DISCUSSION.

Professor Warren remarked that the author had placed before the members of the association the results of his own experiments on Portland cement, and like most experimenters on this material, he had confined his attention to the tensile strength rather than the compressive or transverse strength. There could be no doubt that a cement which possessed a high tensile resistance would behave well when subjected to compressive or transverse stresses. Indeed, in comparing the results of testing cements, both in tension and compression, it was seen that the ratio of the strengths are approximately the same. Hence engineers preferred the tensile test to that of compression, or cross-breaking, in judging of the quality of the material, and in every specification was to be found a clause governing the supply of cement of a given tensile strength.

In designing works, however, the information obtained so carefully on the tensile strength, would not help the engineer in providing the necessary sectional areas to resist the various stresses which might be developed in the structures in which Portland cement was so extensively used.

Cement, whether mixed with sand to form mortar, or with aggregate to form concrete, was rarely ever in direct tension, but more frequently in compression, or it was called upon to resist stresses which were analagous to those developed in a beam when subjected to transverse stress.

As examples of direct tension we had the resistance offered by a joint in a brick-in-cement wall for retaining earth or water, when the line of pressure passed too near the outer edge, but here the adhesive strength of the joint was so much less than the tensile strength of the mortar, that it would be separated from the bricks long before its full tensile resistance was developed.

In larger structures of this class the material should be so disposed that the line of pressure in no case passes so near the edge of the wall as to develope the tensile and adhesive resistance of the mortar, and this rule was uniformly observed.

In the concrete filling of bridge cylinders the material would generally be subjected to direct compression. Under severe wind pressures, however, the piers, acting as cantilevers, would deflect, and the concrete would then undergo transverse stress.

In the foundations for timber pavement the material was also subjected to transverse stress, and its thickness should be determined rather to resist these stresses than those of direct compression. If we imagined the material, upon which the 6-inch layer of concrete rests, to have subsided partially, then the concrete would undergo stresses analagous to those developed in a beam. The unequal deflection produced by heavy concentrated loads would also develope similar stresses.

He considered that the thickness of concrete foundations for buildings, sewers, retaining walls, and columns should be determined in a similar manner to that of the depth of a beam of a given strength and stiffness, and that the same may be said of concrete landings and floors.

Since, therefore, concrete was so often subjected to transverse stress it was important for the engineer to know the modulus of rupture for the mixtures he intended to use. This could only be determined experimentally. We could not derive the modulus of rupture (excepting approximately) in concrete from the tensile or compressive resistance. It had been proposed by Mr. Deacon, M.I.C.E., of Liverpool, to specify that samples of pure cement should be gauged with water and pressed into a mould $10'' + 1\frac{1}{2}'' + 1\frac{1}{2}''$. The block of cement thus formed should be placed in water, and after seven days tested by placing it on supports $9\frac{1}{2}$ inches apart and gradually applying a load of 150 lbs. on its centre. If more than one block out of three were broken within one minute of the application of the load the engineer or architect should have power to reject the whole of the cement from which the samples were taken. This test could be made by anyone at a cost of a few shillings. The modulus of rupture may be derived as follows :—

Set w = breaking load in lbs.
l = span in inches
b = breadth ,,
d = depth ,,
f = modulus of rupture

$$\frac{w\,l}{4} = \frac{bd^2f}{6}$$

$$f = \frac{3wl}{2bd^2}$$

The value of f derived from Mr. Deacon's test—

$$f = \frac{3 \times 150 \times 9.5}{2 \times 1.5 \times 1.5 \times 1.5} = 633 \text{ lbs. per square inch}$$

Mr. C. Coleson, A.M.I.C.E., described some experiments in a paper, printed in Proc. Inst. C.E., vol. LIV., page 264, on the transverse strength of concrete beams, the aggregate of which consisted of six parts of harbour shingle, mixed with three of sand and one of Portland cement. This quantity of sand was found to be necessary in order to fill up the interstitial spaces in the shingle.

1. A beam 21 inches wide × 9 inches deep, on supports 8′ 3″ apart, broke with a weight of 5 cwt.

$$f = \frac{3 \times 560 \times 99}{2 \times 21 \times 81} = 49 \text{ nearly}$$

2. A similar beam 3′ 9″ span broke with 1.04 tons, from which f=32 lbs. per square inch.

3. An experiment made by Mr. J. B. Mackenzie on a similar beam but made with purified coke aggregate gave the value of modulus of rupture = 383 lbs. per square inch.

For ordinary concrete the value of f may be taken at 100 lbs. per square inch.

