flume, it flowed by gravity to the portion of the work where it was required to be deposited. With such concretes it was easy and required but little labour to work the material around and between the reinforceing bars and to obtain a dense, even face against the moulds. The resulting concrete, if properly proportioned, would also be perfectly waterproof with blue metal concrete.

In a paper read before the N.S.W. Institute of Architects last year the author aroused considerable comment by stating that it was a comparatively simple matter to obtain concrete walls 4in. or 6in. thick which would be waterproof, and, although, of course, no disbelief in the statement was expressed, many of those present were inclined to be reserved in their acceptance of it. Since that time the author had had some opportunity of demonstrating the proof of his statements in this regard and would later show views of such work actually carried out in Sydney. Here might be seen such walls which had been perfectly watertight, when 27in. walls of brick and stone, and in less exposed positions, of the same structure, absorbed so much water that they were damp on the inside. The reason for this was, of course, that the materials used in the manufacture of the concrete were non-porous, while brick and stone were the reverse.

Concrete in itself could be made watertight with ordinary cement, without the addition of any special materials, provided that due care was taken in the grading and selection of the aggregates used. There were a number of preparations sold for the purpose of water-proofing concrete, and a number of very interesting tests upon these were recently carried out by the Concrete Institute in London. These tests showed that with one or two exceptions, these compounds were 90 per cent. simple hydrated lime, and whilst their use might be of some assistance in stopping up pores in the concrete it was shown that concrete mixed with them was in no way more waterproof than plain concrete. It was further shown that with the bulk of these materials there was a loss in the crushing strength of the concrete of from 15 to 40 per cent. The author was able to show them that evening photographs of work carried out in Sydney, where concrete that had not been "waterproofed" in any way, was perfectly watertight under 30 feet head of water. This should surely be sufficient argument against the statements one so frequently heard about the impossibility of obtaining thin watertight walls in building construction.

It was often argued that reinforced concrete work was extremely risky because, after the concrete was once filled in, there was no possibility of being certain that the right number of bars had been placed in any given member. The author had always failed to see the force of this argument, because it might just as well be said that if half the bolts were left out of the splicing plate in a steel column before it was cased in concrete, the joint would not be of its designed strength. Obviously, the whole pith of the question was the supervision exercised over the work, and the author submitted that reinforced concrete construction offered no more risks than any other, providing that the work was efficiently supervised. The whole of the reinforcement in any given part of the structure should be set in position, inspected, approved or corrected as the case might demand before concreting was carried out. It was easy at this stage for an experienced man to see at a glance that all was as it should be, and there was very little chance indeed of any mistake occurring.

An architect or engineer, with all the other details of the building to attend to, would not perhaps be prepared to devote the time to such supervision, but the specialist was ever ready to take the crumbs which fell from the rich man's table and to undertake this part of the work for him.

With a view to giving some idea of the cost of this class of work the author would proceed to give some typical examples in which prices were given for the work which was being carried out in Sydney.

As a basis it might be taken that the approximate cost of materials required for one cubic yard concrete were, in Sydney to-day, approximately as under.

1 ton ¾in. bluemetal @ 17/-	17	0		
½ ton Nepean sand @ 12/-	6	0		
1⅓ casks cement @ 15/-	20	0		
6 sq. yards timbering @ 2/-	12	0		
Labour mixing, hoisting and placing	12	0		
			67	0
Use and waste of plant, 5%	3	6		
			70	6
Contractor's Profits, 12½%	8	9		
per cubic yard			79	3

This figure, with reinforcement, might be taken at £5 per cubic yard for average work, and this was the approximate value of work similar to that shown in the diagram for Margarine Factory floors at Marrickville.

