DISCUSSION.

The PRESIDENT: Gentlemen, the way in which you have received Mr. McEwin's paper relieves me of the necessity of making any complimentary remarks. I shall merely call on Mr. Reeks to propose, and Mr. Hart to second, a vote of thanks to Mr. McEwin.

Mr. REEKS thanked Mr. McEwin for having brought the subject before the Association in so able a manner, and said that perhaps it was fitting that he should speak first, as he would be confining himself to the basic principles or foundation of the matter, viz., strength.

Proceeding, Mr. Reeks said: I have prepared a sheet (Table 1) shewing the recognised method of calculating the strength of a ship, which is simply that adopted for any compound girder. These figures shewed a maximum compressed stress in the bottom member of 1.54 tons per sq. in. of metal, and was about what one might expect in a standard or Lloyds ships of the size referred to, though in larger ships much higher stresses are allowed, and have proved satisfactory.

Now, having arrived at the actual figures of a given vessel, and considering that the compression and tensional stresses are alternating every few seconds in a seaway, there appears no reason, from a purely strength point of view, why one should be greater than another, and I have prepared another sheet shewing a vessel of the same dimensions, but altering her scantlings so as to bring equal stresses on both top and bottom members by the simple process of taking material out of the bottom, bringing the stresses on both up to 2.63 tons per sq. in. of metal—not by any means too high a figure for a vessel of this size. This was done with a view to ascertaining what weight of metal could be saved, or, in other words, what would be the amount of

TABLE 1.

	Calculation to Find Neutral Axis.			Calculation of Moment of Inertia, Bulwarks and Rail not considered.			Moment of Inertia. Bulwarks and Rail taken into consideration.		
	Sectional Area in square inches A.	Distance of C. of G above keel in feet.	Moment.	Distance of C. of G. from Neutral Axis h	h^2	$A \times h^2$	Distance of C. of G. from Neutral Axis h	h^2	$A \times h^2$
Keel plate	16·80	0·000	0·000	4·05	16·40	275·52	4·57	20·88	350·78
Botaom plating ...	73·44	·125	9·180	3·92	15·37	1128·77	4·42	19·54	1435·02
Bilge plating ... } Centre through plate }	24·40	·75	18·700	3·27	10·69	260·84	3·85	14·82	361·61
Foundation plate ...	7·68	1·30	9·984	2·83	8·08	62·14	3·33	11·09	85·17
Keelson angles (bot'm)	1·61	·29	·467	3·79	14·36	23·20	4·29	18·40	29·62
Keelson angles (top)...	1·61	1·28	2·061	2·79	7·84	12·62	3·29	10·82	17·42
Centre through plate above foundation plate	·96	1·46	1·402	2·69	7·24	6·95	3·17	10·05	9·69
Bilge plating ... } Side plating ... } Sheer Strokes ... }	77·04	5·00	385·200	·94	·88	67·80	·44	·19	14·64
Sheer do. (above deck)	11·52	9·40	108·288	5·21	28·20	324·86	4·81	23·14	266·57
Deck plating ... } Stringer plates }	60·80	8·80	535·040	4·73	22·37	1360·10	4·23	17·89	1087·71
Stringer angles } Gunwale do. (top) }	4·37	8·94	39·068	4·88	23·81	104·05	4·35	18·92	82·68
Gunwale do. (bottom)	1·60	8·66	13·856	4·63	21·44	34·30	4·10	16·81	26·90
Side stringer angles ..	1·61	4·166	6·707	·13	·02	·03	·35	·12	·19
Area less Bulwarks	283·44[]"	Moments	1129·958		Moment of Inertia	3661·18			
Bulwark plates ..	21·84	11·25	245·70				6·75	45·57	995·25
Rails	2·37	12·66	30·00				8·17	66·79	158·29
Total Area...	307·65[]"	Total Moments	1405·653					Moment of Inertia	4921·54

Distance of Neutral Axis above Keel (Bulwarks not taken in). $= \frac{1129 \cdot 95}{283 \cdot 44} = 4 \cdot 05$ feet

Distance of Neutral Axis from top of Sheer Stroke. $= 5 \cdot 92$ feet

Distance of Neutral Axis above Keel (Bulwarks taken in). $= \frac{1405 \cdot 65}{307 \cdot 65} = 4 \cdot 57$ feet

Distance of Neutral Axis from top of $= 8 \cdot 11$ feet

Steel Vessel—L. 126·25′, B. 25·5′, D. 8·75′. Displacement 330 tons.

