REINFORCED CONCRETE TANKS.

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Oil tanks. High service water tank. Composition of the concrete. Mixing and laying the concrete. Reinforcement. False work. Cost. Experiments made on the works. Calculations. Appendix.

Oil Tanks.

Four reinforced concrete tanks for the storage of oil were constructed during 1916-17 in the new General Stores at Moghulpura. The first of these was of 40,000 gallons capacity. Three others followed; two each of 16,000 gallons capacity and another of 40,000 gallons, while in order to fix upon the most suitable shape the two 40,000 gallon tanks were made octagonal, and the two of 16,000 gallons capacity circular.

These tanks have stood the test of three years with, as was to be anticipated, varying degrees of success. The first tank has proved to be the worst, because it was on this tank that labour, supervision, and experience, was trained and gained, and defects were gradually reduced to a minimum as the work progressed. This tank has horizontal cracks or lines of cleavage in two lines almost parallel to each other and covering almost all the eight faces. The first line appeared about three feet from the bottom, six weeks after the shuttering had been removed and the tank cement rendered. The second appeared, about six feet from the bottom, a few weeks later. Horizontal cracks have also appeared in the other three tanks, but in a less degree, so that the last two tanks of this series are practically water-tight. Weak concrete patches have also been observed in all the four tanks, owing to the segregation of heavier particles of the concrete, due either to defective mixing or to defective pun ning. These four tanks are all ten feet high, with conical roofs, and in most cases the cracks have appeared at about three and six feet from the bottom, but in some cases two feet from the top. Shortly after the false work had been removed from the last three tanks and their surfaces cement rendered, they were kept filled with water for about three months, up to which time no crack had appeared, but a month or so after the water was emptied cracks shewed themselves.

The cracks, though unsightly, can, in the writer's opinion be remedied by the simple device of placing properly designed reinforced concrete bands over them. These four tanks, however, have been constructed to hold oil and the cracks of themselves do not impair the stability of the structures, while three years' experience has shewn that the concrete is not porous.

High Service Water Tank.

It is however, with the design and construction of the 100,000 gallon high service tank that the writer wishes to deal in his paper. This tank is one of a series of three, which are to give the Moghulpura colony in Lahore an improved water-supply, and at the same time to meet the requirements of the fire protection scheme of the new General Stores. The construction was taken in hand shortly after the completion of the four oil tanks. Material began to be collected in May 1916 and the work was completed in March 1917.

The site on which the tank stands is "made" ground, there being six feet of filling at this point; the foundations were, therefore, taken down to a depth of eight feet, *i.e.*, two feet into the natural ground, where the soil was found to be good hard clay, capable of safely bearing as much as 2·5 tons to the square foot.

A circular solid mass of lime concrete, forty feet diameter and three feet thick, rammed in six inch layers, was first laid, and on this seven circular wells, seven feet six inches in diameter and five feet high, were raised and filled in with lime concrete. An eighteen inch cement concrete plug, with four holding down bolts, was placed on each well. On these the grillage was laid and on that the reinforcement of the columns.

Composition of the Concrete.

The concrete used in the plugs and in the footing was a 1:2:6 mixture of cement, sand, and $1\frac{1}{4}$ inch aggregate; while fifty per cent. of Bundi lime was mixed with the Portland cement used. The columns and tank proper were filled with a 1:2:4 mixture, with the addition of $3\frac{1}{2}$ per cent. by weight of Pudlo, which was added to the Portland cement in the construction of the floor and shell of the tank. The use of Pudlo has proved satisfactory and the tank is watertight. The Portland cement used in this work was of English manufacture. It was supplied in wooden barrels, which had been carefully stacked in a room where the doors and windows were left open and sufficient care was taken to allow the undisturbed circulation of fresh air. The barrels were brought to the site of the works as required.

The sand was composed of Pathankot grit and Ravi sand in the proportion of 2:1 and varying more or less uniformly between 1/40 inch and 3/8 inch. The aggregate used in the beams, slabs, and columns was screened so as to pass a 5/8 inch mesh and to be retained on a 1/4 inch mesh. It was composed of Pathankot shingle, and varied more or less uniformly between 1/4 inch and 5/8 inch. Both the sand and aggregate were washed with clean water and stacked for about a month before being used.

Mixing and Laying the Concrete.

The concrete was mixed on three sheet iron platforms, about six feet by ten, with two mixing gangs per platform, which were arranged so as to feed three derricks continuously. Iron pans were used for bringing the materials to the mixing platforms, and each man was instructed to bring only a particular material and to empty a fixed number of pans at each mixing. The aggregate was thrown down first, then the sand, and lastly the cement, the whole being overturned twice dry and three times wet.