Some arched culverts, illustrated in Figs. 1 and 2, which were shortly to be commenced under a railway near Newcastle, would cost approximately £5.50 per

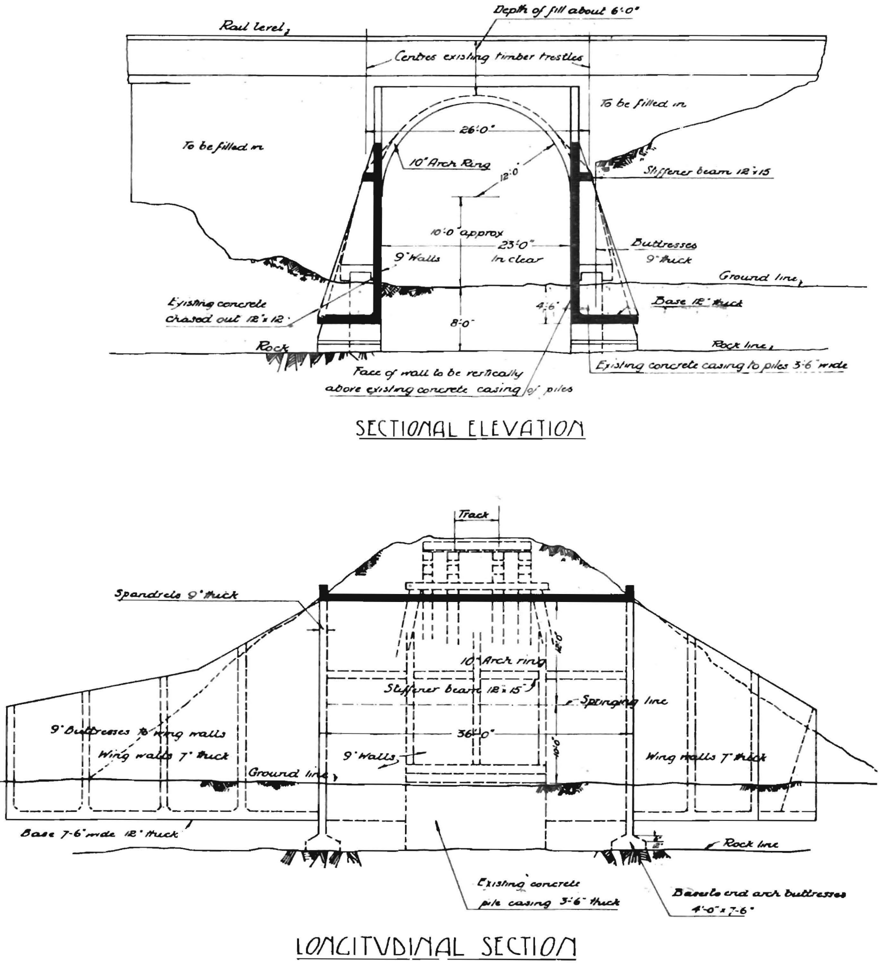
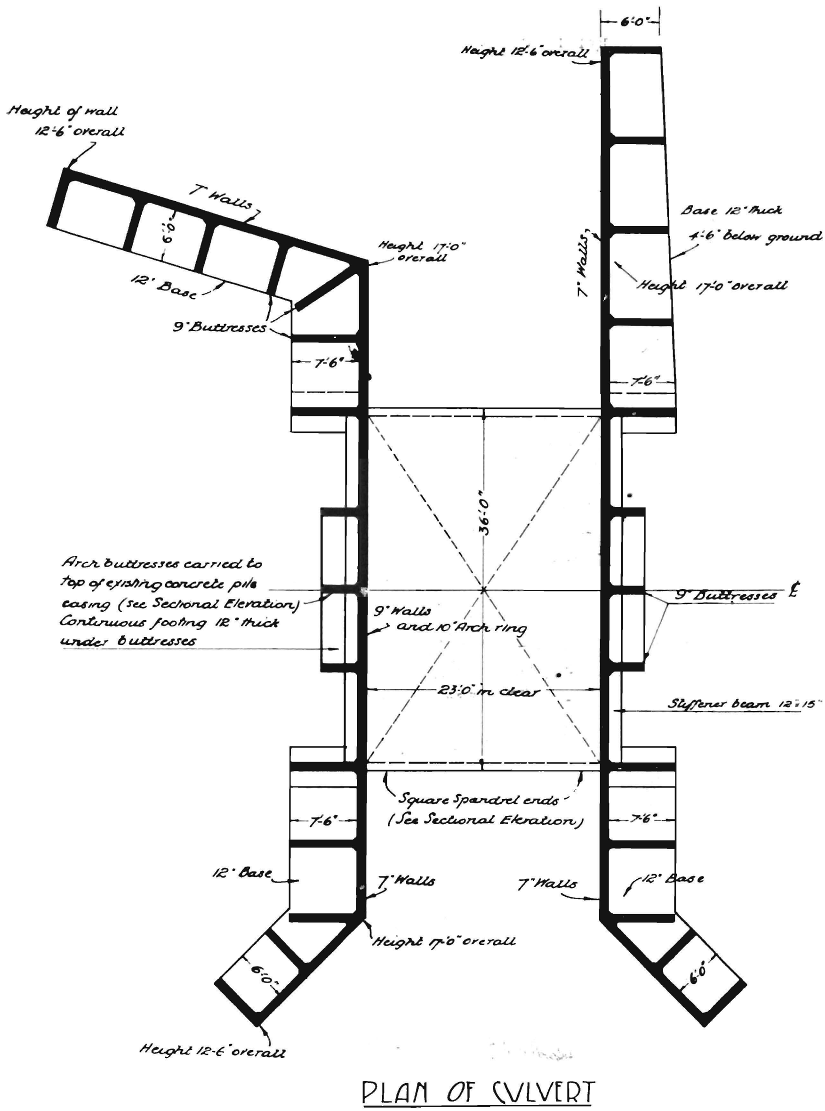


