MINUTES OF PROCEEDINGS,

16TH SEPTEMBER, 1886.

Walter Shellshear, President, in the chair.

The following candidates were balloted for and duly elected:—

MEMBERS:

A. T. DUNCAN.
W. REEKS.
W. F. ROBERTSON.
C. S. WILKINSON.

ASSOCIATE:

J. F. CARSON.

STUDENT:

C. F. KOPSCH.

On the motion of Mr. Smail, seconded by Mr. Pollock, Messrs. J. B. Henson and J. Elder were appointed to make the annual audit of the Society's accounts.

Alteration of Section V., Clause I. of Rules and By-laws.

Mr. Cruickshank moved, and Mr. Mountain seconded,—That the resolution carried at the last general meeting, to increase the annual subscription of members to two guineas, be finally now adopted. Carried unanimously.

A communication *re* forming an "Australasian Association for the Advancement of Science," was received, and on the motion of Mr. Smail, seconded by Mr. Trevor Jones, the President and Vice-President were appointed delegates to attend the preliminary meetings.

Mr. Mountain then read the following paper, the discussion on which was held at a special general meeting on the 23rd September:

NOTES ON PORTLAND CEMENT.

BY A. C. MOUNTAIN, M. INST. C.E.

In undertaking to read before this Association a short paper on the subject of "Portland Cement," the author fears he can contribute but little in the shape of absolutely new matter to the numerous and very scientific researches, the results of which have been presented to the engineering world during the last few years; nor does he now propose to enter minutely into the question of its chemical constituents and method of manufacture, its early history, and subsequent development. He will confine his remarks rather to the experience he has had—as a large user of cement in important public works—with both English and Continental brands; and will place in tabular form the results of some of the tests that he has carried out in connection therewith, in the belief that they will be of interest and possible information to engineers in the colony, where such detailed examinations of the various properties of cement are but seldom undertaken.

Until within a very few years back, it was the almost invariable practice in Sydney to simply stipulate in contracts that the cement should be "of approved brand," or else one especial brand was indicated; and then—provided the cement seemed to be (in appearance, and to the hand of the practical man) "in good order and condition" —it was accepted and used forthwith. Later on, a certain minimum tensile strain was demanded, being generally 400lbs. to the square inch; and it is to be feared that at the present time but little provision beyond the tensile strength of the material is made by the majority of engineers and architects in New South Wales, notwithstanding the extended knowledge of the properties of good cement that has resulted from the experiments of the English, German, and French engineers and chemists.

When it devolved upon the author to carry out the system of woodpaving now introduced so extensively in this city, he perceived the necessity of making stringent conditions for the quality of the cement supplied; and, in order to do so, he foresaw the necessity of making the supply of cement a special contract, irrespective of the construction contracts. This being decided on, it remained to provide for the tests to which cement delivered under this contract would be required to conform; and in this matter—a delicate action, from its novelty in Sydney and from the apparent severity of its requirements—he was fortunate enough to have the hearty co-operation and valuable assistance of Mr. J. B. Mackenzie, M. Inst., C.E., then resident engineer of the Cockatoo New Dock, who was at the time engaged in framing specifications for the cement to be supplied for that work, and whose experience in that direction is probably equal to that of any engineer in the colonies. The result is the compilation of a set of tests *(vide Appendix A)* providing for specific gravity, fineness, progressive strength, fitness for immediate use, and purity of manufacture, which—if complied with – will insure an article that is strong, durable and not liable to "blow" or crack in the work.

Many authorities have contended for the weight per imperial bushel to be not less than 110lbs., 112lbs. being deemed a fair average; but now that so much more attention has been devoted to fine grinding of cement, it is evident that the weight is not a reliable test, as the more finely the same material is ground the lighter will it be, bulk for bulk, owing to the larger proportion of interstitial space to the whole volume, hence the introduction of the specific gravity test, which determines with exactitude the volume occupied by a given weight of cement. Careful chemical experiments made by the Doctors Fresenius (of Wiesbaden) show that a genuine Portland cement almost invariably gives a higher specific gravity than will cement which is adulterated either with hydraulic lime, pulverized slag, trass or the other ingredients usually employed as adulterants; and (as the difference in gravity is very slight between the pure and the "hocussed" materials, varying generally only in the *second* decimal) it is necessary to use great care in ascertaining the result of tests for this purpose, and to insist on all cement standing a minimum gravity test of 3.1.

The chemists above referred to give 3.155 as the lowest figure for a genuine Portland cement; and they further give no less than five additional means of detection, viz:—

Loss by ignition.