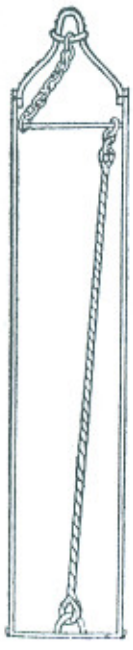


Fig. 1.



Fig. 1 (*a*).

The columns were filled by means of specially designed buckets with detachable bottoms. (Fig. 1.) Each bucket, nine inches diameter and four feet high, was made of 1/16 inch steel plate. It was raised by means of a derrick to a point above the column, and then lowered until it was about a foot or two above the last deposit, when, by an ingenious arrangement (Fig. 1*a*), its bottom was released and the concrete dropped out. The use of these buckets enabled the concrete to be dropped from such a height as to obviate the risk of the heavier particles of the concrete separating from the cement mortar and segregating at the bottom. The concrete once dropped, was rammed by a specially designed cast iron ram (Fig 2) weighing 60 lbs. and shaped to enable it to act like a wedge forcing the concrete against the sides. It was worked by



Fig. 2.

a rope over a pully which was operated by two men. The methodof working the ram can only be described " as the pull-and-let-go method." The ram was pulled out each time a bucket of concrete was ready to enter the column

The filling process may be described as continuous, as it only took about three or four minutes for a bucket to be lowered, filled, raised, lowered, and emptied. In other words, the concrete was deposited in the columns every three or four minutes. The filling of the beams, floor, and shell, was done by the same buckets ; in the case of the shell a sheet iron funnel being placed on the top to receive the concrete from the bucket.

The columns were first filled ; the bracings a week later ; and the beams and tank proper a week after the bracings. This was done so that the concrete in the columns should have a fortnight to set before any load came on it. The pause in filling the bracings was made to enable certain shutterings to be removed before the bracings could be made to unite with the columns.

It may be mentioned that the filling of the beams and the floor of the tank as one portion was a mistake. It would have been much better had the beams and bracings been filled in together, leaving the floor and the shell to be filled as a part by themselves.

As it was, much difficulty was experienced in getting the concrete to pass through the expended metal of the floor to the beams, and even greater difficulty was experienced in punning and tamping it. The result was that the concrete in the beams was not quite so compact as it might have been, but as the beams had been designed, on the score of economy, as T-beams, there was no alternative left but to fill them in as such.

Four columns were filled in one day between 6 a.m. and 4 p.m. and three columns the next day between 6 a.m. and 2 p.m. The bracing was filled by ordinary buckets and took from 6 a.m. to 1 p.m. The beams, floor, and shell, were filled in one go and took from 6 a.m. to 1 p.m. next day. Work was continued throughout the night, labour and supervision being told off in three relays, while Kitson lamps and other flare lights were used.

Reinforcement.

The reinforcement consisted of mild steel rounds and expanded metal, the former being used in the columns, beams

braces and shell, and the latter in the floor. All bending and cranking was done cold. The expanded metal for the floor was bent to take the reverse stresses over the beams, and a twelve inch overlap was allowed to each sheet. The sheets, when laid in position, were correctly arranged over the beam reinforcement, and effectively tied together with one-sixteenth inch telephone wire.

The rodding used in the beams was cranked at points where the reduction of the bending moment allowed of such cranking. All cranking was done at an angle of 45°. By this means single reinforcement was made, not only to help in resisting a part of the shear, but also to take the reverse stresses of continuous beams and slabs. 3/8 inch diameter rods were used as shear stirrups. They were fixed rigidly to the rodding by means of a twist (Fig. 3).

The steelwork in the columns consisted of 1⅛ inch verticals with 5/16 inch helical wrapping at three inches pitch. The verticals were welded to the required lengths and fixed in position by means of special hooping, placed five feet apart. The helical wrapping was prepared on a seventeen inch diameter piece of pipe, fixed up after the model of an Indian

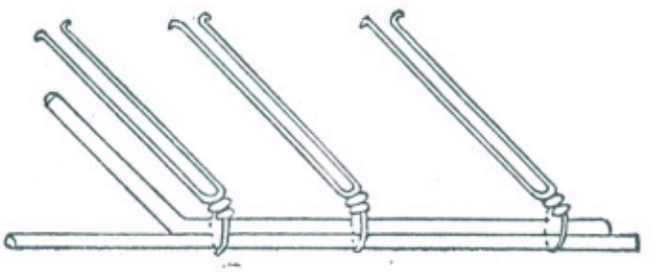


Fig. 3.

