NOTES ON THE ADULTERATION OF PORTLAND CEMENT.

By MR. J. T. N. ANDERSON.

THE main components of Portland Cement as manufactured to-day are similar to the article as manufactured during the last half century. Such improvements as have been introduced in its manufacture from time to time, having tended merely to secure a more uniform quality and to cheapen the product. Of course, the former of these features is an improvement from the engineer's point of view, while from that point of view the latter means no direct improvement in the product itself, and, unhappily its general effect has been in the reverse direction, since the reduction in prices has induced some of the smaller and more unscrupulous firms to adulterate this product with such cheaper materials as can be mixed with cement without being detected, and by this means compete with their more progressive neighbours.

In justice to the cement-makers it is but fair to state that adulteration is almost unknown among the leading manufacturers, and that both in England and Germany they have strenuously opposed the practice. Some smaller manufacturers have openly placed cheaper priced articles on the market, these, however, can hardly be considered as bearing the stigma "adulterated," since they are not sold as pure Portland Cement.

What is, and always has been, accepted as pure Portland Cement is an intimate mixture of carbonate of lime with mud or clay. This mixture is burnt to a state bordering on vitrification, called "clinker," and the cement is obtained by finely grinding this "clinker." To avoid any possible confusion due to ambiguity of terms, it is well to define the adulteration of cement as the addition of any foreign matter subsequent to the process of calcining. Some of those manufacturers mentioned as selling an admittedly adulterated article, argue that such adulteration improves the quality. It is, however, to be noted that in all such cases the adulterant is a much cheaper material than the cement, and, undoubtedly, the manufacturer reaps a certain benefit from the adulteration, while the writer is confident that he can show you that any claim that the quality of the product is improved is made in error. It will be best first to deal with the investigations on this subject which have been made by European authorities. Of British authorities, the most patient and skilful have been Mr. Butler, successor to Henry Faija, and Messrs. Stanger and Blount. While among the eminent German industrial chemists who have investigated the question in their labora-
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The commonest adulterants used are Ragstone, blast furnace slag, furnace ashes, and sand; these are ground together with cement clinker.

About five years ago the adulteration with Ragstone attracted considerable attention, and the matter was taken up by the leading manufacturers, who felt that the honesty of the trade was imperilled. The well-known firm of Messrs. Knight, Bevan and Sturge, through their solicitors, convened a meeting, in October, 1894, of the representatives of British Cement Manufacturers by the following circular:

"2 Suffolk Lane, London, E.C., 26th October, 1894.

DEAR SIRS,—We are desired to call your attention to the following circumstances seriously affecting the trade in which you are engaged. It is becoming notorious that several manufacturers of English Portland Cement are largely adulterating their manufacture by the mixture of Kentish Ragstone, other stone, furnace or oven ashes, disused or exhausted fire-bricks, or other inert material, and so bringing discredit upon the good name of English cement has hitherto borne in comparison for quality with cement of foreign manufacture. Such practices are so detrimental to the best interests of the cement trade, both by the discredit which is thereby attached to English manufacturers and the unfair competition in prices thereby rendered possible, that it is now proposed to establish an Association of English Cement Manufacturers for the purpose of dealing with and, if possible, putting a stop to a practice so unprincipled and disreputable, and so calculated to perpetuate an injury to the trade. We are instructed to enquire if you would be willing to join an Association of Cement Manufacturers for this purpose, and, if so, we shall be glad to hear your views on the subject, and to know if you would attend a meeting presently to be convened. We are, Gentlemen, Your obedient servants, RENSHAW, KEKEWICH & SMITH"

The result of this meeting was that the firms of Knight, Bevan and Sturge; The Woulham Cement Company; Messrs. Barron and Co.; The Tower Portland Cement Company Limited; The Burham Brick, Lime and Cement Company Limited; Messrs. William Lee, Son and Co.; and Messrs. Weston and Company signed the following declaration:

DECLARATION.

"I, , partner of the firm of Messrs., and I, of cement works of Messrs.,

and I, director, resident manager of the cement works of Messrs.,

and I, resident manager of the cement works of Messrs.,

of the Company Limited, cement manufacturers, do solemnly and sincerely declare that I am well acquainted with the practical manufacture of cement as carried on by the said firm or company, and that, according to the best of my knowledge, information and belief, the said firm or company have not on any occasion during the last three years, or within my knowledge at any other time, brought to and added to the calcined product of the kiln, in passing through the crushers, or mill stones, or grinding machinery, or any other subsequent process, a separate supply of raw Kentish rag stone, other stone, furnace or oven ashes, disused or exhausted..."
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I'll fire bricks, or any other material, so that such added material would be ground, sifted or mixed together with the cement and form part of the cement powder, and sent out and sold the cement in this state.

"And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the Statutory Declaration Act, 1835.

"Declared the , 1894, at ."

"Before me,"

Several well known makers did not then sign this declaration, however, preferring to take the very reasonable course of having the allegation that certain adulterants actually improved the quality of Portland cement thoroughly and scientifically investigated. The result of their action was that the London Chamber of Commerce, a body established to protect public interests in such matters, instituted an inquiry on the question. They requested Messrs. Stanger and Blount to make investigations on the matter. That firm made a series of exhaustive tests extending over a period of 12 months, as well as all the usual laboratory examinations, and drew up a report which concludes as follows:—"All materials added to Portland cement after the clinker comes from the kilns are adulterants." In consequence of these exhaustive reports made before that body, it passed the following resolution:—

"That no manufacturers connected with this Chamber be allowed to sell as Portland cement any product to which any foreign substance has been added subsequent to calcining, except calcium sulphate, up to the extent of 2 per cent. for the purpose of regulating the set."

And a declaration form was drawn up and issued by that body to all cement manufacturers in England inviting them to sign it. This finding and action practically agree with that taken previously by the Cement Makers Union in Germany, a Union which regulates the larger portion of the world's Portland cement production.

This account of the action of the London Chamber of Commerce would hardly be complete without giving the report submitted to that body by the celebrated Dr. Michaelis on this matter. The chief question to which he, at that time, turned his attention, was to the prevalent English adulterant, namely, Kentish ragstone. This is a sandy limestone of the lower green sand formation. The following is the text of his letter, the appendix referred to in it is given in appendix II to this paper:

"To the Secretary, Cement Trade Section,

SIR,—I have the honour to forward to the Chamber a treatise on the behaviour of hydraulic cements in sea water, which may be of the greater interest because it throws light upon a question now under discussion by the Chamber, namely, the admixture of improving substances with Portland cement. There is no doubt but that pozzolanas and trasses are most valuable admixtures in all kinds of hydraulic limes and cements, containing as much lime as Portland cements do. The characteristic of pure pozzolanas is that these substances set and harden with quicklime in water. Kentish ragstone is a marl or argillaceous limestone, the clay (silicates) in which, has, in the unburnt state, hardly any pozzolanic property at all. Kentish ragstone cannot, therefore, give rise to a chemical re-action with Portland cement, and it can act physically on it. To decide the controversy about the advantage or uselessness of an admixture of Kentish ragstone with Portland cement, I have made an investigation, the results of which you will find in the
annexed tables. This investigation proves there is no possibility of a chemical improvement and this is shown apart from the already mentioned fact that the clay of this substance has of itself no hydraulic property, by the test of the sand mortars, as the admixture of the Kentish ragstone diminishes the quantity of cementitious matters and lessens the strength; but it proves by the test of the neat cement mortars that Kentish ragstone can, to a certain extent, physically improve Portland cement, as an admixture of 15 to 20 per cent., gives very satisfactory results. It is clearly shown that an admixture within such limits can improve the very best cements (there exists nowhere better Portland cement than that of the "Stern" Works) to a certain extent, as to strength, setting, qualities, colour and plasticity, otherwise one-fifth of a worthless substance in the cement would diminish nearly in the same ratio the strength of the neat cement mortar. But as there is hardly any application of neat cement mortar, it is not a matter of great consequence that, in its neat state Portland cement may be somewhat improved by a judicious admixture of Kentish ragstone. As to the general application of sand mortars, it must be kept in mind that by the admixture of Kentish ragstone the amount of cementitious matter is diminished. I cannot, therefore, defend the addition of Kentish ragstone to Portland cement.