Behaviour to water; i.e., the alkalinity of the aqueous solution.

Behaviour to diluted acid.

Behaviour to chameleon solution.

Behaviour to gaseous carbonic acid.

When it is remembered that these methods require the knowledge of the chemist and the apparatus of an analyst's laboratory, it will be seen how hopeless it would be to expect any engineer, in practice, to submit each cargo of cement that he receives to the requisite chemical processes thereby implied, before he could ascertain if he had to deal with a genuine article or not. And yet, for want of that information, failure, which would mean ruin to his professional reputation, might ensue.

The presence of substances which closely resemble the constituents of the cement itself, is admittedly common, especially amongst the German cements; the result is a feeling of uneasiness and distrust in the use of the material, somewhat similar to the doubt that has been but too general among housekeepers regarding the genuineness of the family butter, since the introduction of oleomargarine and butterine; with this distinction, that in the latter case, in all probability no evil result is likely to accrue from the use of the imitation article; whilst in the case of cement, one has to deal with an unknown factor, and the real quality of the material is only discovered by the mischief it occasions, and the possible injury it may do to the reputation of the user.

These facts point to the necessity for establishing an official testing house for cement, which—by preference—should be in connection with the University authorities, where the general character of all cements imported should be ascertained, and a great deal of loss and inconvenience saved both to importers and consumers.

This system is in vogue in Germany, and answers well there; and from its straightforwardness should commend itself to the favourable consideration of engineers in Australia, where we are even in greater need of some such safeguard than are the continental engineers, who are able to know exactly from what factory their cement comes; whereas here we have largely to depend on the assurance of the *casks and labels* as each shipment comes out; hence the folly of specifying for a *brand* of cement, which can be attached to materials of widely different quality, as the author has had personal evidence of. Apart from the chemical testing for the quality of the material, the author's impression is that the other operations of testing (as described in Appendix A) should be carried out by the engineer in all cases where anything like a large quantity of cement is required; and that samples from each ship-load should be taken, and tested (at all events up to the seven-days test) before being passed.

The author has dealt at some length on the question of adulteration from the fact that he has had occasion to meet here in Sydney with cement thus vitiated; and because it is well known that (in Germany especially) not only is the practice very prevalent, but that what is known as "Blast-furnace slag" mixed with lime is sold there under the name of "Pozzuolana Cement," although the investigations recently made by Dr. C. Schumann on its strength, as compared with that of genuine Portland cement, are so conclusively in favour of the latter that it will, he thinks, hardly develop into a profitable industry.

Another most important test is that for expansion, or fitness for immediate use. A cement (included in the tests recorded in the appendix) that showed admirable strength and fineness, frequently failed at this test, which showed that—before it could be with safety used on work—it would require to be opened out to the air, and turned over so as to thoroughly cool, and thus avoid the chance of expansion when used in the shape of concrete, ordinarily termed "blowing" or cracking. By testing in pats (as prescribed in the specification—*vide Appendix A)* and observing during at least seven days their behaviour both in air and in water, the question of the fitness of cement for instant use out of cask is ascertained. No change occurs if the cement is in proper state, but cracks or puffs at the edges are apparent if the cement is "over-heated," or has free lime present. A great deal of the cracking observable in cement work in this city is due to the fact that this point is not carefully attended to. The author has on record the observation made by a brother engineer on two cements which were spread out, side by side, for air-slacking, in order that their fitness for immediate use might be determined. Whilst thus exposed to the action of the atmosphere, one of the cements absorbed moisture to such a degree that a hard crust formed on the surface, just as might happen to a heap of lime exposed to the air after slaking, thus demonstrating the fact of its unfitness for use in that condition. The other cement, under precisely similar conditions, showed no variation of volume, or expansion, showing that free lime did not exist. There is good reason to believe that cement is often packed when in an over-heated state, and that the process of air-slaking in a partial way goes on whilst in the casks; the result being the skin of caked cement next the inside of staves that is sometimes found in casks free from all indications of damp or sea water. Although cement in this condition is not fit to use at once, and although such cement should be carefully watched, it is not, of necessity, a proof of its being—apart from this defect—a bad article, provided an apportunity exists (and is embraced) to spread and turn over, and allow it to cool for a few days. Along with the above described examination, the observations to ascertain the color and the time taken in setting are also carried on. Nearly all authorities attach a great value to the color of the cement, the best slow-setting cement being of a cold bluish grey tint, the quick-setting being usually of a darker tint; but now that cements are made from so many varying descriptions of limes and clays, experience shows that this dictum should not be *too rigidly* insisted on, as some good cements do not answer its requirements. But, as a general rule, the more nearly the cement approaches the greyish tint, the better are the chances that it is a good sample; whilst all earthy looking, yellowish, or dull brown cements should be looked on with suspicion. A good cement, when mixed up in mortar or concrete, frequently shows a decidedly greenish tint.

