

DISCUSSION.

Mr. A. E. Cutler in opening the discussion said that a reference to the results of sand tests shewed that to be able to speak with any degree of certainty, special tests would hve to be made to enable one to state what increase of bulk would result from the mixture of a certain sand with cement in the proportion of 3 to 1. But if it was assumed that the cement was just absorbed by the voids in the sand, it would be on the safe side for estimating the percentage of mortar to concrete.

Working on figures obtained from a test made by the Water Supply and Sewerage Branch of Works Department with a view to approximating the percentage of mortar and aggregate in the case of 6, 3, 1, Bluestone concrete, the result gave 44.56 per cent. as the excess of mortar over voids, as follows: —

- 13 cubic feet Bluestone (see test herewith).
- 10 cubic feet Bluestone shivers (see test herewith).
- 12 cubic feet Nepean sand.
- 4 cubic feet cement.

Mixed and rammed in place, this made 22.75 cubic feet of concrete, or a loss of bulk of 35 per cent. of the aggregate and sand, which would serve as a check on the figures.

The voids in Bluestone were shewn elsewhere to be 55 per cent., and of shivers, 44 per cent.

$$13 \text{ cubic feet bluestone} \times \frac{55}{100} = 7.15 \text{ voids.}$$

$10 \text{ cubic feet shivers} \times \frac{44}{100} = 4.4 \text{ cubic feet of voids, or } 5.6$
cubic feet solids.

Now if it could be admitted that the solids would all go into the voids in Bluestone, there would still be $7.15 - 5.6 = 1.55$ cubic feet of voids in 13 cubic feet; the 1.55 cubic feet taken from 12 feet of mortar would leave 10.45 of mortar in excess of voids, and $10.45 \text{ in } 28.45 = 44.56\%$.

SAND TEST.

Standard sand was passed through a sieve of 400 meshes to the square inch and retained by a sieve of 900 meshes to the square inch in a mixture of 3 sand to 1 of cement. The cement should fill the voids equal to 38 per cent., but it was found that owing to the difficulty of getting the cement into the voids it was necessary to reduce the percentage of sand to 2½ to 1. A sample of Nepean sand tested by Mr. Roberts of the State testing branch gave the following results as compared with standard sand:—

Weight . . . 92.5 Standard . . 97.9 sample per cu. ft.
 Voids, 38.7 per cent. Standard, 33.8 per cent. Sample.

Both sands were passed through 400 seive and retained on 900 seive.

The usual per centage of voids in sand, as used on the works, was between 26 per cent. and 33 per cent. An unusually good sand made from crushed sandstone at Waverley, showed a percentage of voids equal to 26.2, the following particulars shewed the size of the grains to be well-proportioned, and therefore a saving in cement required to make a solid mass:—

	Standard.	Sample.
Weight per cubic foot,	92.5 . . .	111.1
Voids		26.2 per cent.
Residue on 144 seive		17.26
" 400 "		26.60
" 900 "		20.30
" 2400 "		31.30
Passed through 2400 sieve		20.3
Relative Hardness		86.7

Another test of crushed sandstone showing a low per centage of voids was obtained from a quarry in Williamstreet, Balmain:—

	lbs. Standard	lbs. Sample
Weight per cubic foot, . . .	92.5	102.6
Voids		26.9 per cent
Residue on 144 sieve		5.07 per cent
" 400 "		7.80 per cent
" 900 "		28.90
" 2400 "		46.09
Passed through 2400 sieve		12.10
Relative hardness	93	79.3

An interesting comparison could be made between the Waverley sample and the following sand from Cobar:

Weight per cub. foot	92.5 standard	104.1
Voids	30.6 per cent.	
Residue on 144 sieve	0.19 per cent.	
,, 400 ,,		0.19
,, 900 ,,		0.39
,, 2400 ,,		7.81
Passed through 2400 sieve		91.40
Relative hardness 93 standard		69.50

Materials all more or less damp under conditions generally found on the works. The bluestone was such as would pass through $1\frac{1}{2}$ in. ring screened on a sieve of 1-8 in. mesh. The bluestone shivers were such as would pass through $\frac{1}{2}$ in. ring screened on a sieve of 1-8 in. mesh. 10 cube feet shivers required 4.4 cubic feet of water to fill level with surface of measure or voids in $\frac{1}{2}$ in. shivers (as above) equal 44 per cent. 13 cub. feet of bluestone required 7.15 cub. feet of water to fill level with surface of measure or voids in $1\frac{1}{2}$ in. metal (as above) equal 55 per cent.