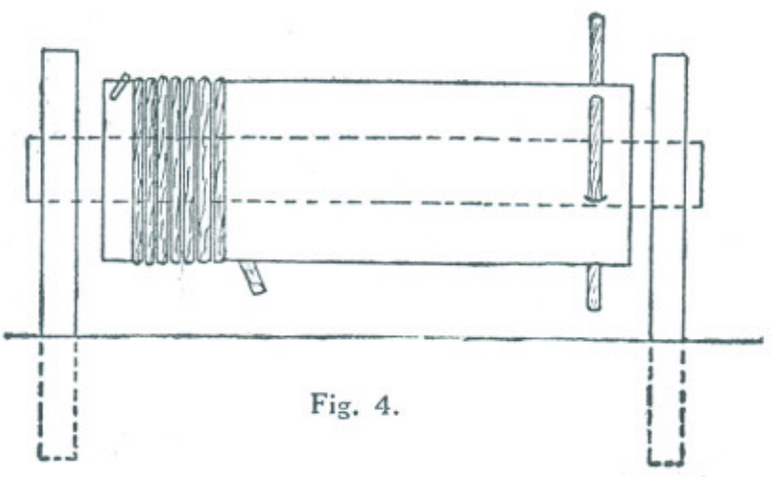


Fig. 4.

lathe (Fig 4). By judicious tamping with a hammer the blacksmith was able to so wind the 5/16 inch rods as to give them the required spring back when released. This wrapping was pulled

over the verticals and tied to them at the correct pitch by telephone wire. The junction in the wrapping was made by splaying the ends and by giving them ten inches overlap. All overlaps were tied together thoroughly with telephone wire.

The skeleton columns were raised into position by a derrick, then centered and straightened, and the false work built round them.

The base of the columns rested on a grillage made of 68lb. flat-footed rails, and though this was not necessary it was laid for greater safety.

It might be mentioned that a reasonable allowance was made for bad workmanship, and defective mixing and laying. Also that while, in the case of the columns and shell, the false work was built round the steelwork, in the case of the beams and floor, the steelwork was laid and centered in the falsework. The usual hooks and wooden chips were employed in the centering.

False Work.

Deodar planks, 1½ inches thick, were used throughout for the falsework. The planks were held together with battens and collars, while runners and fillets were also used wherever necessary. Sufficient allowance was made in the shutterings to allow the air to escape, and it was noticed during concreting that a little water was pushed out along with the escaping air. No false work was removed until six weeks after concreting, and the surface of the concrete was cement rendered as each shuttering was removed. No planks were observed sticking to the concrete, probably owing to the fact that the inside of all planks had been limewashed beforehand.

Cost.

The total cost of the high service tank worked out to Rs. 24,253, including all charges, as shewn under the following heads :—

	Foundation.	Concrete.	Steel work.	False work.	Other heads.	Total.
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Cost.	1,057	5,351	5,792	9,630	2,423	24,253

This does not allow any credit for the timber returned in good condition, and which could have been utilized for three other similar tanks. Affording the minimum credit for the wood released, the cost of the tank worked out to Rs. 22,250 or to Rs. 5 per cubic foot of concrete in position. The cost of a steel tank and staging had been estimated at Rs. 32,000, so that the saving effected by constructing a reinforced concrete tank was 30·46 per cent. while, had three similar tanks been constructed, as was originally intended, the saving would have worked out to about 35 per cent. on the cost of steel tanks and stagings. As a useful guide, the labour employed was analysed under different heads, and the result on a one day basis is shown below :—

Blacksmiths.	Carpenters.	Masons.	Mates.	Khalasies.	Coolies.
924	1,663	108	854	467	7,154

Experiments made on the Works.

Experiment (1).—To ascertain the density of various mixtures. A piece of nine inch pipe, about twelve inches long, was set upright on a wooden plank, and concrete, mixed in different proportions by measure, was poured into it with the following results. Care was taken to keep the totals equal in each case.

Mixture.	Consistency.	Depth of concrete from top of pipe.	Height of concrete in pipe.
1 : 2 : 3.	Wet.	6 1/8	5.7/8
1 : 1 : 4.	Fairly wet.	6	5.5/8
1 : 3 : 2.	Dry.	5.7/8	6.1/8
1 : 1 1/3 : 3 1/3.	Fairly dry.	5.7/8	6.1/8
1 : 1 5/8 : 3 1/5.	Wet.	6	6
1 : 2 : 4.	Wet.	6.1/4	5.3/4*

It will be seen from the above test that the 1:1 : 4 mixture was the most compact, but as there was not much difference between this and the 1:2 : 4 mixture it was decided to use the latter, because it gave the aggregate a slightly thicker film of mortar around it, while at the same time it did not appreciably affect the density of the concrete.

* Measurement made on six-sevenths of the mixture.