Fig. 1.



NEW RED HEAD ESTATE AND COAL CO

ALTERNATIVE SCHEME TO STEEL BRIDGE

Fig. 2.

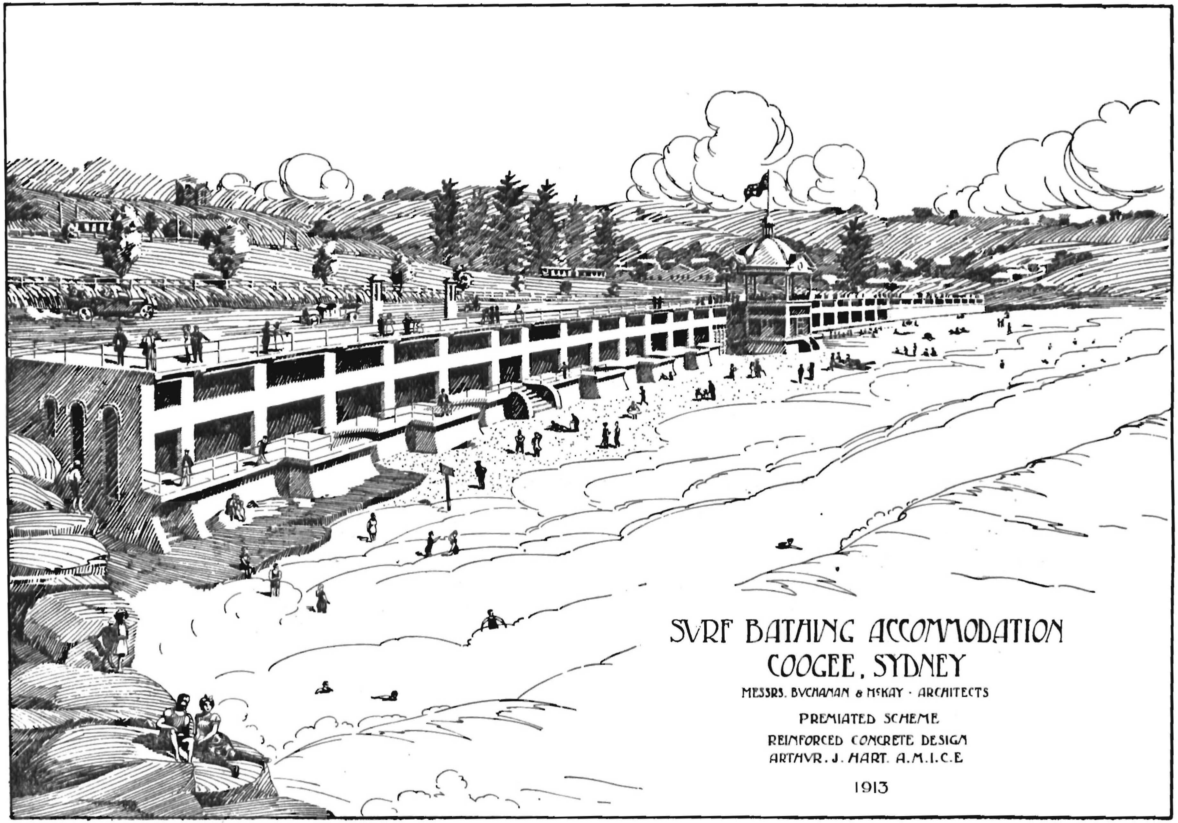

SVRF BATHING ACCOMMODATION
COOGEE, SYDNEY
MESSRS. BVCHANAN & McKAY · ARCHITECTS
PREMIATED SCHEME
REINFORCED CONCRETE DESIGN
ARTHVR. J. HART. A.M.I.C.E
1913

Fig. 3.

cubic yard of concrete. This price included for the buttressed wing walls, but did not include for excavation.