To ascertain the time taken in setting, the cement is made into circular pats tapering to a wafer thickness at edges, which are subjected to the pressure of a wire one-sixteenth of an inch in diameter, and weighted to the extent of 1lb. avoidupois (325lbs. per square inch, or 20·87 tons per square foot.) This is applied from time to time, until the wire makes no indentation on the cement, when the latter is deemed to be set. If this result is arrived at within two hours, it is "quick-setting;" if a longer period is taken, it is called "slow-setting." The latter is the stronger in the long run; the quicker-setting cement generally starting off with a higher initial strength, but arriving at its ultimate strength sooner. There are, however, many works (such as water-works, and where time is a great consideration) for which quick-setting cement is well adapted.

In mixing cement for briquettes to ascertain the *tensile strength* of the material at various periods, great care and uniformity is required on the part of the manipulator, so as to produce the same class of briquette on all occasions. A very slight excess of water will make a great difference in the result. For "neat" tests the proportion of water needed varies (according to the cement) from 15 to 25 per cent.; for "three to one" tests from 9 to 10 per cent. is usually sufficient. As little water as possible should be used. The sand and cement are mixed together mechanically by a revolving beater working in an enclosed basin, the same number of revolutions being given in all cases. Once mixed, the materials are at once transferred to the gun-metal moulds, which rest on iron plates; it is well pressed and crammed into moulds until flush on face, when the briquettes are sufficiently firm to permit of the moulds being removed. They are then kept for 24 hours in a moist atmosphere, and then placed in trays containing water, until the arrival of the different testing periods.

Although a high tensile strain is expected in the tests, it is undesirable to see that result obtained too rapidly, as it is by the steady progressive increase of strength with time that the best cements are known.

This is illustrated by reference to table B (in appendix) where the cement numbered G starting at the 3 days neat test at 354lbs., acquires at 12 months the very respectable strength of 922lbs., and shows during that period constant progression; also, the same material at the 3 to 1 test commences at 7 days with the modest strength of 93lbs. (or only just above the minimum requirement) and, at 12 months, breaks at 424lbs., and shows no indication of having attained its ultimate strength. It will be noticed that many of the other examples which start with a greater initial strain, at the end of the period of 12 months have not acquired an equal power of resistance to tensile strain.

N.B.—The appendices above referred to, and which are attached to this paper, are:—

A.—Extract from specification for supply of cement to the city of Sydney, giving clauses relative to the testing; also a copy of the test-form.

B.—A summary of tests of various brands of English cement, complete up to date, tested by the author for the Municipality of Sydney.

C.—Similar to B, but of German and other continental cements.

Amongst the minor matters to which the author's attention was directed in connection with the floating or rendering for the concrete wood-paving was the question as to the extent to which water could be used in mixing the mortar without impairing its strength. Whilst it is obviously the interest of the workman to use enough water to make the mixture easy to work, it is apparent that the less the percentage of water used, the stronger will be the mortar: at the same time enough water must be employed to let the rendering run easily. To strike "the happy mean" was his endeavour, and to do so he experimented on the mortar as it was then being mixed on the work, and compared it with other tests, with the result that he found that on an average the men were in the habit of using nearly 18 per cent. of water, but that $13\frac{1}{4}$ per cent. of water was sufficient to use for floating in practice, with the advantage that the mortar was $47\frac{1}{2}$ per cent. stronger at the end of 28 days. The result is that he specifies now that *not more than 14 per cent.* of water shall be used for this purpose.

The strengths were as follows:—

No.	Tensile Strength in lbs.		Increase over No. I Test.		Remarks.
	7 days.	28 days.	7 days.	28 days.	
1	100	229			Taken ready mixed from work; containing 17·9 per cent. of water.
2	250	355	150 per cent.	55 per cent.	Materials taken dry from work; guaged with 10 per cent. of water: too dry for floating.
3	237	338	137 per cent.	$47\frac{1}{2}$ per cent.	Same materials as No. 2, but guaged with 13·28 per cent. of water. Found to be sufficient for floating.