With reference to other adulterants it will be noted that Dr. Michaelis mentions that puzzuolanas are a valuable material for admixture with hydraulic limes or cements. Puzzuolana is an hydraulic silicate or a silicate of alumina, and is in such a state that the silicates are soluble and more or less readily combine with the limes, and this action has long been known and was made use of, the author believes, even by the Romans in their hydraulic lime betons. At the same time this material introduces several features which are not encountered in Portland cement as generally used, and in consequence certain precautions must be taken to ensure sound workmanship, which are not usually necessary with ordinary Portland cement.

However, puzzuolana and trasses must not be confounded with the substances most used to adulterate Portland cement which are ragstone, sand, ashes, slags, etc., and which would seem in great part to have been given preference since they can be mixed with the pure cement in considerable quantities without detection by the ordinary user, or, in fact, by the ordinary applied engineering tests. It is worthy of note that in these latter there is practically no soluble silica, nor any compound capable by mere hydration of forming a chemical combination with lime, consequently they cannot safely be regarded, except as inert adulterants. Perhaps the most conclusive experiments on this subject are those recently conducted by Professor Lunge of Zurich, which are given in appendix No. I. These experiments are interesting and worthy of close attention; they prove that the addition of a small quantity of fine sand to a mortar is better than if all coarse sand were used, as is commonly the case on public works. At the same time it clearly demonstrates that the fine sand is in no way a substitute for cement; though from the fact that the finer the sand, the more favourable the results obtained this might have been inferred and the fallacious argument that very fine sand entered into chemical combination might have been urged. Dr. Michaelis and Herr Lunge demonstrate:

1st. That an admixture of neat Portland Cement with either of these adulterants does not materially affect the tensile strength, and in some cases at an early date even shows an improvement, but when gauged with 3 parts of sand to one of the adulterated cement it invariably diminishes its
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value according to the amount of diluent used.

2nd. That briquettes of the admixture gauged with sea water, shows a decided bad effect.

3rd. That briquettes left in air indicates the presence of the adulterant in a very marked degree, both neat and with 3 parts of sand, and show a decided diminution of strength.

Another adulterant much used is blast furnace slag, which on account of its chemical nature has a deteriorating effect on cement. At the same time it must be remembered that there is an article sold as slag cement made by mixing granulated blast furnace slag with slaked lime and sold as such. This material has its own use and is a legitimate product. But the addition of 30 per cent. to 40 per cent. of blast furnace slag with cement clinker as it goes to the crusher, is simply an unscrupulous method of increasing the profits of the manufacturer, and is undoubtedly fraught with much danger to the public. Spent ashes, which have no cementitious value, and any other inert material, when added to cement clinker, is another adulterant of the same category. Also there is used as an adulterant, sand or silica, but that no benefit can possibly be derived from such an addition is confirmed by experiments made by the author. This view is also strongly supported by M. Feret, Head of the French Laboratory at Boulogne, who on a microscopic examination in concretes after several years maturing found even the finest grain of sand to remain intact, and to exhibit their original crystalline structure, when examined under the polariscope. At the same time he established the fact that the coarser particles of cement ultimately became cementitious. (Confirmed by Mr. Butler's experiments.) In the authors experiments samples of finely ground cement were taken, and mixed with drift sand, and ground together. All the samples chosen and the pure cement were treated in exactly the same way, being first ground to a standard degree of fineness, and subsequently tested with standard sands, and using from 9 to 10 per cent. of water, the results of these tests are given in appendix No. III. This and Appendices I. to II. show conclusively that cement so adulterated is deteriorated to an extent almost, and in some cases more, than the proportion of the adulterant added.

It has just been explained that such adulteration is difficult of detection, and not only is this so in Kentish ragstone adulterations, but also in those of slag or sand, when, though large amounts of the added silicates can be easily noticed, yet it is almost impossible to determine without tedious and minute analysis to 10 or 15 per cent. how much adulterant has been added. Now, in the cement market a difference of 6d. per cask will secure a contract and turn the scale between a profit or a loss, and such a difference can be secured by a 10 per cent. adulteration. The inference is plain, namely, that the cement user can be successfully imposed upon and is helpless to protect himself, and the small builder is absolutely at the mercy of the manufacturer. That some means of check is urgently required may be inferred from the fact that many cements can be adulterated to perhaps cent. per cent. without the general user detecting any inferiority, though when mixed with sand for ordinary use the inferiority is almost exactly pro-
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proportional to the adulteration.

To explain how such heavy adulteration is possible without detection, it is necessary to call your attention to the effect of the excessively fine grinding which has recently become the practice in the best cement works. In dealing with this question broad results only are given to avoid confusing the paper by publishing side by side tabulated instances similar in form referring to very different matters.

Briefly put, the coarsely ground cements containing perhaps 20 per cent. of coarse cement clinker, which being temporarily inert, will for the same reason, as has been explained above by Dr. Michaelis, give an even better result than the finely ground product when both are tested by the ordinary neat cement briquette. If, on the other hand, both are tested by the sand briquette test, using, say 3 parts of sand to 1 part of cement, the results are very different, the coarser cement giving a weaker mortar, weaker even in a greater ratio than might be expected from the proportion of inert matter it contained. If, now, a fine cement be mixed with sand, and the mixture ground to an even greater degree of fineness, it stands to reason that the resulting cement, though containing a very much greater proportion than 20 per cent. of above mentioned adulterant, will probably give as good a result when tested with a sand briquette as the coarse cement, and when tested neat will, as stated above, show a much better result than the pure cement used in its mixing, and quite as good a result as is obtained with the neat cement briquette of the coarser cement.

From these considerations it will be seen that a mixture containing over 20 per cent. of sand—viz., 1 part sand and 4 parts cement—will under all tests used by ordinary engineers equal the fair average results of good cements, and when it is further considered that the tests usually exacted in engineering specifications are from 30 to 40 per cent. below the results usually obtained by fair average cement (where the test briquettes are made by experts), it will be readily seen that the cement can be doctored with adulterants to the extent of almost equal parts, and yet give results sufficient to pass muster in nine out of every ten of even public works contracts. Thus, assume a cement which with a mixture of 1 part adulterant to 4 cement gives on a "neat cement" test a tensile strain of 560lbs. per square inch at 7 days, and intimately mix that cement with a further 3 parts of fine sand, making the mixture the half to half mentioned above. The result when tested on the neat cement seven days test will probably be about equivalent to the ratio which the further adulteration would warrant, viz., about $\frac{3}{4} \times 560\text{lbs.} = 350\text{lbs.}$,

and consequently will pass most engineers, though subjected to the ordinary sand briquette tests it would as surely fail. From this it is obvious that only a chemical analysis or the making of satisfactory sand briquettes are capable of showing adulteration. Unluckily, however, such briquettes, though sometimes specified on large works, have never been found practicable by engineers for several obvious reasons, of which the varying quality of sand available, the expert skill required, in their manufacture, the expense of delicate apparatus to weigh
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and gauge the materials, and above all the delay which necessarily occurs between the period when the cement is sampled and the date on which the result will be made known, say at least four weeks, greatly increase the cost of the work to the contractor.