The Coogee Surf Bathing Accommodation, an elevational view of which was shown in Fig. 3, and a sectional view in Fig. 4, consisted of walls, beams, and slabs, would cost £4,400 for the concrete portion of the work.

This was equivalent to £9.20 per lineal foot of the structure, exclusive of excavation. Each lineal foot of the structure contained 1½ cu. yards sandstone concrete, and 1 cu. yard bluemetal concrete. The average value of the concrete in this work was, therefore, £3.70 per cu. yard.

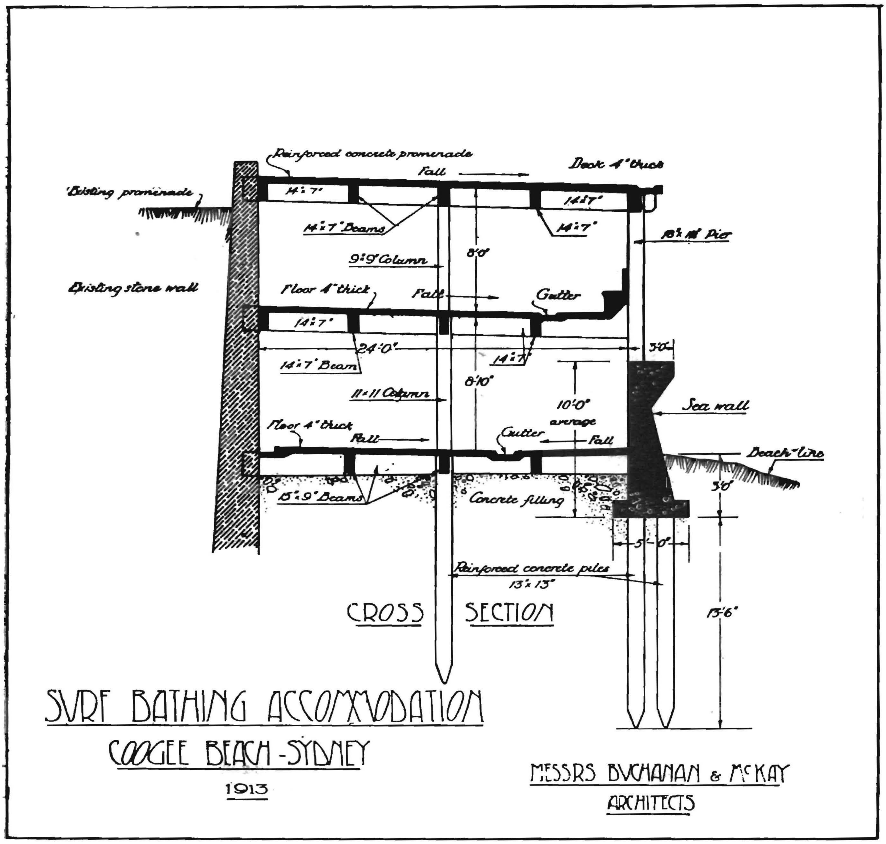


Fig. 4.