The adhesion of the cement mortar to the various materials which were used in the manufacture of concrete was an important matter, as it determined the strength of the resulting concrete. Experiments on this point had not been as complete as was desirable. The adhesion of mortar to bricks of various qualities when subjected to tensile and shearing forces was also a matter upon which experimental data was wanting. It could hardly be taken as demonstrated that smooth pebbles formed a better aggregate than angular fragments of the same material, although it was considered by some engineers that the adhesion of the cement to the smooth surface of the rounded stones more than compensated for the interlacing of the angular fragments. A series of crushing tests would settle this point.

The following table gave the crushing resistances of bluestone and sandstone concretes. The blocks were prepared by Mr. J. Smail, District Engineer, Sewerage Works, Botany.

UNIVERSITY OF SYDNEY.

TESTED BY PROFESSOR WARREN.

Description.	Date when made.	Months old.	Size.	Weight in Pounds.	Total crushing force in pounds.	Crushing force per square inch in pounds.	Remarks.
Sandstone Concrete—							
Cement: Sand: Stone : : 1 : 2 : 5	June 1883	37	6 x 6 x 6	17.5	43,000	1194	Cracked at 30,000 lbs. Two specimens gave each same result
Broken Pipes Concrete—							
Cement : Sand : Stone : : 1:2:5	,,	37	6 x 6 x 6	16.5	53,900	1497	Cracked at 36,000 lbs. Two specimens gave each same result
Cement Mortar, 1 : 2	,,	37	6 x 6 x 6	15.25	28,700	787	
Bluestone Concrete—							
Cement, Sand, Stone : : 1 : 2 : 4...	Dec. 1884	16	3 x 3 x 3	...	10,000	1111	
,, ,, ,, ,, ...	,,	16	3 x 3 x 3	...	10,500	1166	
,, ,, ,, ,, ...	,,	17	3 x 3 x 3	...	10,750	1194	
Cement: Sand: Screenings : : 1:2:4	,,	17	3 x 3 x 3	...	7,000	777	

A similar experiment had been attempted yesterday with blocks 9″ x 9″ x 6″ in the University testing machine, but they all, excepting one, stood more than 100,000 lbs., which was considerably higher than was expected. These blocks were made by the author (Mr. Mountain.)

He quoted Mr. Grant, M.I.C.E., who gave 933 and 833 lbs. per square inch as the crushing resistance of cement concrete formed with Thames ballast in the proportion of one of cement to six of ballast.

The crushing resistance of some other building materials was for

Good Bricks		about	200 lbs.	per square	inch.		
Portland Cement, neat,		,,	5000	,,	,,	,,	
Pyrmont Stone	,,	,,	5000	,,	,,	,,	on bed.
Portland Stone	,,	,,	2693	,,	,,	,,	,,
Bramley Fall	,,	,,	5000	,,	,,	,,	,,

Mr. Jones expressed his satisfaction at Mr. Mountain's contribution to our knowledge of the qualities, properties and performances of Portland Cement as imported into Sydney. He was aware of what large quantities Mr. Mountain used on the streets of Sydney, whereby his opportunities were valuable, and also of the excellent means provided by the City Council for testing. He entirely concurred with Prof. Warren's comment, that as Portland Cement was chiefly employed to sustain pressure, the test of its resistance to that force and also to crossbreaking as a beam would bear more directly on its suitability. The figures furnished from the author's and Mr. Mackenzie's experiments would prove valuable aids in the hands of engineers, and his persistence in setting up a high standard of quality among the requirements of his office would go far to suppress attempts to forward to this colony the refuse of the European markets, it would moreover incite manufacturers to keep up the quality in order to retain the custom. The facts relating to the exposing of cement for a time to the action of the air, to counteract the effect of the cement being packed hot, and of the presence of free-lime, which induced expansion after or in the process of setting, was no doubt a valuable precaution if practicable, but owing to the atmosphere in Sydney being frequently very largely charged with moisture, he feared that the cement would sometimes be prejudicially affected thereby. The process moreover entailed a loss of time, and required a space not always available, and generally the soundness obtained in the concrete used on the city streets without this treatment seemed to render it unnecessary, excepting for works requiring to be thoroughly watertight. In assuming a co-efficient for the strength of cement to resist given stresses, a margin would always have to be allowed, but every set of experiments would tend to narrow the limits of such margin. He felt personally indebted to Mr. Mountain for making public his experience on the question.