Taking 1/35 of Length × Displacement.

Max. bending Moment $\frac{126 \cdot 25 \times 330}{35} = 1190 \cdot 36$

Max. Tensional Stress tons per sq. inch. $\frac{1190 \cdot 36 \times 5 \cdot 92}{3661 \cdot 18} = 1 \cdot 92$

Max. Compress. Stress tons per sq. inch. $\frac{1190 \cdot 36 \times 4 \cdot 05}{3661 \cdot 18} = 1 \cdot 31$

Taking 1/30 of Length × Displacement.

Max bending Moment $\frac{126 \cdot 25 \times 330}{30} = 1388 \cdot 75$

Max. Tensional Stress tons per sq. inch. $\frac{1388 \cdot 75 \times 5 \cdot 92}{3661 \cdot 18} = 2 \cdot 24$

Max Compress. Stress tons per sq. inch. $\frac{1388 \cdot 75 \times 4 \cdot 05}{3661 \cdot 18} = 1 \cdot 54$

Taking 1/35 of Length × Displacement.

Max. bending Moment $\frac{126 \cdot 25 \times 330}{35} = 1190 \cdot 36$

Max- Tensional Stress tons per sq inch $\frac{1190.36 \times 8 \cdot 11}{4921 \cdot 54} = 1 \cdot 96$

Max. Compress. Stress tons per sq. inch. $\frac{1190 \cdot 36 \times 4 \cdot 57}{4921 \cdot 54} = 1 \cdot 11$

Making 1/30 of Length × Displacement.

Max. bending Moment $\frac{126 \cdot 25 \times 330}{30} = 1388 \cdot 75$

Max. Tensional Stress tons per sq. inch. $\frac{1388 \cdot 75 \times 8 \cdot 11}{4921 \cdot 54} = 1 \cdot 29$

Max Compress. Stress tons per sq. feet. $\frac{138 \cdot\cdot 75 \times 4 \cdot 57}{4921 \cdot 54} = 1 \cdot 29$

TABLE 2.

Taking 60 square inches out of lower portion of girder making Neutral Axis distance equal above and below, and also making Stresses (Tensional and Compressive) equal.

(STEEL VESSEL.)		Sectional Area (A) in square inches.	Distance of C. of G. above keel in ft.	Moment.	Distance of C. of G. from Neutral Axis (h.)	H^2	$A \times H^2$
Keel plate...	Less 8·00	8·8	0·0	0·00	4·88	24·80	218·240
Bottom plating and Bilge	,, 39·17	34·27	·125	4·284	4·89	23·91	819·396
Centre through plate ...	,, 7·4	17·00	·75	12·75	4·33	18·75	318·750
Foundation plate... ...	,, 4·0	3·68	1·30	4·874	3·81	14·55	53·433
Keelson Angles (bottom)	,, ·5	1·11	·29	·322	4·75	22·56	25·041
Keelson Angles (top) ...	,, ·5	1·11	1·28	1·421	3·75	14·06	15·606
Centre through plate above foundation plate	,, ·5 Total 60·07	·46	1·46	·671	3·65	13·32	6·127
Bilge plating ... Side plating ... Sheer Strakes ...		77·04	5·00	385·200	·04	·001	·007
Sheer Strakes (above deck)		11·52	9·40	108·288	4·33	18·75	216·000
Deck plating ... Stringer plates ...		60·80	8·80	535·04	3·79	14·36	873·088
Stringer angles ... Gunwale angles (top)		4·37	8·94	39·068	3·90	15·21	66·447
Gunwale angles (bottom)		1·60	8·66	13·856	3·63	13·18	21·088
Side Stringer angles		1·61	4·166	6·706	·83	·69	1·111
	Total area	223·37	Total moments	1112·391	Moment of Inertia		2634·333

Distance of Neutral Axis above keel $\frac{1112 \cdot 39}{223 \cdot 37} = 4 \cdot 98$ feet.

Distance of Neutral Axis from top of Sheer strake = 4·99 feet.

Weight of fore and aft members equal 60 tons equal 28·344 square inches.

Less 60 square inches = 12·68.

∴ 1/5 of weight saved.

Taking 1/35 of Length by Displacement.

Max. bending Moment $\frac{126 \cdot 25 \times 330}{35} = 1190 \cdot 36$

Max. Tensional Stress tons per square inch. $\frac{1190 \cdot 36 \times 4 \cdot 99}{2634 \cdot 33} = 2 \cdot 25$

Max. Compressive Stress tons per square inch. $\frac{1190 \cdot 36 \times 4 \cdot 98}{2634 \cdot 33} = 2 \cdot 25$

Taking 1/30 of Length by Displacement.