It has been shown that from consideration of strength of materials, even such harmless adulteration as the admixture of pure sand, introduces a decidedly dangerous element into engineering and other structural works since the cement may be far weaker than the ordinary tests lead the user to believe, and consequently his work may fail.

Those who adulterate cements, on the other hand, have stated that the admixture of foreign materials subsequently to calcining has a beneficial effect, since it removes the tendency which occurs in fresh cements containing free limes to "blow." Such may be the case, but the presence of free lime is easily determined and the evil removed in properly maturing the cement in air, and consequently the only way in which adulteration could be an improvement might be from the manufacturers point of view, who is, by this means, enabled to place his goods so much sooner on the market, and at so much less expense, since he will be saved from keeping a large and costly stock to mature, and from the expense of erecting extensive stores for that purpose. But at the same time this effect of adulteration from the engineer's or consumer's point of view, is a most objectionable feature, instead of being an advantage as it has been represented by specious agents, who wish the public to only compare their cements with the bad or immature cements which occasionally are found on the market. The reason of it being objectionable will be readily seen from a consideration of what it is which slacks the free lime, namely, the moisture present in the adulterant, and as this is not present in constant quantities or in quantities which the manufacturer can readily control, it is obvious that to ensure there being sufficient moisture to properly effect the slacking of all the free lime, there will almost certainly be a considerable excess of moisture which cannot but have a most detrimental effect on the cement itself. It will partially perish the cement by incipient setting.

From the facts laid before this meeting there will be seen to be little doubt but that some of the adulteration of cement has been most harmful, and that the adulteration with harmless materials has not such a harmless effect as to make the adulterated article equal to the good pure cement from which it is prepared. And as the adulterants are all cheaper than the pure cement, it is obvious that in purchasing the adulterated article without knowing the amount and quality of the adulterant, the user and engineer at least lay themselves open to be financially imposed upon. To the author this fact, along with the fact that this adulteration is so easily practised without detection, shows that it is in the highest degree desirable that efficient checks should be placed on the manufacturers and merchants to protect the public against a very serious danger to the stability of all cement structures, and he ventures to suggest that this Institute should do something in the matter by appointing a committee to report further thereon.
APPENDIX I.

Report of Professor Lunge and C. Milberg, of Zurich, on the action of Silicates. Read before the German Cement Manufacturers' Union in Berlin on 23rd Feb., 1898.

It has been stated that finely ground quartz sand partly amalgamates with the uncombined lime in cement. I therefore made the following experiments to ascertain to what extent cement mortar is affected when gauged with sand sieved to the following degrees of fineness:—1st. Sand passed through a 776 mesh. 2nd. Sand passed through a 5806 and caught on a 32,257 sieve. 3rd. Sand passed through a 32,257 mesh (180 x 180 holes to the sq. inch), and obtained these results.

<table>
<thead>
<tr>
<th>MORTAR 2 and 1.</th>
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<th>MORTAR 4 and 1.</th>
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<tbody>
<tr>
<td></td>
<td>600 Parts C'ment</td>
<td>300 Parts C'ment</td>
<td>800 Parts C'ment</td>
</tr>
<tr>
<td></td>
<td>1200 Parts Standard Sand.</td>
<td>300 Parts Sand passed thro' a 775 Sieve.</td>
<td>300 Parts Sand passed thro' a 32,257 Sieve.</td>
</tr>
<tr>
<td>7 days ...</td>
<td>428 lbs.</td>
<td>144 lbs.</td>
<td>169 lbs.</td>
</tr>
<tr>
<td>28 &quot;</td>
<td>503 &quot;</td>
<td>195 &quot;</td>
<td>222 &quot;</td>
</tr>
<tr>
<td>90 &quot;</td>
<td>544 &quot;</td>
<td>250 &quot;</td>
<td>291 &quot;</td>
</tr>
<tr>
<td>Weight of Briquettes ...</td>
<td>838 gr.</td>
<td>764 gr.</td>
<td>792 gr.</td>
</tr>
<tr>
<td>7 days ...</td>
<td>206 lbs.</td>
<td>73 lbs.</td>
<td>94 lbs.</td>
</tr>
<tr>
<td>28 &quot;</td>
<td>77 &quot;</td>
<td>105 &quot;</td>
<td>134 &quot;</td>
</tr>
<tr>
<td>90 &quot;</td>
<td>297 &quot;</td>
<td>128 &quot;</td>
<td>136 &quot;</td>
</tr>
<tr>
<td>Weight of Briquettes ...</td>
<td>776 gr.</td>
<td>738 gr.</td>
<td>759 gr.</td>
</tr>
</tbody>
</table>

This proves that the substitution of the fine sand in lieu of a portion of the cement considerably diminishes the tensile strength, at the same time it appears that the finer the sand is ground, the less unfavourable are the results. For this reason it might be imagined that fine sand admits of chemical combination. It will also be observed that strength and density of the mortars made with fine sand increase in equal ratio, the sand completely filling all the cavities in the mortar. The best results being obtained with the sand which passed through a 32,257 mesh sieve, further experiments were made with it, gauged with compo.
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composed of 4 and 1 and 6 and 1, and I obtained the results as follow:—

<table>
<thead>
<tr>
<th>Mortar of 4 and 1.</th>
<th>Mortar of 5 and 1.</th>
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<tr>
<td><strong>Mortar of 4 and 1.</strong></td>
<td><strong>Mortar of 5 and 1.</strong></td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>7 days</strong></td>
<td><strong>7 days</strong></td>
</tr>
<tr>
<td><strong>28”</strong></td>
<td><strong>28”</strong></td>
</tr>
<tr>
<td><strong>90”</strong></td>
<td><strong>90”</strong></td>
</tr>
<tr>
<td><strong>Weight of Briquettes</strong></td>
<td><strong>Weight of Briquettes</strong></td>
</tr>
<tr>
<td><strong>776 gr.</strong></td>
<td><strong>751 gr.</strong></td>
</tr>
<tr>
<td><strong>796 gr.</strong></td>
<td><strong>795 gr.</strong></td>
</tr>
<tr>
<td><strong>776 gr.</strong></td>
<td><strong>795 gr.</strong></td>
</tr>
<tr>
<td><strong>796 gr.</strong></td>
<td><strong>795 gr.</strong></td>
</tr>
</tbody>
</table>

From these figures it will be seen that an addition of this very fine sand increases the density of the mortar, and on that account increases the tensile strength. To decide whether or no a chemical action takes place with the fine sand I mixed two samples of mortar of 4 parts sand to 1 part cement. To the one sample I added 50 per cent. of finely ground sand, and to the other 50 per cent. of finely ground marble, both sand and marble having passed through a 32,257 sieve. I obtained the following results:—

