and as there is 24.3 cubic feet of stone in the 27 cubic feet of concrete, there must be 27 ÷ 24.3 equal 2.7 cubic feet of excess mortar required to make the 27 feet of concrete.

Then 12.45--27 equal 9.75 cubic feet of interstices in the 24.3 cubic feet of broken stone.

Then 9.75 x 100 ÷ 24.3 equal 40.1 per cent. of interstices in the broken stone, which seems rather too small for stone broken to a 2½in. gauge. The interstices in metal broken to 2½in. gauge total about 50 per cent., so that there was only about 0.3 cubic feet excess mortar, and there could have been only about 24.6 cubic feet of solid concrete made from the above mixture.

(No. 4.) River gravel and coarse, clean, sharp river sand. The gravel not to be larger than 2½in. gauge, larger pebbles to be discarded or else broken smaller. The concrete to consist of one (1) cask of cement to twenty-four (24) cubic feet, by measure, of gravel and sand as shall be directed.

This is not a very clear specification.

(No. 5.) This concrete to comprise—

1 measure cement, 3 measures clean, sharp sand, 5 measures blue stone broken to 1½in. gauge, then screened through a sieve of ⅛in. mesh.

The volume of interstices in this class of stone may be taken at 40 per cent.

Then 5 x ·40 = 2 cubic feet as the volume of interstices

$$\frac{(1 \div 3)\,3}{4} = 3 \text{ cubic feet of mortar}$$

Then 3 − 2 = 1 cubic foot of excess mortar

(1 x 100) ÷ 5 = 20% of excess mortar in the concrete

For ordinary concrete 10 per cent. excess mortar is ample, so that 6 measures of stone might have been used, and the concrete would have been of equal strength to that with only 5 parts of stone. The difference in the volume of concrete made from 1 cask of cement is as follows, assuming the cask to contain 4¼ cubic feet:—

$$\text{Mortar} \frac{(4{\cdot}25 + 12{\cdot}73)\,3}{4} = 12{\cdot}75 \text{ cubic feet}$$

Interstices 21·25 x 40 = 8 5 ,, ,,

Mortar in excess 4·25 ,, ,,

Then (4.25 x 100) : 21.25 equal 20 per cent. excess mortar, and the volume of concrete made from the above

proportions is 21.25 x 4.25 equal 26 cubic feet from one cask of cement.

Then (4 25 x 100) ÷ 21·25 = 20% excess mortar, and the volume of concrete made from the above proportions is 21·25+ 4·25 = 26 cubic feet from one cask of cement.

By increasing the stone to 6 measures instead of 5, the following figures are the result:—

$$\text{Mortar } \frac{(4{\cdot}25 \div 12{\cdot}75)\ 3}{4} = 12{\cdot}75$$

$$\text{Interstices } 25{\cdot}5 \times 40 = 10{\cdot}2$$

$$\text{Mortar in excess} \qquad 2{\cdot}55$$

Then (2·55 x 100) ÷ 25·5 = 10% excess mortar, and 25·5 ÷ 2·55 = 28 05 cubic feet of concrete from 1 cask of cement.

(No. 6.) This concrete to be composed of 1 full cask of cement, 8 measures of sand, and 20 measures of stone broken to 2½ in. gauge,

then $\frac{(4{\cdot}25 + 8)\ 3}{4} = 9{\cdot}19$ cubic feet of mortar. The volume of interstices of the stones, if they are to be filled and have 10% excess mortar, should be

20 ÷ 10 = 2 cubic feet of excess mortar. Then

9·19 − 2 = 7·19 cubic feet volume of interstices.

Therefore (7 x 100) ÷ 20 = 33·9%, which seems too low a figure unless shivers or gravel be mixed with the 2½in. gauge stone, to reduce the percentage of the interstices.