Mr. J. M. Smail said that having listened with great pleasure to the paper read by Mr. Mountain on such an important subject as Portland cement, he must congratulate him for placing on record information which would be of the greatest utility to those whose professional duties were connected with the construction of works in which Portland cement played an important part. The object in testing cement was to ascertain its fitness for certain work, whether on land or in water, and every engineer had to judge as to the quality of cement which formed the matrix of the material to be used in the work, and it was according to the manner in which such tests were carried out that the work would be stable or not. If such an end could be attained it would be better to have one uniform system of testing, not only with regard to cement, but all materials used in construction. In some cases engineers specified the cement to stand a high tensile strain after seven days, while others preferred a minimum strain at three days and showing a proportionate increase of strength at seven and twenty-eight days respectively. He thought it was obvious that the latter was most calculated to give good results and be an element of strength in the work. He could quite concur with Mr. Mountain in his remarks about earlier specifications specifying "approved brands," also one "particular brand," but it would have to be remembered that at that period there were no machines in the colony for testing cement, and the brands then imported were few, also that concrete so largely used at present, was little thought of. The first system of testing cement before it was used in work was introduced by Mr. W. C. Bennett, M. Inst. C.E., the Chief Engineer for Roads during the construction of the iron bridges over Parramatta River and Iron Cove, in 1879. The machine used was on Bailey's pattern, the weight being applied by water passing, by means of a pipe, from a reservoir on top of standard to a cylindrical vessel at end of lever, a shut-off cock was connected by a rod to the lever, and when fracture of briquette took place the descent of the lever shut the cock and prevented the water passing to the vessel. Attached to the vessel was a gauge-glass ; the water rising in same shewed the weight in pounds at which the briquette was broken.* The briquettes were $1\frac{1}{2}'' \times 1\frac{1}{2}''$, made in gun-metal moulds. On the commencement of the new system of sewerage works every parcel of cement used on the works had been put through a system of tests to ascertain its suitableness for same. The standard tensile strain had been fixed at 445 lbs. per square inch, after seven days old, and fineness of grinding to be such as to only leave 2 per cent. after being passed through a sieve of 35 meshes to the lineal inch, and when compared with results given in tables of tests given by Grant, Faija, and other authorities, the test could not be considered other than moderate. Even with this moderate standard many of the earlier brands could not come up to it. Mr. Mountain was of opinion that the weight test was not reliable. There was no doubt that taken by itself it was not a sufficient guarantee of the cement being first-class, but when taken with other conditions there was a certain amount of reliability with it as to make it of sufficient importance to be included amongst the tests. In a paper read before the Inst. of C.E., by Mr. Grant, vol. LXII., he said :—"To judge of the quality of cement by its weight alone, without regard to raw materials of which it is made, is impossible, but having regard to these, it is within certain limits one characteristic of strong cement, and it is desirable that it should be ascertained as nearly as possible." With regard to specific gravity, Mr. Grant said in a discussion on a former paper, "Mr. Bramwell suggested that it would be better to ascertain the specific gravity than the weight of cement. The author still ascertains the weight of cements in a manner which has been described, and he has for a long time for experimental purposes, but without practical benefit, taken their specific gravity." In the discussion on this paper, Mr. Faija says "that he was surprised that when Mr. Grant alluded to specific gravity he did not take it in combination with the weight per bushel. The two together afforded a fairly accurate measure of the value of cement. A heavy specific gravity and a heavy weight per bushel would indicate a finely ground cement, whereas a light specific gravity and a heavy weight per bushel was almost sure to be a coarse one." If, therefore, an engineer wished to have a strong, finely ground cement, it would be necessary to have the two requirements, viz., weight and specific gravity. There was another

* This machine is now substituted by one of Adies' latest, fitted with a patent automatic regulator for regulating the application of the weight on lever.

important element in testing of cement, and that was the uniformity and time of applying the weight. In a table given by Mr. Faija, in a paper read before the Inst. of C.E., vol. LXXV., some very interesting results were given of experiments made on this point.