Experiment (*2*).—A 1:2:4 mixture of concrete, mixed thoroughly with about fifteen per cent. of water, was filled into a hollow cube and left to dry inside a room for fourteen days. It was then removed from this box and left to dry for another two days under a tree. It was then weighed and found to be 136·7 lbs. per cubic foot.

Experiment (*3*).—A test was made to ascertain the percentage of voids in shingle and sand. Two similar vessels of equal capacity were taken; the one filled with sand or shingle and the other with water. The sand and shingle used were got from the stacks which had been washed previously and were then dry. The vessel with water was graduated on the inside. It was found that the sand contained about thirty-two per cent. of voids and the shingle about thirty-six per cent.

Experiment (*4*).—Shingle cement blocks were made of a 1:2:4 mixture and tested to ascertain the periods of initial and final set. One placed immediately in water shewed initial set after twenty hours and final set after thirty-six hours, when the water had nearly evaporated. A block placed in air shewed initial set after twelve hours and final set after twenty hours, while a block placed in the sun shewed initial set after about fifteen minutes and final set within six hours, but it was cracked in many places. The writer was not satisfied with the above results, and would be glad to hear of the experience of some other members. He is aware that cement when incorporated in concrete takes longer to set than if it were "neat."

Experiment (*5*).—Briquettes were made and tested for strength in tension. They were gauged in clean water placed in the shade for about twenty-four hours and then under water for twenty-one days. The result of the test is as below :—

Description.	Proportion.	Breaking stress.	Remark.
		lbs.	
Bundi lime and Portland cement	1 : 1	533	Each test was the average of three briquettes.
Bundi lime and sand	1 : 1	275	
Portland cement	Neat	513	
Bundi lime	Neat	523	

It is clear from these tests that Bundi lime and Portland cement, mixed thoroughly, shewed the best results, and also that Bundi lime shewed up better than Portland cement. There was, however, nothing to shew that Bundi lime would maintain its strength or improve with age. It is possible it may deteriorate rapidly, and it was, therefore, resolved not to risk it ; so that, but for the bracings and a little used along with the Portland cement in the footings, Portland cement was used throughout the construction of the high service tank.

Experiment (6).—A $\frac{3}{4}$ in. round mild steel rod, as supplied to the works by the Stores Department, was prepared to a test piece of eight diameters. It was tested to destruction by Messrs. Lacey and Watkins of the Loco. Department, and gave way at 13·1 tons ; the elongation and contraction were clearly visible to the naked eye under a stress of about 11·5 tons.

Experiment (7).—A number of mild steel "rounds" of $\frac{3}{4}$ in., 1 in. and $1\frac{1}{8}$ in. diameters were splayed, overlapped, and welded. The overlap was taken at three diameters and the diameter of the rod at the welding itself was bulged out by about $\frac{1}{8}$ in. (Fig. 5). These rods were also tested by Mr. Watkins, and in each case gave way under full stress at a point away from the welding. This shewed conclusively that the welding was stronger than the rod. Welded rods were used in the verticals of the columns, in the shell, and to take the tension in the beams.

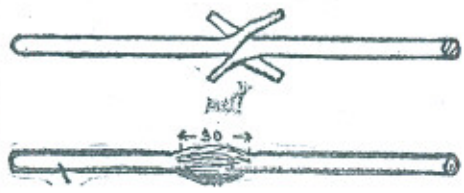


Fig. 5.

Calculations.

The tank was circular, with a partition to allow of half being emptied and cleaned out at a time. Its effective depth was fourteen feet, the capacity 100,000 gallons, equal to 16,000 c. feet, to which must be added the space taken by the partition, making the diameter nearly $38\frac{1}{2}$ feet.

To find the sectional area of the steel hooping in the shell.

Formula used $\omega = \dfrac{\cdot 215\ H_w\ \delta b}{f}$ *

ω for 14 ft. depth = $\frac{3}{4}$ in. rods four inches pitch.

ω ,, 10 ft. ,, = $\frac{5}{8}$ in. ,, ,, ,,

ω ,, 8 ft. ,, = $\frac{1}{2}$ in. ,, ,, ,,

* See Appendix on page 154 for notation employed throughout.

For practical reasons rods of less than $\frac{1}{2}$ in. diameter were not used, and when it was finally decided to use double reinforcement in the shell, $\frac{5}{8}$ inch rods at five inches pitch were used for half the depth and $\frac{1}{2}$ inch rods at the same pitch for the remainder.

The verticals were calculated for reinforced slabs fixed between two hoopings. The concrete worked out to about half an inch and the reinforcement to about $\frac{1}{3}\frac{1}{3}$ in. From practical considerations it was decided to use $\frac{1}{2}$ in. verticals placed a foot apart, while the concrete was taken as six inches at the bottom, tapering to four inches at the top. The horizontal hoopings were tied to the verticals by telephone wire, and both the verticals and the horizontals were arranged to break joint.