<table>
<thead>
<tr>
<th>Table No. 3.</th>
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<tr>
<td><strong>Table No. 3.</strong></td>
</tr>
<tr>
<td><strong>40 Parts Cement.</strong></td>
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<tr>
<td><strong>160 Parts Standard Sand.</strong></td>
</tr>
<tr>
<td><strong>7 days</strong></td>
</tr>
<tr>
<td><strong>28”</strong></td>
</tr>
<tr>
<td><strong>90”</strong></td>
</tr>
<tr>
<td><strong>Weight of Briquettes</strong></td>
</tr>
<tr>
<td><strong>786 gr.</strong></td>
</tr>
<tr>
<td><strong>826 gr.</strong></td>
</tr>
<tr>
<td><strong>826 gr.</strong></td>
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</tbody>
</table>

The breaking strain in both cases is increased in the same proportion, and as it is quite impossible for the carbonate of lime in the marble to form any chemical combination with the cement, it is conclusive that neither does the silica in the finely ground sand. It does not affect the value of these experiments even were the particles of sand, which are as fine as flour, chemically acted upon at a later date. Although it will be seen
that the addition of fine sand increases the strength and density of mortar, no one would go to the trouble of adding it in practice, for the reason that equal and even better results are obtained with natural sand, which contains grains of all sizes. The following experiments prove this:—I made a mortar of 400 parts cement, 200 parts fine sand (passed through a 32,257 sieve) and 1600 parts of standard sand; also a mortar of 400 parts cement and 1800 parts Rhine sand, the Rhine sand having first been passed through a 20 x 20 sieve, and retaining all the fine particles. I obtained equal results in both cases. Further, the mortar made of Rhine sand and cement showed an increase of 117 lbs. at 90 days over the one made of standard sand and cement, whereas the mortar made of cement and fine and standard sand only showed an increase of 57 lbs. in the same time.

<table>
<thead>
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<th>TABLE No. 4.</th>
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<tbody>
<tr>
<td>400 Parts C'ment</td>
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<tr>
<td>1600 Parts Standard Sand.</td>
</tr>
<tr>
<td>7 days ...</td>
</tr>
<tr>
<td>28 &quot; ...</td>
</tr>
<tr>
<td>90 &quot; ...</td>
</tr>
<tr>
<td>Weight of Briquettes ...</td>
</tr>
</tbody>
</table>

APPENDIX II.

Explanation of Table.—Comparative experiments on the strength of Portland cement mortars, prepared with two Portland cements, A and B neat (I.), and with sand (II.), unmixed and mixed with Kentish ragstone, and with fine sand (III.).

The test briquettes were made with parallel and even surfaces. They remained for the first 24 hours in a moist atmosphere, and then in fresh water of 60 degrees to 65 degrees Fahr. up to the moment when they were broken. Immediately before that operation the density of the briquette was ascertained. The strength of compression was ascertained with the same briquettes, which, when broken by tensile strength, were again put into water, bound together by an india-rubber band, and crushed in a hydraulic press of the highest precision. Though the results obtained in this manner are somewhat different from the strength got with cubic briquettes, they are far more reliable in this case, as only the relation of strengths can be of interest, and the great advantage of this method is that the strength is obtained from the very same mortars, the tensile as well as the compressive strength. The substances used were:—

A. Stettin Portland cement, "Star" brand (Toepffer, Grawitz and Co.).

B. Oppeln Portland cement, "Groschowitz" (Schlesoet, Gesellach, Groschowitz, Upper Silesia).

C. Standard sand of Berlin (Freienwalde), washed quartz sand between the wire gauze sieves with 400 and 800 meshes per square inch, marked "St. S."
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D. Fine quartz sand "F.S.", washed Freienwalde sand, which passes the wire gauze sieve with 600 meshes per square inch.

E. Mixed grained quartz sand, "M.S.", (70 per cent. of St. S., and 30 per cent of F.S.). This mixed grained sand was purposely used in order to reduce as much as possible the favourable, merely physical action of finely powdered substances, when mixed with the coarse-grained standard sand.

F. Kentish ragstone of such a fineness of powder that it passed wholly the wire gauze sieve, with 6000 meshes per square inch. The figures given represent the mean of ten single tests, and are in pounds per square inch. The arrangement of the figures in the tables below in five groups makes it clearly evident that the admixture improves the strength, or at least does no harm to the strength of neat cement; but that it diminishes the strength of sand mortars, not, however, to such an extent as an admixture of finely sifted washed quartz sand. (III) table of results of strength of tension and compression of Portland cement, neat and sand mortars, pure cement and cement with admixture of Kentish ragstone and with admixture of fine sand. The figures of strength are in pounds per square inch; each figure is the mean of ten single tests. The briquettes hardened in water of 60 degrees Fahr. to 65 degrees Fahr. Density immediately out of water, superficially dried:

St. S. = Standard sand between 400 and 800 meshes per square inch.
F.S. = Fine sand through 6000 meshes.

| M.S.—Mixed Grained Sand, 70 per cent. St. S. + 30 per cent. F.S. |

<table>
<thead>
<tr>
<th>Mixture (Weight)</th>
<th>Water</th>
<th>7 days</th>
<th>28 days</th>
<th>90 days</th>
<th>365 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tensile</td>
<td>Com-</td>
<td>Tensile</td>
<td>Com-</td>
</tr>
<tr>
<td>1</td>
<td>100 ct. A</td>
<td>19</td>
<td>575</td>
<td>6190</td>
<td>683</td>
</tr>
<tr>
<td>2</td>
<td>100 ct. A</td>
<td>19</td>
<td>411</td>
<td>5177</td>
<td>633</td>
</tr>
<tr>
<td>3</td>
<td>100 ct. A</td>
<td>19</td>
<td>407</td>
<td>5850</td>
<td>673</td>
</tr>
<tr>
<td>4</td>
<td>100 ct. A</td>
<td>42</td>
<td>253</td>
<td>2262</td>
<td>272</td>
</tr>
<tr>
<td>5</td>
<td>100 ct. A</td>
<td>42</td>
<td>225</td>
<td>2252</td>
<td>296</td>
</tr>
<tr>
<td>6</td>
<td>100 ct. A</td>
<td>41</td>
<td>198</td>
<td>1714</td>
<td>274</td>
</tr>
<tr>
<td>7</td>
<td>100 ct. A</td>
<td>20</td>
<td>523</td>
<td>5417</td>
<td>578</td>
</tr>
<tr>
<td>8</td>
<td>100 ct. A</td>
<td>20</td>
<td>507</td>
<td>6024</td>
<td>667</td>
</tr>
<tr>
<td>9</td>
<td>100 ct. A</td>
<td>20</td>
<td>514</td>
<td>6011</td>
<td>959</td>
</tr>
<tr>
<td>10</td>
<td>100 ct. A</td>
<td>42</td>
<td>201</td>
<td>2350</td>
<td>262</td>
</tr>
<tr>
<td>11</td>
<td>100 ct. A</td>
<td>42</td>
<td>177</td>
<td>1863</td>
<td>256</td>
</tr>
<tr>
<td>12</td>
<td>100 ct. A</td>
<td>42</td>
<td>179</td>
<td>1829</td>
<td>229</td>
</tr>
<tr>
<td>13</td>
<td>100 ct. A</td>
<td>40</td>
<td>209</td>
<td>2671</td>
<td>306</td>
</tr>
<tr>
<td>14</td>
<td>100 ct. A</td>
<td>50</td>
<td>209</td>
<td>2671</td>
<td>306</td>
</tr>
<tr>
<td>15</td>
<td>100 ct. A</td>
<td>39</td>
<td>176</td>
<td>1734</td>
<td>261</td>
</tr>
<tr>
<td>16</td>
<td>100 ct. A</td>
<td>38</td>
<td>156</td>
<td>1831</td>
<td>230</td>
</tr>
</tbody>
</table>
APPENDIX III.