Max. bending Moment $\frac{126 \cdot 25 \times 330}{30} = 1388 \cdot 75$

Max. Tensional Stress tons per square inch. $\frac{1388 \cdot 75 \times 4 \cdot 99}{2634 \cdot 33} = 2 \cdot 63$

Max. Compressive Stress tons per square inch. $\frac{1388 \cdot 75 \times 4 \cdot 98}{2634 \cdot 33} = 2 \cdot 63$

reinforcement necessary in such a vessel to provide for the tensional stresses. This shewed that one might reduce by 20 per cent. the total weight of the fore and aft members, which, of course, includes the bottom plating and deck, the side plating representing the web of the girder.

At this point I stopped, having, so to speak, provided for the reinforcement only, leaving the expert in concrete to carry on and provide the skin and means of keeping the water out, presenting him, as it were, with this 20 per cent. item towards the weight of his necessary material. Doubtless savings could also be made in thwartship members, but it was, for the moment, unnecessary to discuss that.

Mr. Hart: It is a very real pleasure to me to second the vote of thanks to Mr. McEwin. I am sure we have all appreciated the masterly way in which he has presented the subject, and I feel sure, too, that the majority of us have not looked at this question before in the way that it has been presented to us this evening.

The idea of building concrete ships reminds me of the play "Milestones," which dealt with a family who, for generations, had been interested in wooden shipbuilding. The family had made their fortunes in building wooden ships, and a suggestion by a younger son that iron ships should be built instead of wooden, led to a quarrel which ended in the son being driven from the home and expelled from the firm, as the father said he was mad. The son started shipbuilding on his own account; but later on when his son in turn suggested ship construction in steel the iron shipbuilder said that his son was mad also.

Mr. McEwin has said that the proposal to build concrete ships is not so revolutionary as was the substitution of iron for wooden ships; but we do not wish to place ourselves in a similar position to-night to the fathers who were too conservative in their views to admit the possibility of construction in a new material. I am bound to admit that prior to reading the author's paper, I had not given much serious consideration to this matter, and I certainly entertained doubts as to the possibility of concrete ships for ocean-going purposes—I wish particularly to emphasise the words "ocean-going." I am well aware that concrete vessels are adaptable for, and are already in extensive use in still waters. The one great problem seems to me to be the skin cracking of the concrete, which always occurs under stress, and which would admit the salt water to the steel, causing rust, and very quickly leaving the ships useless. This is, to me, the great difficulty which I do not see any particularly simple way of overcoming; but the paper has suggested some very feasible ideas which would tend, at any rate, to minimise difficulties of that kind.

We are informed that one vessel of 3000 tons has been launched, but it still remains to be seen how she will stand the stresses which have to be encountered at sea—which will be the real test which must be passed before the vessel can be deemed satisfactory.

Passing over the question which is raised by the statement that all these ships could be moulded from the same set of forms, which is open to considerable doubt, and going on to the statement that a vessel of concrete should be but little heavier than a wooden vesel of similar capacity, the truth of that assertion would depend upon the manner of building the structure. It might be correct if the ship were built by depositing a thin skin of concrete upon a metal skeleton; but if the boat were built in the manner which would probably be adopted here—that is, by pouring concrete between wooden moulds, it would be from four to six inches thick, and the weight might be easily double that of a wooden ship.

With regard to the statement that the maintenance of concrete vessels would be very low, I do not agree that it would be so, on account of the difficulty I have before referred to with the risk of cracks occurring. I have, however, heard it said that in the event of one of these vessels being damaged by collision or otherwise, the repairing of it would be a matter of very great difficulty and much expense. At first sight this would appear to be so; but on more careful reflection, it seems to me that if the boat were docked, and portions round the fracture cut away, and new steel bars spliced in with the old reinforcement, and new concrete deposited to replace the parts cut away, then repairs could possibly be effected at a cost not much greater than that which would be necessary with steel ships.

As to the concrete of the ships being impervious to sea water, it is not certain that this material will resist the action of sea water for an indefinite space of time; but, of course, if we could at this juncture build ships which would have a life of only a few years they would have served their turn. The experience of different authorities as to the action of sea water on cement concrete appears to differ. An article which appeared recently in "Engineering" dealt with some facts concerning test concrete blocks which were exposed for some years on the sea beach in such a position that they were alternately wet and dry, and in some instances the blocks were badly fretted with the lapse of time. The Sydney Harbor Trust has used a great deal of reinforced concrete in positions between wind and water, and up to the present it seems to be resisting the action of the sea water very well. We may hear tonight from some of the Harbor Trust engineers who may be present the statement contrary to "Engineering" that sea water does not adversely affect concrete, shewing that one man's experience is not always that of another.