To calculate the floor of the tank.—The largest slab in the floor was worked out and the entire floor was laid of one thickness ; but as the slab was fixed on all sides a factor of reduction of 0·83 was used.

Formulæ used.

$$k = \sqrt{r^2 m^2 + 2rm} - rm,$$

$$T = \frac{M}{rbd^2 (1 - \frac{1}{3} k)} \text{ and } C = \frac{2 M}{kbd^2 (1 - \frac{1}{3}k)},$$

The bending moment was taken as $= \frac{wl^2}{12}$ and from the success of the structures designed this value appears to be satisfactory. It was adopted on the assumption that all beams and slabs, though continuous, were to be treated as partially fixed. The weight of the reinforced concrete was taken as 150 lbs. throughout the calculations and the bending moment as $\pm \frac{wl^2}{12}$. The working stresses assumed for beams and slabs were 600 lbs. per sq. in. for concrete in compression, and 16,000 lbs. per sq. in. for steel in tension. The slab worked out to an effective depth of six inches, and a total depth of seven inches with No. 30 expanded metal.

To calculate the auxiliary beams.—These beams were for economical reasons calculated as T-beams, though it would have been better, for facility of construction, (as already stated)

had they been calculated and designed as simple beams. The formulæ used were

$$M = \frac{wl^2}{12}$$

$$bn^2 + 2mA_t n = 2mA_t d.$$

$$I = \frac{bn^3}{3} + mA_t (d-n)^2$$

$$C = \frac{Mn}{I} \text{ and } T = \frac{mMn^1}{I} \text{ where } n^1 = (d-n)$$

The T worked out to an effective depth of 20 in. and total depth of 22½ ins. with six one inch diameter rods. Nine inches width was allowed.

To calculate the stringer beam.—This beam was also calculated and designed as a T-beam.

Formulæ used.

$$M = \frac{wl^2}{12}$$

$$n = \frac{2mA_t d + be^2}{2(mA_t - be)}$$

$$I = \frac{be^3}{12} + \frac{be(n - \frac{1}{2}e)^2}{4} + mA_t (d-n)^2$$

$$C = \frac{Mn}{I} \text{ and } T = \frac{mMn^1}{I} \text{ where } n^1 = (d-n)$$

This beam worked out to an effective depth of 28 ins. and a total depth of 31 ins. with eight 1⅛ inch rods. A width of twelve inches was allowed.

Arch beams.—These beams were not calculated, but interpolated for strength between the stringer and the auxiliary beams. Their ends were turned in concrete, shaping them into false arches.

To calculate the shear stirrups.—Formula used.

$$A_s = \frac{S_h - T \sin \alpha}{T \sin \beta}$$

Allowing 60 lbs. per sq. in. for the concrete, the shear reinforcement worked out to 3·6 sq. ins. for the stringer beam; allowing nothing for concrete, the steel worked out to 4·4 sq. ins. Twenty-one stirrups of two $\frac{3}{8}$ in. rods were used in a stringer, and eighteen stirrups of two $\frac{3}{8}$ in. rods in each auxiliary beam. The above formula allows for cranked rods and diagonal shear stirrups, while T in the formula = 12,000 lbs. per sq. inch.

Columns.—The tank was arranged to rest on one centre and six outside columns at a height of forty feet above rail level. The total load on the columns was 1,330,340 lbs., that on the central column being 227,548 lbs. and on each outside column 183,799 lbs. Here the working stress were taken as 500 lbs. to the sq. in. for the concrete and 12,000 lbs. per sq. in. for the steel.

The formulæ used (for actual stress) was

$$C = \frac{W}{A + A_v (m - 1)}$$

$$T = mC.$$

The formula used to ascertain the ultimate allowable stress, with the particular form and section of wrapping, was $C = k_1 c (1 + f_1 s r_1)$. The working or allowable stress on central column worked out to 710 lbs. per sq. in. with eighteen inch core, and the actual stress to 620 lbs. per sq. in.

Wind Pressure.—The intensity of wind pressure was taken as 35 lbs. per sq. ft. on the diametral plane and a factor of reduction of ·78 was taken as the tank was circular, so that the total wind pressure was ·78p multiplied by the area of the diametral plane, and was equal to 15,570 lbs.

The pressure on each column when the wind acts in the most critical direction is given in the following table :—

Column.	Pressure.	Formula used.
	lbs.	
1	246,200	$\frac{W}{N} + \frac{M}{R}$
2 & 6	210,116	$\frac{W}{N} + \frac{M}{4R}$
3 & 5	185,724	$\frac{W}{N} - \frac{M}{4R}$
4	149,134	$\frac{W}{N} - \frac{M}{R}$
7	remains unaffected.	