A circular reservoir, 72ft. diameter, recently completed at Randwick for the Australian Jockey Club, cost £6 per cubic yard of concrete or £5 per 1000 gallons of water stored. This tank was 8 feet deep, and was only constructed of ordinary 4:2:1 bluemetal concrete. See Fig. 5.

The workshop, illustrated in Fig. 6, consisting of a two storey, and a single storey building, now approaching completion at Redfern, cast 4.70 pence per cubic foot of building space. This building being outside the jurisdiction of the City Building Laws, had been constructed with 4in. walls, floors, and roofs, and the price given was for the building complete with all usual fittings, and included for excavation of an average depth of 2 feet over the site.

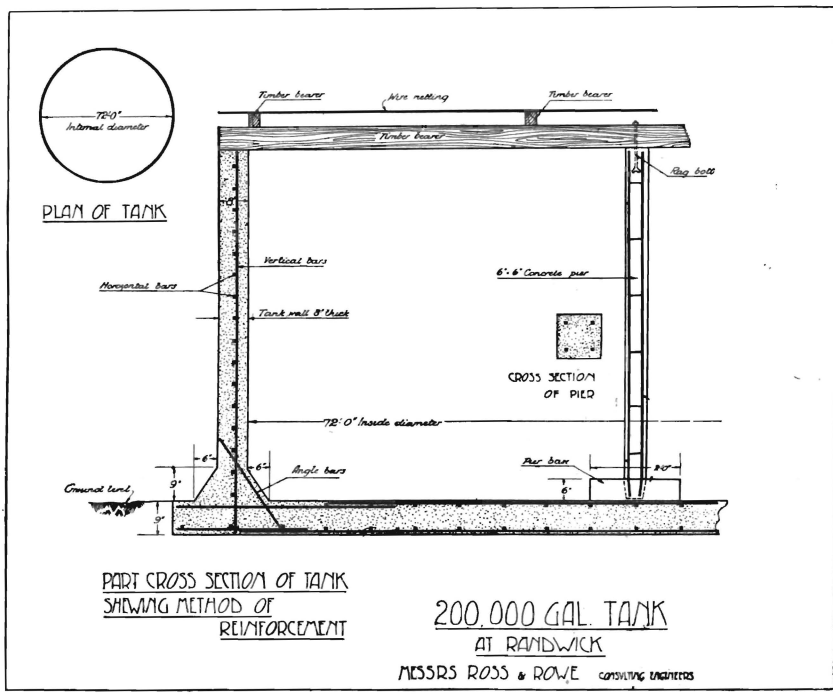


Fig. 5.