13 cubic feet bluestone	} thoroughly mixed and	
10 ,, ,, shivers		thrown (dry) into box =
21.5 cubic feet, or a loss	of bulk of 6.52 per cent.	
13 cubic feet Bluestone	} thoroughly mixed (dry)	
10 ,, ,, Shivers		and thrown into box
12 ,, ,, Nepean Sand		and not rammed, =
27.74 cubic feet, or a loss	of bulk of 20.75 per cent.	

The above well rammed (dry) equal 25.00 cub. feet, or a loss of bulk of 28.57 per cent. The same when wetted and mixed as for concrete and rammed into box equal 22.74 cub. feet, or a loss of bulk of 35.03 per cent.

NEPEAN SAND.

Sample intended for use as standard sand selected by Mr. Grimshaw on 27th August, '96 test, No. 71.

Relative co-efficient of strength of sample when mixed with cement in the proportion of 3 sand, 1 cement, compared with standard sand, when mixed in the same proportion with the same cement.—

					Standard Sand.	Sample.
Co-efficient for tensile strain	...	...	...	lb.	100	92.8
" " crushing "	...	...	...	lb.	100	
Loss of weight by washing	...	...	...	%	0.0	0.2
Weight per cubic foot	...	...	...	lb.	92.5	97.94
Dosage	...	...	...		2.58	2.96
Voids (worked back from Dosage by me)	...	...	...	%	38.76	33.78
Residue on sieve 400 sq. inch	...	...	...	%	0.00	0.00
" " " 900 "	...	...	...		100	100
Hardness co-efficient	...	...	...		(99.67)	91.84
					} 88	

Issued to Mr. Grimshaw, 12th October, '96, made with test No. 1437.

Standard Sand.	Sample.	Dosage = $\frac{40 \text{ oz.}}{\text{ozs water reqd to fill voids in qt.}}$
200	230	40oz. water equal 1 quart
230	200	1oz. water equal 1.7455 cubic inches.
245	205	1qt. water equal 69.82 cubic inches.
245	235	$\frac{40}{2.58} = 15.5038 \text{ oz. water in voids.}$
235	200	$\frac{15.5038 \times 100}{40} = 38.76 \% \text{ voids.}$
220	250	
225	190	
215	175	
225	215	
230	185	
200	190	
...	225	
Total ...	2470	
Average ...	225	
Co-efficient	100	

Mr. Baltzer (visitor) said he must congratulate the author upon the able and explicit manner in which the principle that should be followed in deciding the ratios in which the various aggregates and cement should be mixed to ensure the maximum of strength with a minimum quantity of mortar. The principle which should be followed in deciding the ratios in which cement and the aggregates should be mixed in order to correctly determine the component parts of solid concrete, as set out by the author must be acknowledged to be the correct basis to work upon. The many varied uses of concrete, viz., for foundations, water-tight walls, and other structures, rendered it necessary for the engineer to prepare specifications suitable for such uses, for it was evident that different aggregates and their proportions were necessary for different classes of work.

If it were merely a matter of strength only in the concrete, then the least possible quantity of sand should be used (with the cement), as the strength of the concrete depended on the strength of the mortar—provided always—that there was enough mortar to coat the whole surface of every fragment of the aggregate, so that the pieces should always have a film of mortar between them sufficient to fill the voids between the aggregates solidly. If impervious concrete was required, it was necessary not only that the voids in the aggregates be completely filled by the mortar, but also that the voids in the sand be completely filled by the cement. Here we had two different concretes, each suitable for its requirements, in which the ratio of the cement mortar to the aggregate might vary, yet in both cases the concrete was the most economical for its purpose. Accepting the four salient points stated as the correct basis upon which to determine the component parts of solid concrete, and taking them in their order:—

No. 1. This proportion could be readily settled by the tensile test, and its imperviousness to water.

Nos. 2 and 3. Also could readily be settled by measurement, and as suggested.

No. 4. This point was the only real difficulty to contend with.

The author accepted the quantity as from 8 per cent. to 12 per cent. The question was whether this quantity was sufficient to cover requirements and risks? His experience of concrete work for nearly 20 years was inclined to think not.

First, what were the so-called risks?

Variation in the percentage of the interstices of the same aggregate.

Nature of the sand, if fine or coarse.

Variation in the nature of the aggregates, whether round, flaky or angular.

Variation in amount of water used.

Imperfect mixing.

Variation in workmanship, ramming, etc.

Variations of thickness of works, etc.