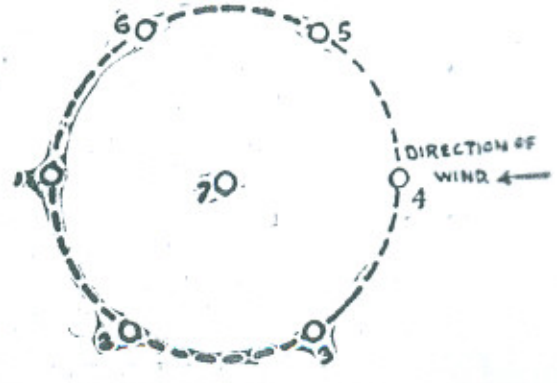


Fig. 6.

These are the results when the wind acts in the direction *P* shewn in the diagram. All columns are designed to resist the greatest pressure, *i.e.*, 246,200 lbs.

The actual stress in the concrete core (19 ins.) works out to 465 lbs. per sq. in.

Wind Bracing.—No allowance was made in the columns for bending, because they are so placed as to answer to the condition of concentric loading as nearly as possible; but as the ratio of length to least diameter is about 1 to 20, the columns are tied together in the centre by radial and lateral bracings.

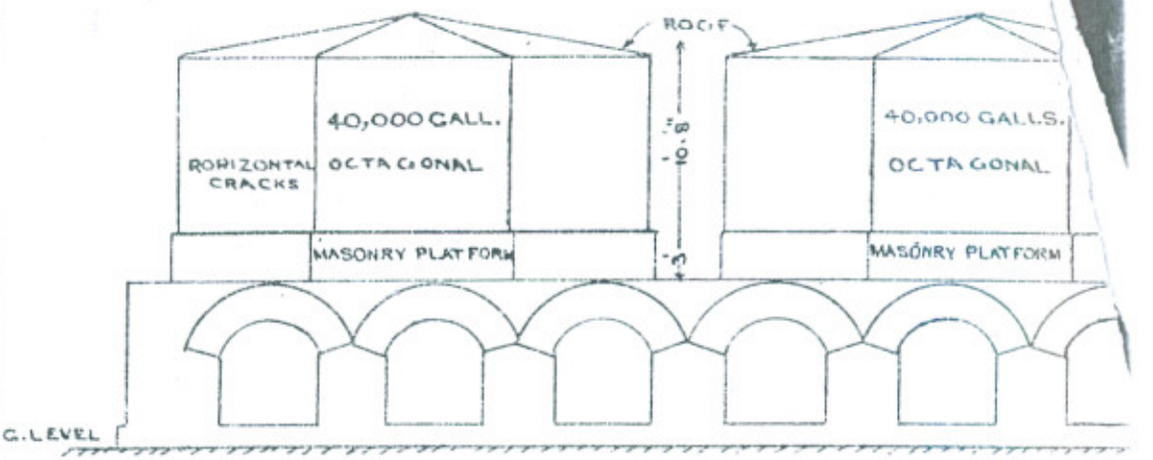
Partition.—This was calculated as consisting of continuous slabs partially fixed and held in position by tie ribs. These tie ribs are calculated as T-beams with the total pressure of water acting at a third of the depth, the bending moment being taken as $\frac{W.\ L.}{3}$. The ribs were reinforced for shear with $\frac{3}{8}$ inch stirrups.

In conclusion, the writer wishes to acknowledge the advice, help, and encouragement, he received from Messrs. Harvey, Rodgers and Wilson, without which it would not have been possible for him to have done the work.

APPENDIX.

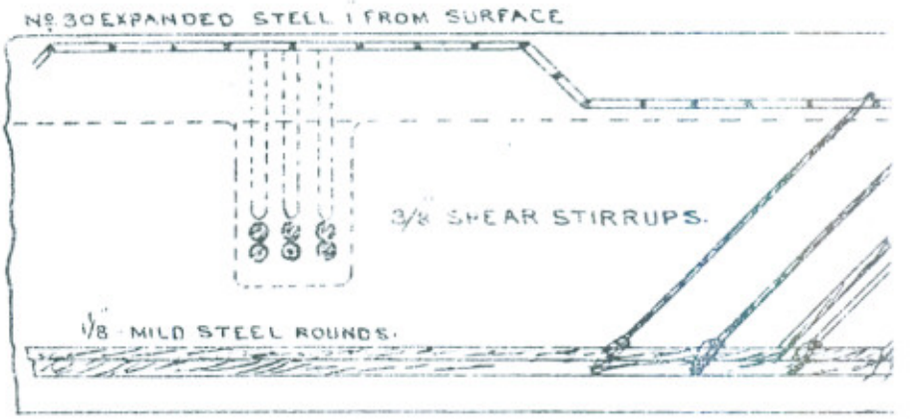
Notation used.