The author's paper states that mineral oil does not adversely affect concrete, but I have first-hand knowledge that it has so affected, and does so affect, concrete in many instances, which is another illustration of the case in point.

The information that Swedish and Danish concrete shipbuilding companies have constructed 3000-ton ships is most important, and the fact of firms experienced in this class of work being willing to put money into ocean-going vessels is the best kind of proof that they have faith in the suitability of reinforced concrete for the purpose.

Some mention has been made by the author of a motor boat which was reinforced with steel which had been galvanised. The solution of the problem may lie in this, or other similar, method of preventing the steel from rusting; but it would considerably add to the cost of construction.

It may be possible by using light meshes to reinforce close to the surface to overcome surface cracks. I have tried very hard in the course of my ordinary work to overcome the tendency of concrete to crack at the junction, but I have not yet evolved a satisfactory method of overcoming this difficulty, which would represent a serious menace in ship construction.

The author's paper represents reinforced ships as being completely rigid and seamless. Those of us who are concerned with these things know that such an ideal construction is almost unattainable, and that there have to be joints, and it is at the joints that the cracks are most likely to occur, and they represent a great difficulty.

Further, when concrete is being poured, a chalky substance is formed on the top of the concrete. This "laitance," as it is called, is a very dangerous thing, as it forms at all joints; and as it has but little cementitious value, it is soon washed out, and leaves a place for the sea water to penetrate, and from the cracks thus formed very serious results may accrue.

The cracks which are first noticed in concrete under stress are not always the first cracks that are formed. It was found by accident that if concrete beams were left to season in water, and then tested, the hair cracks were made visible by the appearance of water much sooner than if the concrete were tested dry; and when the author talks of cracks being observed in concrete under test, I would like to know the means by which they were observed. Of this we may be sure—that as soon as hair cracks occur in the skin of a concrete ship, salt water will certainly find them, and trouble will begin. If the suggestion of using oily concrete were adopted as a means of checking the ingress of water to the cracks, it would be necessary to select an oil with great care in order to obtain one which would have no deleterious effect on the concrete.

The use of medium steel in lieu of mild steel reinforcement is suggested in this paper. It is quite common in practice to employ steel of the type in which the elastic limit is about 50,000 and the ultimate tensile strength 80,000 lbs. per sq. inch.

Mr. Reeks said that he knew little about concrete; I know little about shipbuilding, but I feel that we should be very grateful to Mr. McEwin for the paper he has put before us, and I hope that further use will be made of it.

Mr. Adams: I have listened to Mr. McEwin's paper with great interest, more especially because some three or four weeks ago, in conversation with him, I expressed the opinion that I did not think the building of commercial ships in reinforced concrete practically feasible. Mr. McEwin has succeeded very well in opening the way to a useful discussion in this connection.

I have had a considerable amount of experience in reinforced concrete construction in relation to the harbor works at this port. As you probably know, in addition to reinforced concrete bridges, viaducts, sheet piling and lighthouses, we recently built and launched two large reinforced concrete pontoons, probably the largest then afloat. The first, now in use at No. 5 Ferry Jetty, Circular Quay, was launched in 1914. It measures 110ft. in length, 60ft. in width at once end, and 70ft. at the other, the depth being 7ft. 9in. It has about 3ft. 6in. of freeboard, and displaces 783 tons. It is divided into 44 watertight compartments, firstly to provide against the liability to be sunk by collision, and secondly, to stiffen it to withstand the continual shock of the ferry boats when berthing. The sides, bottom and deck are 5in. thick, and doubly reinforced; the bulkheads are 4in. thick, and also doubly reinforced.

This being the first of its kind built here, and one of the largest afloat at the time anywhere, no risks were taken, and it is perhaps stronger than future experience may warrant. It is not a ship; it has to stand more severe usage than a ship would ordinarily experience, owing to the severe shocks often given by large ferry boats, which continue day after day to bump it while berthing.

The second pontoon, which is a little smaller, was launched in 1915; it is substantially of the same construction, and is now at Milson's Point.