To make solid concrete it was necessary that good cement, sand and aggregates should be used, that the sand should be well coated with cement, and that the mortar filled in all the interstices, and kept the aggregates from touching one another. To accomplish this latter object, it was necessary for the mortar to act as a joint between the aggregates, which necessarily must bulk the whole body, and hence the voids between the aggregates were necessarily increased. In the case of testing the voids in the aggregates by means of water, the different parts of the aggregates were touching, which latter contingency could not be allowed in solid concrete. Hence it appeared to him that in using the sand and aggregates available in the district with the object of making a solid concrete, that this object could not practically be achieved without increasing the bulk of the aggregates by a quantity of excess the mortar beyond the amount required to fill the voids. What that quantity was, was very debateable, as it depended so much on the nature of the sand, coarse or fine, and on the size of the aggregates, and whether round, angular, or flakey; round requiring the least margin of excess mortar, whilst the flakey aggregates required the most. A test made with $\frac{3}{4}$ in. bluestone shivers to find the voids was made thus:—The metal was thoroughly soaked and then emptied into a sieve and dried with bags. The quantity taken was .482 cub. feet, which was placed in a vessel and well shaken down. Water was then poured in, and it was found that .216 cub. feet of water was necessary to fill in the voids, or 45 per cent. of the aggregate. Taking 8 cubic feet of this aggregate there would be 3.6 cubic feet of voids, and with a 10 per cent. margin as suggested for excess mortar, equal .8 cubic feet, a total of 4.4 cubic feet should suffice for the mixture to make a solid concrete according to the paper. Taking into consideration the flaky nature of the $\frac{3}{4}$ in. shivers, and their uniformity of size, also the coarseness of the sand used, he calculated that concrete to be solid, and have all the aggregates properly bedded, and with clean surfaces must increase in bulk $37\frac{1}{2}$ per cent. above the aggregates, or in other words, taking the aggregates at 8 cubic feet, the concrete to be solid must bulk up

to 11 cubic feet. The quantities required to mix together to make 11 cubic feet of concrete were:—

4 cubic feet cement.

5.5 „ sand.

8 „ $\frac{3}{4}$ in. shivers.

The voids in 8 cubic feet of $\frac{3}{4}$ in. shivers as ascertained were, 3.6 cubic feet, so that there was an excess of mortar of 1.9 cubic feet, or 23 $\frac{3}{4}$ per cent. of the aggregates.

(1.) The $\frac{3}{4}$ -inch shivers were very flaky, and on account of their flat surfaces would be close together, so that a great quantity of cement mortar was required to make a good joint.

(2.) The sand being of a coarse nature made the joints between the aggregates larger than would be necessary with finer sand.

The exhibits were of the $\frac{3}{4}$ -inch shivers and sand used.

The plate was made from a mixture of—

4 cubic feet cement.

8 „ sand.

8 „ $\frac{3}{4}$ -inch shivers.

which mixture bulked to 13.5 cubic feet of concrete.

The amount of sand used in this case showing an excess of mortar of 5.4 cubic feet, or 67 $\frac{1}{2}$ per cent. of the aggregates. It might be mentioned here that this excessive quantity of mortar was put in on account of the necessity of adhesion between the concrete and steel.

In conclusion he was of opinion that an excess of mortar up to (say) 20 per cent. was necessary if solid concrete was required. The quantity of this excess mortar in concrete varied with the nature of the aggregates, if flaky, round or angular, coarseness of the sand, care and manipulation in the working. For general practise he favoured an excess of mortar and an excess of water to remedy any risk from the causes already given. In the latter part of the paper, on the subject of specification for concrete the author was of opinion that under the item cement, the testing as to the tensile strength of the briquettes of 1 of cement to 3 of sand (standard) should be included. The latter to stand not less than 100 lbs. per square inch after 7 days, and 200 lbs. after 28 days.

Mr. G. A. Mansfield said as an architect he could readily appreciate the difficulty met with in specifications of concrete. The great question of ramming after mixing was to ram lightly and in the composition he had always found round sand more satisfactory than angular.

Professor W. H. Warren in mixing advocated Nepean gravel. The standard methods laid down were more or less right. He personally advocated 1, 2, 5 concrete as rather better than 1, 2, 4.

Mr. J. Shirra desired information as to what became of the water that was mixed with the sand. No shrinkage after setting was in his opinion good concrete. Ordinary good cement would contract in setting.

Mr. Hector Kidd, in reply, went through the various points raised. His object had been more to collect the information at his disposal in the form of notes, and let the members have practical methods to go upon in the making of concretes. In reply to Mr. Shirra, he did not know what became of the water in the concrete—it was really a chemical question. Referring to specifications for concretes, he had seen some that would do credit to a Chinese Government in the old days, so constructed as to be utterly useless in constructing concrete work.

He agreed with Mr. Cutler as to the spade being the best means of ramming and packing in concrete.

The discussion had been a most interesting one, and he felt that the annals of the Association had benefitted from the remarks of the various gentlemen who had spoken on the subject.