A = sectional area of concrete core in square inches.
A_s = sectional area of steel in shear in square inches.
A_t = sectional area of tensile reinforcement in sq. ins.
A_v = sectional area of vertical reinforcement in sq. ins.
m = modular ratio = 15.
M = bending moment.
C = safe compressive stress in concrete in in-lbs.
T = safe tensile stress in steel in in-lbs.
r = ratio of A_t to $bd = \frac{A_t}{bd}$
k = fractional depth of neutral axis = n/d.
n = distance of neutral axis from compressive edge.
d = effective depth of beam in inches.
b = breadth or width of beam or slab in inches.
W = total load in lbs.
H_w = head of water in feet.
f = safe stress per square inch in steel in hooping.
l = length in inches.
e = total thickness of floor slab in inches.
I = moment of inertia in inch units.
w = load per foot run.
L = length in feet.
S_h = total shear at any point.
S = factor of safety.
α = angle of cranked rods to the horizontal.
β = angle of shear stirrups to the horizontal.
δ = internal diameter of hoop in inches.
ω = sectional area of steel in hooping.
c = breaking weight of concrete at three months.
k_1 = reciprocal of factor of safety.
f_1 = form factor.
s = spacing factor.
r_1 = volume ratio of lateral reinforcement to hoop of core per unit length.
N = number of columns.
R = (for circular tanks) radius of the circle passing through the centre of the columns.
P = total pressure of wind in lbs.
p = actual wind pressure in a particular case.



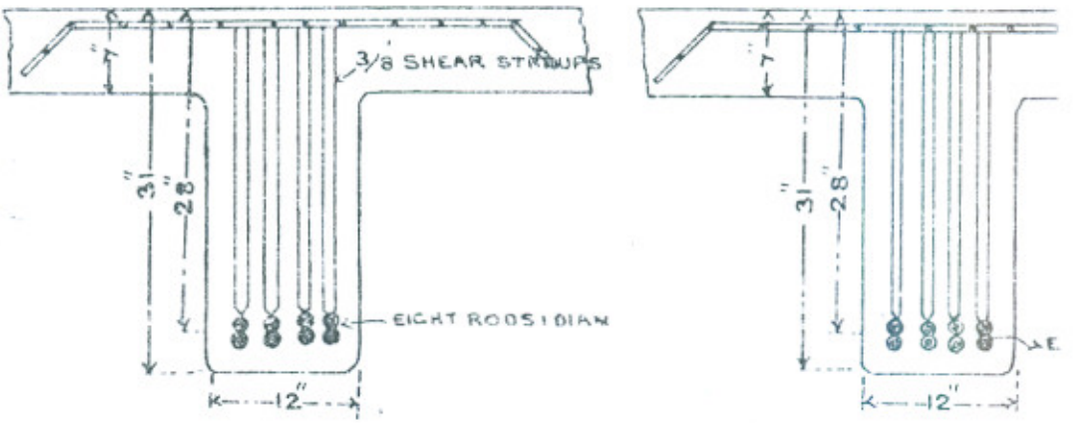
FIG

PART SECTION OF
SHOW
REINFORCEMENT OF BEAM,



1 RODS ←

FIG. 2



STRINGER BEAM

ARCH BEAM

DISCUSSION.

MR. WALLACE, in rising to introduce his paper, said he ad nothing to add to what he had written, but would be pleased answer any criticisms which might be made.

MR. A. P. LIVINGSTONE LEARMONTH enquired if the hor could suggest any probable reason for the horizantal cracks ich had appeared in some tanks and not in others. Was there difference in the design of the shell ? The high service k, as regards the shell, was built continuously without a stop. as this the case also with the oil tanks which cracked slightly ? ot had "planes of work" formed through ceasing work for the at the point where the cracks appeared ? There had been a d deal of correspondence in the American "Engineering News" ut so called "planes of work" about a year ago.

Mention was made* of the provision for the circulation air. Was this to keep the cement cool ? and, if so, was there evidence to show that cement deteriorated with high nospheric temperatures ? The old idea of spreading out ment in layers in a store to aerate had been found to be ite wrong, as there was a certain amount of airstaking with rtland cement as with ordinary lime, and the most modern actice was to keep cement in air-tight bins. The mixing floors ere small. He had found in practice that one gang could mix ght cubic feet of cement at a time and would like to know if e author had come to any conclusion as to the best quantity to ix at one time. It would also be interesting if the author could ply a detailed analysis of rates showing the percentage of the t of materials, labour, falsework, etc., per cubic foot of concrete, o the rates at site for steel and for cement. He had furnished e author with an analysis of rates for some reinforced concrete rk he had in hand.