(No. 7.) This concrete to be composed of 2 parts blue stone broken to 2½in. gauge, 2 parts of gravel up to the size of an egg, and 2 parts of coarse sand and 1 of cement. The concrete is stated to be in the proportion of 6 to 1. It is evident from the remarks of Mr. Hayter, quoted in the notes, that when the stones broken to 2½in. gauge and the gravel and sand are mixed together, the volume will not be in the proportion of 6 to 1. This is readily shown as follows:—

The stone itself cannot shrink, and may be assumed to contain 50 per cent. interstices, and the gravel 34 per cent. interstices, and the mixture of the two, say, 36 per cent. interstices.

	cubic feet		solid contents		cub ft. measure
Then	2 measures of stone give		2 x 0·50	=	1·00
	2 „	gravel	2 x 66	=	1·32
			cubic feet solids		2·32

The interstices of the mixture are, say, 36 per cent.: then $(2{\cdot}32 \div 100) \div 64 = 3{\cdot}625$ cubic feet of mixture.

Volume of interstices $3{\cdot}625 \times {\cdot}36 = 1{\cdot}305$ cubic feet.

Volume of mortar $\frac{(1 + 2)\,3}{4} = 2{\cdot}25$ cubic feet.

Then $2{\cdot}25 - 1{\cdot}305 = 0{\cdot}945$ cubic feet excess mortar. Then $(0\ 945 \times 100) \div 3{\cdot}625 = 26\%$ of excess mortar.

This seems an excessive amount of excess mortar.

The volume of concrete from 1 cask of cement which can be made from this mixture is as follows:—

Cement 4.25 cubic feet, sand 8.5 cubic feet, stones 15.4 cubic feet.

$\frac{(4{\cdot}25 + 8\ 5)\,3}{4} = 9{\cdot}562$ cubic feet of mortar.

$15{\cdot}4 \times 0\ 36 = 3{\cdot}544$ cubic feet of interstices : then $9\ 562 - 6\ 5\ 14 = 4{\cdot}108$ cubic feet of excess mortar : then $15{\cdot}4 \div 4{\cdot}106 = 19{\cdot}418$ cubic feet of solid concrete to one cask of cement, and $(4{\cdot}108 \times 100) \div 15{\cdot}4 = 26\%$ excess mortar.

If the volume of excess mortar had been reduced to 13 per cent., the volume of solid concrete with the same strength of cement mortar could have been increased by 11.4 per cent.

In bringing this subject before the Association, the writer has been influenced by an earnest desire to elicit an expression of opinion from the members, and to draw attention to a method of determining the ratios of cement, sand, and aggregates, in the mixing of concrete of any desired composition that will ensure the maximum of strength with a minimum quantity of mortar.

The following specifications, based on the foregoing examples, may be of interest to members who frequently have to design and carry out works in Portland cement concrete:—

SPECIFICATIONS of Cement, Sand, Aggregates, Mortar, Grout, and Concrete, to be used in the Buildings and Foundations of a Sugar Factory.

(1.) Cement.—The whole of the cement for the buildings and foundations referred to in this specification is to be of Portland cement of the best quality, ground so

fine that there will be no residue in a sieve of 5806 meshes per square inch without rubbing.

Should there be any residue, a quantity of cement proportional to such residue must be added.

The cement, when landed at the site, is to be put into a dry shed provided for that purpose, having a wooden floor or runners not less than 3in. deep laid on the ground to keep the casks clear of the surface.

(2.) Sand.—Sand for mortar and concrete is to be as hard, sharp, and angular as can be obtained in the locality, free from all earthy matter, washed perfectly clean, and screened if that be deemed necessary. When used for mortar, the sand is to be passed through a sieve of 300 to 400 mesh per inch.

(3.) Mortar.—No. 1 mortar is to be composed of sand which has been passed through a sieve of 300 to 400 mesh per inch, and cement in the proportion of 1 cubic foot of cement to 2 cubic feet of sand, the proportion of each to be correctly ascertained by measurement. The two materials are to be mixed together with no more water than is requisite to bring the mortar to the proper consistency.

Mortar No. 2 is to be composed of the same cement and sand as No. 1, but in the proportion of 1 cubic foot of cement to 3 cubic feet of sand; in all other respects the specification of Mortar No. 1 is to apply to No. 2.

The mortar is to be mixed as required, and on no account is any to be used which has become partly set, nor is any water to be added to the mortar after it is once mixed. Mortar in all cases is to be beaten up on a board to the required consistency.

(4.) Grout.—The grout is to be used for bedding, filling, and packing the spaces between sole plates, column bases, and wall plates; to be made of No. 1 mortar, to be mixed in quantities as required, with a minimum quantity of water.