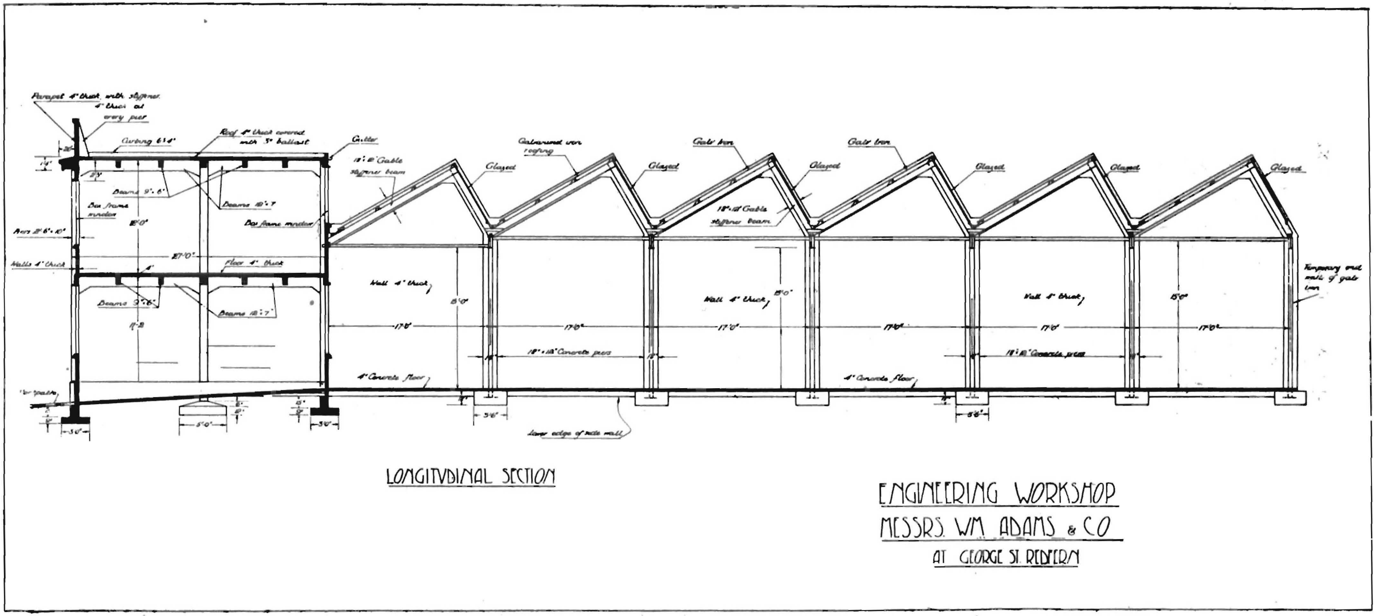

Glazed
Galv. Iron
4" Concrete floor
LONGITUDINAL SECTION
ENGINEERING WORKSHOP
MESSRS. WM ADAMS & CO
AT GEORGE ST. REDFERN

Fig. 6.

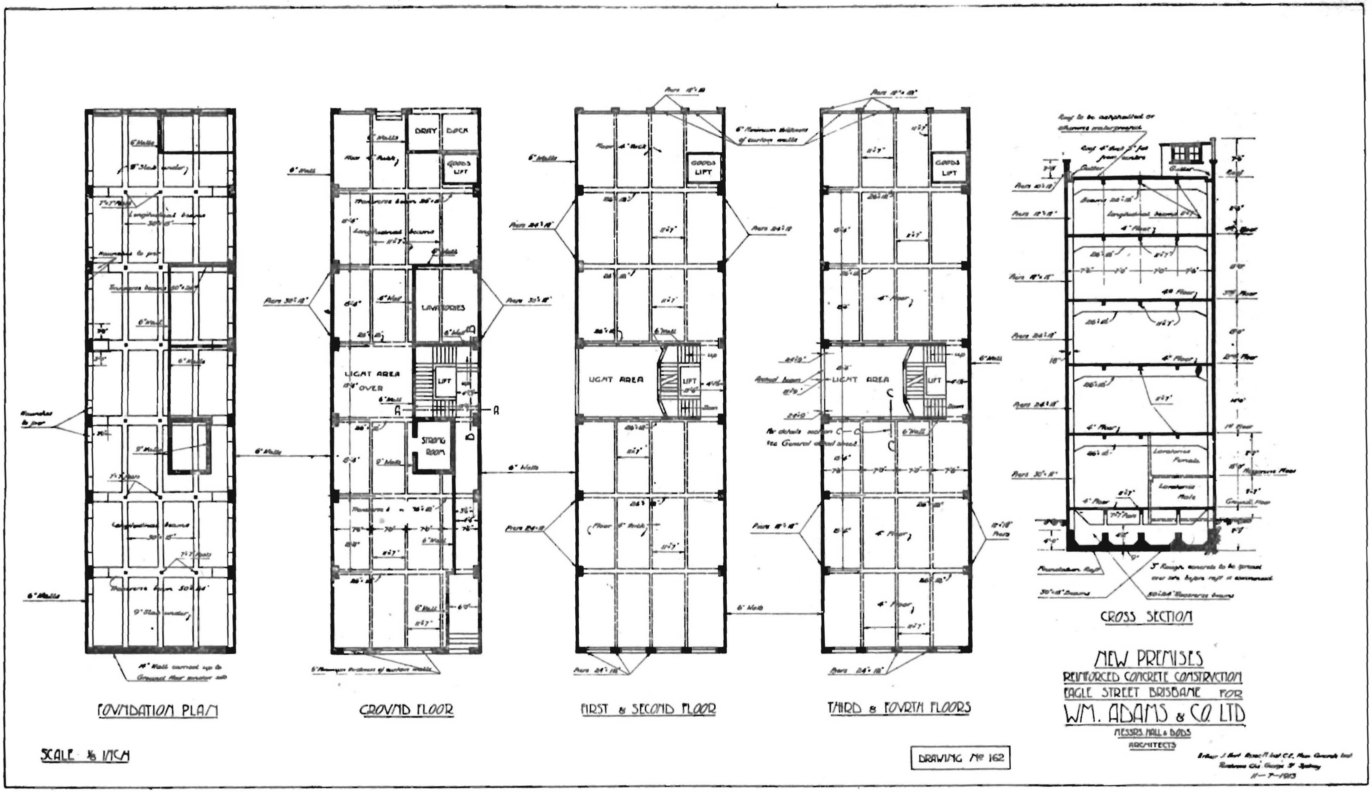
These figures, which were typical of general practice, had been selected to cover as wide a range as possible of different types of work, and would give some idea of the economy which such construction effected over similar buildings in brick, stone, and slab construction.