Experiments With Sand Adulterated Cements.

In all the following tests the briquettes were the ordinary 1-inch section briquettes. A Faija testing machine and a Michael's testing machine were used, and the load was applied at the rate of about 100 lbs. in 15 seconds. The sand used was in all cases sharp river sand, passed through a 400-mesh sieve, and retained on a 900-mesh sieve, 6 briquettes were made of each batch:

<table>
<thead>
<tr>
<th>Date</th>
<th>Where Tested</th>
<th>Proportion of Adulterant in Finished Product</th>
<th>Tensile Strain to Break</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>7 days</td>
</tr>
<tr>
<td>June</td>
<td>Burnley</td>
<td>Pure</td>
<td>268</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25 per cent.</td>
<td>156</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 per cent.</td>
<td>109</td>
</tr>
<tr>
<td>July</td>
<td>Burnley</td>
<td>Pure</td>
<td>218</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 per cent.</td>
<td>92</td>
</tr>
<tr>
<td>August</td>
<td>University</td>
<td>Pure</td>
<td>308</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 per cent.</td>
<td>69</td>
</tr>
<tr>
<td>Sept.</td>
<td>Fyansford</td>
<td>Silicate cement*</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fyansford cement</td>
<td>168</td>
</tr>
</tbody>
</table>

*As pure cement briquettes on the seven days’ test these cements gave practically equal results, viz., Silicate cement, 420lbs.; Fyansford cement, 450lbs.
Mr. Geo. Higgins: I am glad to notice that several gentlemen who are connected with the manufacture of cement are present. Information of the kind which they are able to give us is much needed, especially on points about which differences of opinion appear to exist. For instance, Mr. Anderson declares that the addition of finely-ground sand, or other inert material, to Portland cement is injurious, while I understand him to say that puzoulnana or trass may be added with beneficial results. On the other hand, I find that Professor Warren, in reporting upon a material called "Silica Portland Cement," describes it as a mixture of Portland cement with finely ground hydraulic silica, saying that "This may take the form of puzoulnana, trass, santorin, earth, or sand." Apparently then Professor Warren and Mr. Anderson arrive at opposite conclusions, and, strangely enough, they both quote Dr. Michaelis in support of their views. Professor Warren quotes the following statement of Dr. Michaelis, viz., "In respect of its quality, as well as its behaviour in the cement masses, these become as much the more excellent the richer they are in hydraulic silica, at least in so far as the true object of these cements comes under consideration, viz., their hardening and durability in water. For structures in water, especially for the application of Hydraulic cements in sea-water, the chief protection lies in stopping the pores and fixing the lime. Both are attained to a prominent degree by enrichment with hydraulic silica capable of swelling up strongly, for, on the one hand, the silica fixes the lime, and, on the other, it closes the pores in the highest degree." Now one point on which I hope we shall get some information is as to the meaning of the term "Hydraulic Silica." Silica we know to be a definite body—the di-oxide of silicon—familiar, in an almost pure state, in quartz crystals and grains of sand. Can it be said to "fix the lime" or to "swell up strongly?" I hope also to learn what the constitution of silica cement is. What particular kind of hydraulic silica is it that is added to Portland cement? Is it added after calcining? If we compare the chemical analysis of a sample of silica cement with that of a good average Portland cement (as given by Henry Reid in his well-known book) we find that good Portland cement has 60 per cent. of lime, while silica cement has only 35·3 per cent. Portland cement has 24·3 per cent. of silica, while silica cement has 12·6 per cent., 12·6 per cent. of what is called "Soluble Silica," and 41·2 per cent. of "insoluble silica," or a total
ADULTERATION OF CEMENTS.

of 58.8 per cent. Here I would ask what is "Soluble Silica?" I think the term is not scientific. We know silica to be insoluble except in hydro-fluoric acid. Perhaps soluble silicates are meant. Now the only silicates soluble in water are those of the alkaline metals. The silicates of the alkaline earths are soluble in acid. Compounds of the two are insoluble in water and acids. Now it is scarcely likely that silicates of any of the alkalies are present in quantity in silica cement, because the analysis shows 0.83 per cent. of alkalies as compared with 15 per cent. in good Portland cement. Nor is silicate of alumina apparently present in excess, for silica cement contains about 4 per cent. of alumina, while good Portland cement contains 10.8 per cent. I have here a report upon some tests of silica cement made by Mr. W. L. de Roberts. He gives a list of the advantages of mixing ground silica to Portland cement in place of an inert material. If he means by "ground silica" what is ordinarily understood by the term, he evidently does not consider it an inert material. Thus Mr. Anderson and he are directly at issue. The first of the advantages is that the finely-ground sand in proximity to the free lime found in all cements tends to the formation of a meta-silicate, or colloidal silicate, which is recognised as being the most stable compound in cement; the formation of this meta-silicate is accompanied by an increase in volume while setting. For marine work this should be of value, as the combination with the free lime would prevent the sulphate of magnesia in the sea-water from acting injuriously by attacking the free lime to form sulphate of lime." Now, Mr. Anderson tells us, that good Portland cement should have no free lime, and also that there can be no chemical combination between sand and lime, and I think Mr. Anderson is right. The second advantage mentioned by Mr. de Roberts is "The excessive firmness of the silica cement." Here he and Mr. Anderson agree. Thirdly—"The impermeability of silica cement to water." Fourthly—"The freedom from expansion with age." Fifthly—Erdmenger and Lundteigen have shown by experiments that, by the admixture of trass and silica-bearing cement, the progressive increase in strength is greater than without the addition of ground silica. Here it seems that "trass and silica-bearing material" are taken to be one and the thing as "ground silica." There appears to be a strange confusion of terms; but, perhaps, some gentleman more familiar with the subject than myself may show that the fault lies with me. Here, however, is a clause which seems to show that "ground silica" is added to ordinary cement to make "silica cement." The same chemist also shows that, with fine grinding, the silica cement, when mixed with sand, may be of greater strength than the original cement when mixed with sand without the ground silica. Referring again to Mr. Anderson's paper, on page 4, he calls attention to the fact that "the addition of a small quantity of fine sand to a mortar is better than if all coarse sand were used, as is commonly the case on public works." This confirms what the Metropolitan Board of Work's experiments proved with reference to the retention of the fine dust, or "toppings," which result from the crushing of bluestone. In the table on page 12, Appendix III., there appears to be an omission in the last two lines. In September, at Fyansford, some experiments appear to have been made, showing that silicate cement had a tensile strength of 56lbs. per square inch after seven days setting, and that Fyansford cement
ADULTERATION OF CEMENTS.

had a tensile strength of 168 lbs. per square inch in the same time. Some
and must surely have been mixed with these cements; but the propor-
tions are not stated. Mr. Anderson’s suggestion that this Institute
should do something in the matter of appointing a Committee to report
further upon the subject of the adulteration of cement is one that I hope
will be given effect to. Of course it will depend upon whether or not
members have the leisure necessary for the prosecution of a slow and
arduous investigation. In any case, I hope and believe that much good
will result from the discussion on this important subject.