In this table it will be seen that the greatest strength of this mortar, which, it may be stated, is of two parts of sand to one of cement, was obtained with only ten per cent. of water. This, however, was practically found to be too stiff to be insisted on.

The author also caused tests to be made to ascertain the relative strength of different materials when made into briquettes with cement. These were all carried out under similar conditions with the same cement. The materials were thoroughly dry before using and were mixed (by hand) on the slate table of the testing-room; ten per cent. of water was found to be sufficient in each case.

The proportions are all by weight (3 of aggregate to 1 of cement), but as the weights of the different materials tested vary considerably when equal bulks of each are taken, a comparison was also made in that respect which is attached to the table for general information.

No.	Tensile Strain in lbs.		Increase.	Remarks.
	7 days.	28 days.		
1	145	182	25.5 per cent.	Made with crushed sand-stone, same as for standard tests.
2	127	170	33.8 per cent.	Similar to No. 1, save that the sand was washed and dried.
3	141	183	29.7 per cent.	Nepean River sand as used for floating.
4	114	166	45.6 per cent.	Nepean River sand, thoroughly washed and dried.
5	211	279	32.2 per cent.	Bluestone dust, as used for grouting; passing through ⅛ inch sieve.
6	217	306	41.0 per cent.	Equal quantities by bulk of bluestone dust and five-sixteenths screenings.

It will be seen from this table that, both in the case of the crushed sand-stone and the Nepean River sand, an absolute loss in strength was occasioned by *washing* them; thus indicating that some cementitious property is removed by that operation.

Taking No. 1 the standard for making and testing briquettes as a basis, we find that

No. 2 is 12·4	per cent.	weaker	at 7 days,	and	6.5	per cent.	weaker	at 28 days.
3 ,, 2.7	,,	do.	,,	,,	.54	,,	stronger	,,
4 ,, 21.3	,,	do.	,,	,,	8.7	,,	weaker	,,
5 ,, 45.5	,,	stronger	,,	,,	53.2	,,	stronger	,,
6 ,, 49.67	,,	do.	,,	,,	681	,,	do.	,

In the last two cases (Nos. 5 and 6) the large excess of strength is due to the difference of weight of the materials, thus reducing the bulk in the case of the heavier ones, as is shown in the following table, which gives the actual weights of the different materials, and also the corresponding proportions of volume to weight, and conversely.

No.	Description of Materials.	Weight in lbs. per cubic ft.	Percentage of increase on weight of No. 1.	Ratio of volume to 3 to 1 by weight.	Ratio of Weight of 3 to 1 by volume.
1	*Crushed sand-stone*, as used in ordinary tests for briquettes	83.15	Nil.	2.95 to 1	3.04 to 1
2	*Crushed sand-stone* (but washed and dried.)	92.14	11.1 %	2.67 ,,	3.37 ,,
3	*Nepean River sand* (as used for floating or rendering)	104.77	11.6 ,,	2.35 ,,	3.81 ,,
4	*Nepean River sand* (washed and dried)	106.22	17.6 ,,	2.31 ,,	3.88 ,,
5	*Bluestone dust* passing through ⅛in. mesh	113.15	22.1 ,,	2.17 ,,	4.24 ,,
6	*Equal bulks* of Nos. 5 and 7	119.71	34.3 ,,	2.05 ,,	4.38 ,,
7	*5-16ths screenings*, passing through ½ inch but not through ¼ inch mesh	94.45	...	2.6 ,,	3.45 ,,
8	*1 inch screenings*, passing through 1 inch but not through ½ inch mesh	89.78	...	2.74 ,,	3.28 ,,
9	*¼ inch screenings*, passing through ¼ inch but not through ⅛ inch	91.73	...	2.68 ,,	3.35 ,,
10	River gravel, screened from sand, ½in. to 2½in. gauge	114.90	...	2.14 ,,	4.2 ,,
11	River gravel and sand, as used for concrete	130.67	...	1.96 ,,	4.6 ,,
12	Portland cement, used in test [q2]	81.99	...	...	...

This table shows that whilst the standard material used for cement tests is very nearly equal in weight to the cement employed, (and consequently nearly similar in volume) the greater density of the bluestone screenings causes (in the case of No. 6 in the table) the ratio of volume to be only a little over 2 to 1 for the *weight* test of 3 to 1. Following up this enquiry, the author caused tests to be made, from which the following table is prepared, showing the difference in tensile strength between briquettes in which the materials were proportioned by weight, and those in which the proportions were determined by volume. The numbers correspond with