When the advantage of reduced cost was coupled with the advantages of longer life, strength increasing with age, decreased fire risk, and increased available area of floor space owing to the use of thinner walls, it was difficult to see why more use had not been made of the material in the complete interior of city buildings as was allowed under the present Act, which only stipulated that the exterior walls should be made of a certain thickness.

In this connection the author thought that the diagram shown in Fig. 7, of a building in Brisbane, for which tenders were now being called, would be of interest.

This building, being on made ground, was originally designed to be carried up in brick walls, supported on piles averaging 50 feet in length. The design of the building in reinforced concrete had enabled the piles, with their grave risk of damage in driving, to adjoining buildings to be replaced by a raft foundation the construction of which would, of course, not damage adjoining property in any way. The use of 6in. walls had also increased the available floor space by 10 per cent., which, in itself, meant a very appreciable increase in annual rental value. The building also, when completed, would be as fireproof as was possible, and the insurance policies would need to cover the contents of the building only.

The construction also would allow of the maximum possible value being obtained from the lighting arrangements, and would, of course, be entirely rat proof and sanitary from every point of view.


FOUNDATION PLAN
GROUND FLOOR
FIRST & SECOND FLOOR
THIRD & FOURTH FLOORS
CROSS SECTION
DRAY DOCK
GOODS LIFT
LAVATORIES
LIGHT AREA OVER
LIGHT AREA
LIFT
STRONG ROOM
NEW PREMISES
REINFORCED CONCRETE CONSTRUCTION
EAGLE STREET BRISBANE FOR
WM. ADAMS & CO. LTD
MESSRS. HALL & DODS
ARCHITECTS
SCALE ⅛ INCH
DRAWING No 162
11-7-1913

He had now endeavoured to put before them some points of interest in reinforced concrete construction. In the discussion which he hoped would follow, he trusted that many other points of interest would be raised, and which he could deal with in reply.

Discussion.

Mr. James Vicars, in proposing a vote of thanks to the author, said that the subject, as Mr. Hart had presented it to them that night, had appeared extremely simple, but on a very careful perusal of the paper he was forced to the conclusion that its apparently remarkable simplicity was largely attributable to the manner in which the author chose to convey his thoughts.

The matter dealt with was, he thought, at least so far as the majority of the members present were concerned, an exceedingly complex one, yet, as he had already remarked, it had been put before them that night as if there was little in it, and he desired, on his own account, to pay a tribute which he thought was due to the author for the able way in which he had treated it.

He would also like to take the opportunity of asking a few questions which had occurred to him whilst the paper was being read. Mr. Hart, in premising his remarks, stated that the majority of papers which one had the privilege of hearing read at such gatherings as these, were too theoretical, and that he therefore proposed to confine himself to the more practical aspect of the subject. Personally he was entirely in accord with him,