Mr. G. S. Potter: The first point I propose to deal with is the question
as to how Prof. Michaelis is quoted both by Mr. Anderson and Professor
Warren. Here is an extract from a paper by Prof. Michaelis (Engineering
April 2nd, 9th and 23rd, 1897):—“About one third of the whole quan-
tity of lime present in the cement is quicklime. The presence of this
quicklime causes continual expansion and contraction, which goes on for
considerable periods. All these evils must be mitigated if the
quicklime, remaining (or becoming) free in the hardening process, can be
laid hold of by offering to it hydraulic silica and alumina. The Council
of German Cement Makers, in 1882, opposed this idea in the following
terms:—‘Normal Portland cements do not require a so-called improving
addition. Such an addition produces rather a decrease of strength which
is nearly proportionate to the amount of the addition, and, further, the
Council is unfortunately of the opinion that the means of coercion which
the factories, desiring to furnish for the future an unadulterated article,
have at hand are not sufficiently effective to hold in hand these improper
practices; and, the more so, that the desire for gain, which here forms the
only motive, does not even disdain to cover itself with the mantle of pre-
tended science.’ In my open letter to the Council, in 1884, which was
directed against this malicious insinuation, I advanced once more, with
regard to the hardening in fresh water, the full proof of the correctness of
my theoretical propositions. At the Royal Testing Station in Building
Materials in Berlin, also, no other results could be obtained but such as
formed undoubted confirmation of my assertions. Prof. von Tetmeyer,
the same year, published his observations on the effect on Portland cement
of the admixture of certain substances which showed an increase of tensile
and compressive strength, although the density of the substances was
much below that of Portland cement. Thereby the actual improvement of
Portland cement by suitable additions was clearly proved to every unbiased
mind.” This extract undoubtedly shows that Dr. Michaelis is a strong
advocate of additions to Portland cement. The next point is that I have
been asked to explain what silica Portland cement is. In our process we
take ordinary Portland cement and grind with it a proportion of sand, the
whole being reduced to an impalpable powder. The theory is that, when
the water is added, the free lime forms a colloidal combination with the
finely pulverised silica. Objection has been taken to the use of the term
hydraulic silica as applied to insoluble silica, and I admit that there is a
reason in this. I also admit that, theoretically, it may be said that there
can be no combination between the free lime and the insoluble silica, but
as against that, our tests with sand mixtures show that there must be
combination, otherwise the tensile strains would be reduced, which they
ADULTERATION OF CEMENTS.

are not. I am authorised by Mr. Mountain to give the following tests made at the Town Hall:

<table>
<thead>
<tr>
<th>Test</th>
<th>Neat Cement</th>
<th>No. 1</th>
<th>No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 days test</td>
<td>489 lbs. per sq. in.</td>
<td>164 lbs. per sq. in.</td>
<td></td>
</tr>
<tr>
<td>28 &quot;</td>
<td>521.6 &quot;</td>
<td>188.5 &quot;</td>
<td></td>
</tr>
<tr>
<td>3 months test</td>
<td>580.8 &quot;</td>
<td>208.6 &quot;</td>
<td></td>
</tr>
<tr>
<td>6 &quot;</td>
<td>634 &quot;</td>
<td>270.8 &quot;</td>
<td></td>
</tr>
<tr>
<td>12 &quot;</td>
<td>744 &quot;</td>
<td>314 &quot;</td>
<td></td>
</tr>
</tbody>
</table>

The neat cement took 15.6 per cent. of water. The 3 to 1 test of sand to 1 of cement is not.

No one can find fault with those tests, and if the effect of the addition of the finely ground silica were that of an adulterant, the 3 to 1 tests could not have been what they are. A further proof that there is a combination is shown by the fact that, according to tests made in Sydney, our silica Portland cement and one other brand are the only two that have shown an increase of tensile strain after being kept for 12 months in salt water.

One gentleman has suggested that the standard test should be 3 to 1. In this I fully concur. You never use cement neat, so what is the use of testing it neat. The 3 of sand to 1 of cement test is by far the best, but there should be a standard sand, and the mixture should be by weight. I also strongly advocate the Deval hot bath. No inferior cement will stand it, and results can be arrived at more rapidly. My contention is that engineers should interfere with manufacturers as little as possible. You can establish standards for tensile and compressive strains, and if cements comply with these what more do you want? In your specified analysis you insist upon having an excess of lime. You then try to counteract it by having the cement matured as it is called; that is, you have it exposed to the air in order to get the free lime carbonated, and only a small proportion of it is acted upon. There have been various specifications for
fineness and weight per bushel, which, in some cases, have been self contradictory. By tying the manufacturers down in every possible way you will certainly prevent the possibility of any improvement. It seems to me that compliance with specified tests for strength should be quite sufficient. I trust that Mr. Anderson's suggestion that a Committee should be appointed to inquire further into this matter will be acted upon.

Mr. John Gibson: "I have read Mr. Anderson's paper with much interest, the matter being of vital importance to the manufacturers. To show that the subject requires investigation, I propose to bring under the notice of this Institute results of tests of an adulterated cement which came under my notice a few months ago. The neat cement gave the following tensile results per square inch: At 7 days, 169 lbs.; at 32 days, 234 lbs.; and at 3 months 340 lbs. After the addition of H.Cl. to any of the cement an unusually large quantity of sulphuretted hydrogen was given off, and the mass had a tendency to blacken. An analysis of the cement gave these results:

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insoluble in H. Cl.</td>
<td>13.8</td>
</tr>
<tr>
<td>Silica alumina</td>
<td>7.1</td>
</tr>
<tr>
<td>Iron oxide</td>
<td>27.1</td>
</tr>
<tr>
<td>Lime</td>
<td>48.9</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>2.0</td>
</tr>
<tr>
<td>Loss at red heat</td>
<td>6.0</td>
</tr>
</tbody>
</table>

All this goes to prove that the cement was adulterated, and that the adulterant was slag. Now, to show the danger that may arise from the use of slag when added to cement, I shall read the following extract from a paper upon the adulteration of Portland cement, by Messrs. Elanger and Blount, read before the London Section of the Society of Chemical Industry on 1st November, 1897:

'It may be mentioned incidentally that ordinary slag contains a good deal of sulphur (e.g., 1 per cent.) in the form of calcium sulphide. This, slowly oxidising, would be likely to expand in the mass of the set cement and cause stresses, which could hardly fail to be injurious, and might be positively dangerous.'

The cement I have just spoken of, and which was not of English or colonial make, had been purchased as Portland cement, and presumably the usual market price had been paid for it; further, the labels on the casks stated their contents to be Portland cement. A sample of another cement, which as a preliminary chemical examination indicated, had been dosed in the same manner, but not to the same extent, gave the following tensile results per square inch:—At 7 days, 414; at 32 days, 522, and from the test alone it would be concluded that the cement was satisfactory. The practice of adulterating mixed cement appears to be almost as old as the manufacture of that article itself, nor is the attempt to prove that the addition of inert materials to cement after manufacture has a beneficial effect—a recent innovation. Some 15 or 18 years ago a Mr. Alexander McAra, of Glasgow, patented a process for improvements in Portland cement by cooling, air slaking and maturing, all of which was right enough. This process, however, included the addition to the cement under treatment of a small percentage of finely pulverised carbonate of lime (limestone) for the following reasons—I quote from a pamphlet circulated by Mr.
ADULTERATION OF CEMENTS.