These instances give very little lead towards the construction of reinforced ships. They are watertight, and sweat only a little in places. In all the compartments in the No. 6 and 7 jetty pontoons, where the ventilation is good, a wax match can be struck on the floor; it was not practicable to secure ventilation through the deck in all compartments. The pontoon at Milson's Point was not pumped out for 13 months, when it was found that two compartments had several inches of water, which proved to be nearly fresh; while the remainder were more or less wet on the floor. But the draft of these pontoons being only 5ft., the hydrostatic pressure is not great. Probably with a draft of 25 or 28 feet the sweating would be greater; but no ship is ever absolutely watertight, and all ships sweat on the skin, bulkheads and stanchions, owing to condensation of moisture.

Mr. Hart has raised the question of cracks in concrete, and not without cause. My experience is very similar to his in this respect. Concrete, while lying dry, shrinks, and therefore hair cracks or crazes must appear. This is very marked where the concrete is on dry land; but where it is in the water the shrinkage is very much less, and the hair cracks insignificant. I have failed to find any in these two pontoons. There are a few marks of rust on the surface, but these seem to come from loose ends of binding wires and slippings that have fallen into the concrete.

When this question came up a short time ago, I had, as already remarked, doubts as to its practicability, for various reasons. I had not, up till then, seriously considered the matter. Since, I have thought it over rather fully, and am quite satisfied that reinforced concrete steamers can be successfully built up to 4000 or 5000 tons gross, at least, if not of greater size.

I can readily appreciate the objection of naval architects who have not in the natural course of their calling had much to do with reinforced concrete. This offers a serious difficulty.

Another difficulty to be overcome arises from the fact that the present advocates of this system are neither seamen nor naval architects, but engineers who are not supposed to understand the requirements of naval construction.

Those who build ships naturally turn to the experts in seafaring matters for advice. Recommendation to build concrete ships is not likely to come from men whose whole training has been in steel, or even in wood, and the opinions of engineers would not carry much weight.

Apart from the question of mere construction is that of seaworthiness. Some seafaring men seem to think that an absolutely rigid vessel, such as a concrete ship would prove, would be defective in weatherliness. I do not hold this view.

Another question to be faced is that of insurance. It is certain that insurance would be either extremely high at first, or not obtainable at all; but it would become normal with success. All these difficulties, however, will be extremely hard to overcome.

A concrete vessel of about 4000 tons would weigh about $2\frac{1}{2}$ times a steel vessel. In normal time, when freights are low, this would perhaps be serious, since the difference in weight between an iron and a steel ship, though small, was sufficient to knock out the iron vessel.

On the other hand, the maintenance of hull in a concrete vessel would be very low compared with that of steel, which requires protecting from corrosion, both within and without.

Perhaps the objection most effectively urged against the use of reinforced concrete is the brittleness of the concrete, and consequently its inability to withstand the impact or abrasion. But there are ways in which this objection can be overcome entirely.

With regard to strength, or ability to safely carry heavy cargoes in rough seas, no insuperable difficulty would be experienced. A reinforced concrete ship could be built as strong, and stronger, if necessary, than an ordinary steel vessel.

As to cost, at present time, standardised concrete ships would only be a little more expensive to build than composite, or all timber, ships. All steel is, of course, out of the question at present. The propelling power would have to be internal combustion engines, Diesel or semi-Diesel. There are several engineers in the Commonwealth capable of designing and superintending the building of reinforced concrete ships.

I believe that reinforced concrete ships can be successfully built, and that they will be built. It is significant that a start has already been made in Norway, as mentioned by Mr. McEwin.

Mr. WILSON: I should be prepared to admit that the construction of reinforced concrete vessels is quite practicable; it is also possible that if a large number were taken in hand they would be cheaper to construct than steel vessels. The question, however, as to whether the reinforced concrete vessel will stand the test of a sea voyage under heavy weather conditions has still to be answered; the vessels which the lecturer states are being built in Sweden (some of which are already launched) have still to undergo this test, and after they complete one or two voyages, our knowledge of the subject under review should be considerably advanced.

When considering the possibility of designing a reinforced concrete ship, we should be fully seized with the importance of taking into account the stresses which come on the structure of a vessel in a sea-way. Even leading naval architects admit that there is still much to be learned about these stresses; if, however, the position of the supporting pressures and the weight of the hull and cargo are known, it is a comparatively simple matter to compute the bending moment and the intensity of the resulting stresses, tensile and compressive, which the structural material will suffer. A vessel of the size quoted by Mr. McEwin may be at one moment supported on the crest of a wave having a length equal to her own length, thus making her tend to hog; the next moment she may be in the trough of a wave,