With reference to experiment No. 4 on page 146. The ly test he had made in practice for the initial set of cement was e ordinary British standard test of penetration by a needle, one illimetre square, weighted with 300 grammes, applied to a ment pat four centimetres thick, but this, of course, was in-plicable to concrete, and it was new to him that cement set icker neat than when incorporated in concrete. It would be of terest to hear how the author tested the concrete for initial t.

* Page 140.

In the test for tensile strength, 513 lbs. per square inch, a twenty-one days, seemed a low breaking stress. Although 4 lbs. per square inch was the minimum permissible British standard he had rarely found briquettes of any well-known brand at hom to break under 600 lbs. per square inch after seven days. The recent tests of two samples, each of six briquettes of Indian manufactured cement, by the Government Test House at Alipore showed—

Tensile breaking stress.	Bundi cement.	Katni cement,
after 7 days ...	710 and 696lbs.	684 and 653lbs.
after 28 days ...	757 and 759lbs.	757 and 709lbs.

so that the imported cement used in these concrete tanks seemed to have been distinctly inferior to that from either Bundi or Katni, and this might explain why Bundi lime was found superior to the cement used.

CAPTAIN GIBB stated that experience in Canada showed that cement concrete proportioned 1 : 1½ : 3 or 1 : 2 : 4 and graded by Fuller's Rule was water proof, without the use of special water-proofing compounds. He described the buildi of a flume, in section a hydraulic catenary, with the shell inches thick, poured all from the top, in which the use of aggregate gave no trouble by clogging. He criticized certain technical points of the design, and mentioned some useful graphs that saved much labour in calculations.

MR. F. H. BURKITT remarked that the testing of the cement looked as if it had been suspect. The cement received from England for works with which he had been connected had been of good quality.

MR. F. W. WOODS remarked that four tanks were shown,* each ten feet high, with conical roofs, and enquired why the tanks were subjected to pressure, by being filled with water before the concrete had time to set ? It was noticeable that cracks did not appear till after the water was let out. Considere's experiments showed that, when reinforced concrete was allowed to set under water, the tendency was for the concrete to expand during the process of setting, but that when it was allowed to set in dry air, the tendency was to contract. It was a mistake to keep the tanks filled with water whilst setting, and so subject them prematurely to irregular stresses, the inner surface of the concrete having quite a different condition of setting to that of the outer surface.

* Plate facing page 152.

MR. WALLACE, replying, said that the cement barrels were stacked in a room with plenty of ventilation in order to prevent their getting damp. He did not agree with Mr. Learmonth that it was wrong to aerate cement before using it on works, and held that, whenever the humidity of the air admitted, cement might with advantage be turned at least twice before being used. Where the moisture in the air was considerable, arrangements should be made, if possible, with the manufacturer to aerate cement at his factory before sending it out on works. Mr. Learmonth had also remarked that the mixing platforms were small, but they were large enough to feed one bucket at a time ; the purpose for which they were intended. The materials for the tanks had been bought at the scheduled pre-war rates and he regretted he had not a copy of the estimate in order to go into details.

With regard to the design of the circular oil tanks and the high service tank, there was no difference in the scheme of reinforcing the shells, except that single reinforcement was used in the former and double reinforcement in the latter, and he agreed with Mr. Woods in thinking that this double reinforcement was the reason why the shell of the high service tank had not cracked. Regarding Mr. Woods's suggestion that the cracks in the oil tanks might be due to the tanks having been filled with water before the concrete had time to set, he was afraid he had not made this point clear in his paper. As a matter of fact no water was allowed into the tanks for six weeks, when the shuttering, which had been kept moist by means of drip buckets, was removed. The horizontal cracks could not, therefore, be due to water pressure having been brought to bear on imperfectly set concrete. Neither could the cracks be due to the expansion of the conical roof, as suggested by Capt. Gibb, as in that case vertical cracks should also have appeared. Finally the cracks could not have been due to ' planes of work', because the concrete in all the oil tanks, except the first, had been poured in one continuous operation.

As regards testing the cement, he had used a pen-knife or his thumb nail to test the initial set both of cement and concrete, and while he agreed with Mr. Learmonth that government tests on Bundi lime and Katni cement had shown good results, he contended that Portland cement was an old and tried material, increasing in strength with age, while little was known in this connection concerning indigenous products. The percentage of addlo used was based upon the weight of the cement and not upon the weight of the concrete.