McAra:—"Any free lime which exists in the cement is first air-slacked and rendered inert, after which by re-absorption of carbonic acid from the carbonate of lime, it acquires a certain degree of hydraulicity, and I claim that by my process the Portland cement is rendered not only safer to use, but increased in strength and usefulness." Now it does not require any extensive knowledge of chemistry to discover the after fallacy, not to say absurdity, of Mr. McAra's contention, and, needless to say, his process has never received any general recognition. It seems that now we are faced by another school of cement doctors, who advocate for its improvement the addition of finely ground silicate to finished cement. Now if these additions took the form of soluble silicates, such as puzzuolanas, trass, etc., something might be said for their contentions, but when the silicates are in the insoluble form of sand or of those contained in Kentish ragstone, I think their beneficial claims may be classed with those of Mr. McAra for the addition of finely pulverised carbonate of lime. This view is strongly supported by the interesting and conclusive experiments made by the well-known chemist, Professor Zurich, which are given by Mr. Anderson in appendix 1. Finally, I protest against the use of the term Portland in connection with cements to which additions have been made. Call them slag cements, ragstone cements, or sand cements, so that the consumer may thoroughly understand what he is buying and using; also let them be judged by their own standards and upon their individual intrinsic merit, and not by comparison with an article to which after all they must bear the relationship of the adulterated to the pure.
DISCUSSION ON "PORTLAND CEMENT ADULTERATION."

On December 6th, 1899.

(Continued.)

PROFESSOR KERNOT stated he had seen Professor Warren, of the Sydney University, the day previous to the meeting, who had assured him that he did not consider this Silicate cement should be properly called an adulteration. The speaker stated that a quantity of this cement, and would make a careful experiment, which will take 3 or 4 months. Professor Warren will also have the result of 12 months' experiments out shortly.

Mr. A. C. Mountain.—Such a paper as the one we have now under consideration revives, at an opportune time, a question which caused much controversy some years since, and which is one that it is desirable to have now definitely settled, seeing that engineers are being asked to pronounce on the merits of a preparation of cement and Silica which, it is alleged, offers some advantages over the pure Portland Cement.

In a paper written in 1886, and read before the Engineering Association of New South Wales, I referred in unmistakable terms to the evils of adulteration in cement, and pointed out the fact that not only were the German chemists averse from it, but that the manufacturers of Germany, as early as '83, had formed themselves into a body pledged not to use any adulterant, and clearly defining what they accepted as a genuine Portland Cement. In the paper now under discussion, Mr. Noble-Anderson has shown that the British manufacturers have also agreed to recognise similar principles. It would thus appear that in both countries—large producers of cement—chemical experts, manufacturers, and, presumably, the users of the articles (the engineers and architects) agree in thinking that no advantage is derived by the addition of any foreign matter whatever to the ingredients which are considered necessary to the constitution of a sound cement. It became speedily apparent, however, that the finer ground cement of the Germans shewed some distinct advantages over the rough cements that, until recently, were produced in England. Experience shewed that not only does the finer cement go farther in the work, but that it was less liable to "blow"—these advantages quite compensating for the cost of the additional grinding.

As regards the less finely-ground cement, it was further alleged that the coarsest particles were not only inert, but absolutely detrimental. In an excellent paper on this subject (Proceedings of Inst. of C.E., Vol. CXXXII, p. 343), Mr. D. Butler shows, however, that this is wrong, and that though slow in acting, even the very coarsest particles of the cement do combine and shew both tensile and compressive strength.
I mention these facts to deal with the claims that are made for a compound of Portland Cement and Silica, reference to which was made at the last meeting by previous speakers. As far as I can gather, it is claimed that an improvement to ordinary Portland Cement is obtained by mixing the same with a certain proportion of sand, and intimately and finely grinding them together.

It is evident that something more than an ordinary mechanical mixture is here intended, otherwise the advantage will be simply due to the more thorough grinding of the cement, giving it enough additional strength to counteract the presence of so much inert matter.

The results of some tests carried out under my directions were quoted by Mr. Potter, and shew certainly a very respectable record for Silica cement; but, to be all convincing, it strikes me it would be necessary to observe the tests of the cement used in making the Silica cement, when ground to equal fineness, but without admixture, with any sand. Unless it can be clearly shown that the addition of the sand produces a cement of greater strength than the pure cement would give if ground of equal fineness, I fail to see the utility of the sand.

But, on turning to some tests recorded in the paper already alluded to, I find that taking a type of a good sound English cement, and a similar class of German cement, they compare favourably with Silica tests, although much less finely ground; e.g., English cement left 29·9 per cent. on "C" sieve; German cement left 26·3 per cent. on "C" sieve; whilst Silica cement left only 12·5 per cent. on "C" sieve.

<table>
<thead>
<tr>
<th>Tests</th>
<th>English: Baye and Barrow</th>
<th>German: K. and Meyerstein</th>
<th>Silica</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3 to 1</td>
<td>3 to 1</td>
</tr>
<tr>
<td>7 days</td>
<td></td>
<td>459</td>
<td>532</td>
</tr>
<tr>
<td>28 &quot;</td>
<td></td>
<td>610</td>
<td>738</td>
</tr>
<tr>
<td>3 mons.</td>
<td></td>
<td>674</td>
<td>869</td>
</tr>
<tr>
<td>6 &quot;</td>
<td></td>
<td>805</td>
<td>865</td>
</tr>
<tr>
<td>12 &quot;</td>
<td></td>
<td>922</td>
<td>901</td>
</tr>
</tbody>
</table>

From the foregoing table would anyone here present venture to assert that either of the above-named cements would not have shown still greater strength, good though their results already are, had they been as finely ground as is the Silica cement, with which they have been compared? But the operation of grinding is a purely physical (or mechanical) one; and as pointed out by Mr. Anderson, has been proved to produce no chemical change in the ingredients.

With reference to the second claim, viz., that the Silica is free from...
all tendency to "blow," and is therefore safe to use. I would point out that
this safety is due more to the excellence of the grinding than to the
presence of the sand. Mr. Butler, whose paper I have before alluded to
says on this subject, and I see that Mr. Anderson has noted the fact:

"Efforts were thereupon made to procure one or two unsound cements,
and ascertain the effect of grinding them extremely fine. Cement P was
specially prepared by the author as an over-limed, unsound cement. When
treated in the Fiaja apparatus it "blew" badly, and disintegrated almost
entirely; but after being ground extremely fine, this "blowing" charac-
teristic had practically disappeared. Cement Q, on the other hand, was
a badly manufactured cement, being made from a very hard chalk,
insufficiently reduced during the amalgamation of the raw materials. This
sample also "blew" very badly when treated in the Fiaja apparatus, but
after being ground extremely fine these indications disappeared entirely.

"That the finer grinding of cement should, to a considerable extent
correct a tendency to "blow," is a most important feature, the reason of
which may be readily explained. "Blowing," or unsoundness, may gener-
ally be traced to one of two distinct faults in manufacture, viz., over-liming
(or excess of lime), under-burning (or insufficient calcination), both giving
rise to the presence of free or loosely combined lime. Of these two forms
of unsoundness, by far the most insidious and dangerous is that due to
over-liming, as the uncombined lime is confined within the hard-burned
coarse particles, and it may be weeks or even months before the water can
penetrate sufficiently to cause it to expand and betray its presence. *
* The beneficial effect of fine grinding, therefore, is that the uncombined
lime, which would otherwise be confined within the coarser particles and
subsequently cause mischief, is hydrated by the water during the operation
of gauging, and thus rendered innocuous; or, if the cement has been pre-
viously spread out to mature, the moisture in the atmosphere acts upon it
in a similar manner."