No. of Briquettes.	Speed.	Average result lbs. per square inch.
	lbs. sec.	
129	100 in 1	560.75
129	100 ,, 5	506.43
145	100 in 15	452.20
145	100 ,, 30	430.96
90	100 in 30	417.27
90	100 ,, 60	403.05
40	100 in 60	416.75
40	100 ,, 120	400.87

From the foregoing results it would be seen that the increase per cent. due to increased speed of applying strain was as follows. Taking the lowest speed of 100 lbs. in 120 seconds as a starting point by applying the strain at the rate of

100 lbs. in 60 seconds, the increase was 3.96 per cent.
,, 30 ,, ,, ,, ,, 7.488 ,,
,, 15 ,, ,, ,, ,, 12.416 ,,
,, 1 ,, ,, ,, ,, 23.142 ,,

The size and moulding of briquette was also worthy of consideration. The one inch section appeared to be the one adopted by experts in England and the Continent. To fill large moulds required an amount of mortar, which, if gauged at one time, would be useless for testing purposes, as by the time one or two moulds were filled the mortar would have commenced to set, and if used for forming briquettes it was questionable if useful results would be obtained; on the other hand, if one or two gaugings were required to fill the moulds, it was quite probable that the results obtained from briquettes would vary very much for the reason that it was almost impossible to mix two gaugings exactly alike. To obviate this, the smaller briquette had been introduced in England, having been the recognised size for some time previous on the Continent of Europe, and a further improvement had been introduced by Mr. Faija in his cement gauger. The machine was 10 inches in diameter and 6 inches high, gauged about 4 lbs. of cement at a time, which was sufficient for 10 briquettes of the 1 inch section. Some experiments had been made with cement as to its settling capabilities and strength when mixed with salt water. For some time it had been thought that the use of salt water for concrete was injurious, but when viewed by the light of actual experiments it would be seen that under certain conditions the mixing of concrete with salt water was advantageous as regards strength. Mr. Faija had, in a paper read before the Inst. C.E., vol. LXVII. of Proceedings, given some very interesting results of tests with salt as compared with fresh water for mixing. The cement used had been considered only as a fair sample of ordinary commercial manufacture.

Weight per standard bushel	112 lbs.
Specific gravity	2.97
Fineness on No. 25 sieve	nil.
,, 50 ,, ...	18 per cent.
,, 70 ,, ...	25 ,,
Time taken to set when gauged with fresh water	25 minutes
Gauged with sea water	120 minutes

Amount of water used in gauging for sea and fresh water was 17.24 per cent.

No. 1 was gauged with sea water and placed in sea water.
2 ,, ,, ,, ,, ,, fresh ,,
3 ,, fresh ,, ,, ,, sea ,,
4 ,, ,, ,, ,, ,, fresh ,,
5 ,, sea ,, and left in air.
6 ,, fresh ,, ,, ,,

He had selected from numerous results tests made at 7 days and 12 months.

7 DAYS TESTS.

No. 1	470 per square inch.
2	425
3	634
4	512
5	418
6	526

12 MONTHS TESTS.

No. 1	835
2	764
3	1064
4	840
5	1120
6	1060

From these experiments it would be seen that the highest result was obtained at twelve months with briquettes gauged with sea water and left in air, next in order came cement gauged with fresh and placed in sea water. From a few tests made by himself with cement mixed with salt and fresh water, the average results were :

	7 days test.
Mixed with fresh water	460.74lbs.
,, salt ,, ...	493.06lbs.

Mr. Faija thought that the deductions to be made from his experiments were "that the salts in sea water have a damaging effect on cement gauged with sea water and afterwards immersed in either see or fresh water; but a beneficial one when the cement is only exposed to the action of the air, and further, that the same salts have a highly beneficial effect when acting in cement gauged with fresh water, and that for all marine purposes those portions of the work which are above high water, should be gauged with sea water, while those portions which are below the water level should be gauged with fresh water." The introduction of appliances and a system of testing by all the Government departments, and the City Council had greatly improved the quality of cement imported to this colony, and had proved a protection to the manufacturers who would not manufacture anything but a first-class article; while at the same time deterring some exporters from turning the colonies into an Imperial dust bin to shoot rubbish into.

Mr. Fischer said that while he agreed in the main with the contents of Mr. Mountain's paper, which was without doubt a valuable contribution to the Society's first annual volume, he felt it incumbent on him in common justice towards the German cement manufacturers, —who, Mr. Mountain informed us, had of late attempted to supply the market with adulterated cements,—to bring under the notice of the members the following resolutions passed at the sixth general meeting of the Society of German Cement Manufacturers, held at Berlin in March 1883, and at which no less than 57 manufacturers of cement had been present, including those who enjoyed the best reputation. He thought it would be too tedious although he had no doubt that it might prove interesting to some of the members, to enumerate all the tests that had been made by the highest authorities, such as Dr. Herzog, Dr. Delbruck, Prof. Bernouilly, &c., for the purpose of arriving at some definite conclusion on this question of adulteration. Consequently he should only give a translation of the resolutions passed at