(5.) No. 1 Concrete is to be composed of 1 measure of cement, $2\frac{1}{2}$ measures of sand, and 5 measures of broken stone or gravel. The broken stone and shivers, or gravel, to be mixed in such proportions that the interstices of the aggregates will be about 42 per cent. of their volume. The stone to be broken to a $2\frac{1}{2}$in. gauge,

or if gravel be used it should not be larger than would pass through a 2½in. ring.

The following are the approximate quantities of dry material, based on the above ratios, estimated to make 1 solid cubic yard:—

Cement	5.	cubic feet
Sand	11.36	,,
Stone	25.00	,,

Mortar $\frac{(5 + 11{\cdot}25)\,3}{4} = 12{\cdot}187$ cubic feet mortar

Interstices in metal and shivers, 42 per cent.

Then $\frac{25 \times 42}{100} = 10{\cdot}5$ cubic feet interstices

∴ 12·187 − 10·5 = 1·687 cubic feet excess mortar which is about 7 per cent. excess mortar and 25 ÷ 1.687 equal 26.687 cubic feet equal 22.7 cubic feet concrete to 1 cask cement containing 425 cubic feet.

(6.) No. 2 Concrete is to be composed of 1 measure of cement, 2¾ measures of sand, and 5¼ measures of broken stone or gravel. The broken stone and shivers, or gravel, to be mixed in such proportions that the interstices of the aggregates will be about 42 per cent. of their volume. The stone to be broken to a 2½in. gauge, or if gravel be used it should not be larger than would pass through a 2½in. ring.

The following are the quantities of dry materials, based on the above ratios, estimated to make 1 solid cubic yard:—

Cement	4.39	cubic feet
Sand	12.07	,,
Stone	25.24	,,

Mortar $= \frac{(4{\cdot}39 \div 12{\cdot}07)\,3}{4} = 12{\cdot}345$ cubic feet.

Interstices in metal and shivers, 42 per cent. app.: then $\frac{25{\cdot}24 \times 42}{100} = 10\,6$ cubic feet.

∴ 12·345 − 10·6 = 1·745 cubic feet excess of mortar, which is about 7% excess of mortar, and 25 24 + 1·745 = 26 98 solid cubic feet = 26·1 cubic feet of concrete to one cask of cement.

(7) No. 3 concrete: To be composed of 1 measure of cement, 3¼ measures of sand, and 6.3 measures of

broken stone or gravel. The broken stone and shivers, or gravel, to be mixed in such proportions that the interstices of the aggregates will be about 42 per cent. of their volume. The stone is to be broken to a $2\frac{1}{2}$ in. gauge, or if gravel be used, it should not be larger than would pass through a $2\frac{1}{2}$ in. ring.

The following are the quantities of dry materials to make one solid cubic yard:

Cement	3.88 cubic feet
Sand	12.61 ,,
Stone	25.23 ,,

$$\text{Mortar} \frac{(3\,88 + 12{\cdot}61)\,3}{4} = 12{\cdot}37 \text{ cubic feet}$$

Interstices $25{\cdot}22 \times 42 = 10\,59$ cubic feet.

$\therefore$ $12{\cdot}37 - 10{\cdot}39 = 1{\cdot}78$ cubic feet, which is about 7% excess mortar, and $25{\cdot}22 + 1{\cdot}78 = 27$ cubic feet of concrete $= 29{\cdot}58$ cubic feet for one cask of cement.

(8.) No. 4 Concrete: For filling in where mass is required more than strength: Is to be composed of 1 measure of cement, $4\frac{1}{4}$ measures of sand, and 8 measures of broken stone or gravel. The broken stone and shivers, or gravel, to be mixed in such proportions that the interstices of the aggregates will be about 42 per cent. of their volume. The stone is to be broken to a $2\frac{1}{2}$in. gauge, or if gravel be used it should not be larger than would pass through a $2\frac{1}{2}$ in.ring.

The following are the quantities of dry materials based on the above ratios, estimated to make one solid cubic yard:—

Cement	3.4 cubic feet
Sand	13.6 ,,
Stone	25.14 ,,

$$\text{Mortar} \frac{(3\,3 + 13{\cdot}6)\,3}{4} = 12\,4$$

Interstices $25{\cdot}14 \times 42 = 10{\cdot}56$

$\therefore$ $12{\cdot}84 - 10{\cdot}36 = 2{\cdot}28$ excess mortar, which is about 9% in excess, and $23{\cdot}14 = 2{\cdot}28 = 27{\cdot}42$ cubic feet concrete, $=$ 34 72 cubic feet of concrete to 1 cask of cement.

(9.) Material: The cement and sand are those specified in clauses 1 and 2.

The broken stone and shivers are to be of hardstone or gravel of approved quality, to be free from dirt, clay,

or quarry refuse, and washed thoroughly clean if necessary, the stones to be broken and screened to the specified gauge.

(10.) Test boxes: Test boxes to be made so that a sample of the sand and broken stone, shivers, and gravel which is being used for concrete material, may be placed in them to ascertain by exact experiments the proportion of voids or interstices in those materials, and according to the results of these tests, the relative proportions of sand to broken stone, shivers and gravel, may be slightly varied from those specified in clauses 5 and 6; but the specified proportion of cement to sand will be adhered to.

(11.) Concrete mixing: The specified proportions of the materials are to be carefully measured off in boxes constructed for that purpose. The dimensions of the boxes (see clauses referring to boxes) to be arranged so that for each gauge of aggregate and sand one cask of cement estimated to contain 4.25 cubic feet of cement may be used.

The broken stone and shivers are first to be mixed together in the stated proportions and after being gauged in the measuring box are to be spread on a timber platform.

The cement and sand are to be well mixed together. The stones, sand, and cement are then to be turned over with shovels three times a day dry, water to be slowly added with a rose-headed can or hose, while the materials are again turned over three times as before, or oftener, until a thorough mixture is obtained.

The timber platform on which the concrete is to be mixed is to be not less than 14 feet wide and of sufficient length to permit of the mixing being done in one direction, that is to say, the concrete will be moved during the mixing from the end of the platform, where the materials are gauged, to the end next where it is to be deposited.

The greatest care is to be taken to avoid wetting the concrete too much. The concrete should not be wetted so that it cannot be punned without spouting. It should be well punned into position, and special care is to be taken to thoroughly pun and stir it close to the outside

face of the work, so that there may be no voids on the outside face when the boards are removed.

Depositing concrete: The concrete is not to be thrown from a height, or slid down a shoot, but must be deposited by a barrow or box close to the level of the work.

The concrete is to be used fresh, in layers not more than 12 in. thick, each layer to be properly spread and well rammed, and if allowed to set, to be roughed and picked up and run over with cement grout before any more concrete is deposited.

Any concrete wetted so that it cannot be punned without spurting, or that has not sufficient consistency to retain its form when squeezed in the hand, is not to be put into the work until it has had sufficient cement, sand, and stone (in the same ratio as the specified mixture) thoroughly mixed with it to bring it to the proper consistency.

The test for the correct quantity of water to be used in mixing the cement, is that the surface of the concrete, when thoroughly rammed, will just show water on the surface.

Moistening concrete: The exposed surface of the concrete foundations and walls, is to be kept well moistened until the surface has set.

During workmens' meal hours and other intervals, the surfaces of fresh concrete exposed to the sun should be covered with old galvanised iron, and before depositing fresh concrete the surface should be moistened, and, if necessary, washed with thin grout.

(12.) Rubble Concrete: Rubble, or plumstones, to the maximum size that can be handled by two men, may be built into the body of the concrete as closely as will permit of proper ramming and packing round them. Where this is done the excess mortar in the concrete should not be less than 12 per cent.

The stone to be hard and clean, to be bedded in the concrete with at least 4 inches of concrete between each block, in every direction; no portion of any block to come within 12 inches of the top, bottom, or outer faces; blocks to be thoroughly bedded in the fresh concrete and all the concrete round blocks to be rammed and consolidated.

Mr. Jas. Shirra said he would like to hear the subject discussed from the marine engineering standpoint. It must be apparent to all that the making of concrete played no small part in the completion of the engineering of a steamer, and he was anxious to know what was actually required in that direction and how far different was it to the concrete ordinarily used.