The writer further explains that the fine-grinding means a more rapidly-
setting cement, whilst the growing demand of engineers is for a slow-
setting material. To counteract this tendency, the German cement
manufacturers sanction the addition of small percentages of gypsum, not
in excess of 2 per cent., which is ground up with the clinker. Even this
small admixture is, however, pronounced to be detrimental if the cement
has to be used in sea-water.

I find that John Watt Sandeman, M. Inst. C.E., one of the most
practical authorities on the question, in a paper (vol. cxxi., page 214),
read before the Institute of Civil Engineers, makes the following
remarks:

"Finely ground cement, by taking more sand than coarse cement,
makes a proportionately stronger concrete. It also gives greater freedom
from expansion or "bleowing," should such be liable to occur from excess
of free lime, as this would be in the condition of fine powder and would
more readily become air-slacked. * * *

The author's firm has for
some years used large quantities of cement ground so fine that only 2 per
cent was contained by a sieve of 5,800 meshes to the square inch, and
about 10 per cent. by a sieve of 14,400 meshes per square inch. The
advantage obtained by fine-grinding has been found to be so great that
the author recommends that this degree of fineness should now be generally
adopted."

The above extracts clearly show that the strength, soundness, and
general usefulness of the cement is increased by fine grinding. It may
also be shown that this is chiefly—if not entirely—manifested in those
cases where cement is mixed with sand, or aggregates, for the making of
mortar or concrete; in the case of neat cement an actual falling off in tensile
strength being sometimes encountered.

In the case of cements, as to which some doubt arises as to their “fitness
for immediate use,” the common practice of engineers in charge of large
works to have same spread out in a covered shed with a wood floor for two
or there weeks, and regularly turned over before use, is found to give very
satisfactory results.

Having thus dealt with the questions of fine-grinding and “blowing,”
it becomes necessary to consider the practical issues, and bear in mind the
responsibilities and anxieties of an engineer in selecting the cement for
work, the success of which often will depend on the durability and sound-
ness of the cement used. Mechanical tests are all that can be employed.
And time often will not admit of these being brought to a satisfactory
conclusion before the cement is placed in the work. Chemical tests are
practically out of the question; but, even were that not the case, analysis
does not show the degree of calcination, nor would it disclose the extent
of adulteration.

The engineer, then, is left to his judgment and to his experience of
cements which he has already used and tested, and trusts to the uniformity
of method pursued by the manufacturer. Whether he would be disposed
to place equal confidence in the regularity and uniformity of a cement
admittedly mixed with a less costly material, is a very moot point! To my
mind, the remedy for this uncertainty is to have the whole of the cement
(whether imported or made in the colony) subjected to a careful testing by
some Governmental authority. The Customs, which obtains a large
revenue from the article, could afford to pay for this and probably the
University would be the proper institution to conduct the examination and
analysis.

In any case, I am quite in accord with the suggestion which has been
thrown out—that a conference should be invited to meet to consider what
is the best thing to be done to ensure certainty and some uniformity in the
cement supplied to us; and this conference might include chemists, large
users, and merchants, as well as architects and engineers. Feeling, as I
do, that, in the above remarks, I have naturally been actuated by the con-
servative caution which an engineer is apt to exhibit when brought face to
face with some radical change in the constituents of a material which
hitherto had not been interfered with after leaving the manufactory, I am
still free to confess that the reports on silica cement, written by Professor
Warren, M.Inst. C.E., and those prepared by the officers of the Public
Works Department of New South Wales, speak strongly in its favour; in
addition to which Professor Warren has personally assured me that his
experiments with this material have quite satisfied him as to its utility.
DISCUSSION ON PORTLAND CEMENT ADULTERATION.

Of course, these are laboratory tests on samples only, and it will remain to be seen if they are confirmed when tried on the larger scale. I further understand that the Silica, or Sand Cement as it is called there, has a large use in the United States of America.

Under these circumstances, I think fuller enquiry is certainly desirable. A comparison should be made between the strength of silica cement and the cement from which it has been prepared after it has been ground to an equal degree of fineness. It will thus be discovered:

1° Whether the admixture of sand gives any additional strength to the cement, or whether the extended adhesive property of the cement (due to the extra grinding) simply allows of a certain adulteration without material sacrifice of strength; and (2°) if the union of the finely ground cement and sand is a chemical one, causing results that a purely physical blend could not procure.

These appear to be all-important points that need to be satisfactorily settled. And to do this, observations for quite two years under the ordinary testing methods, together with chemical and microscopic examination, will be required.

Mr. Richard Taylor.—Mr. Higgins asks how is it Messrs. Anderson and Warren arrive at different conclusions relative to the merits of silica and sand admixtures with Portland cement, both quoting Michaelis as authority. Mr. Potter answered this question last meeting, stating Michaelis’s remarks were capable of any construction you like to place on them. Michaelis was a man who said if it does not suit you to call it black, call it green, etc. Michaelis is about the greatest living authority on limes and cements—his remarks are to the point, not capable of a double construction, not a man who says one thing and means another. Mr. Potter quotes Michaelis as one of his strong authorities in support of his argument as to the quality of silicate Portland cement, and it is a pity he should have referred to a gentleman who, according to his own words, was so unreliable an authority and such a turncoat. Mr. Higgins asks:

What are soluble silica and hydraulic silica? I am not surprised at the question, especially after reading pamphlets of the Federal Company and Mr. Potter’s remarks at last meeting. These firms so mixed up the word silica and enshrouded the word in so much mystery that I doubt if they understand the meaning of it themselves. In the first place we have soluble silica and soluble silicates, viz., those soluble in a weak solution of H.Cl or strong alkaline solution, and have the property of combining with lime on hydration; also as its silicates in amorphous state, i.e., non-crystalline, insoluble in H.Cl, but combine with limes at high temperature 3000deg. Hydraulic silica comes under one of these headings. Crystalline silica, quartz sand insoluble in H.Cl., forms no combination with lime in hydration or heat. Meaning of silica to cement manufacturing chemist—Michaelis in all his remarks states that such silica bearing compounds as puzzolana and trass—these silicates which are capable of forming a combination with lime on hydration—that improve limes and cements. The Federal Co. also support this theory themselves in the reference they make to fire tests. Mr. Potter gives us a definition of silica cement. I am glad he admits no chemical combination between his added sand and lime. When
he continues his remarks "that if there were combination he could not get such a tensile strain"—to put it mildly he is begging the question. I will answer that question. Tensile strain which he gets—which I admit is good, although results obtained by Mr. Anderson do not bear these out—are due to the one simple cause, fine grinding of the cement itself and of that alone. You can term it meta silicate, colloidal silicate, combination, use as many high sounding words as you like—in plain English, all due to the fine state of reduction to which cement is brought. Take residue of any ordinary cement on an 80 or 123 screen; residue at early dates has practically no cementitious properties. Grind that residue as fine as the rest of the cement, and you will get results in mortar tests greatly surpassing (at early dates) those obtained with the original cement (which contained the coarser residue). Sand finely ground and mixed with this fine cement—which Mr. Potter admits does not combine with the lime in the cement—merely acts as a diluent, and only has the effect of again reducing the strength of the cement in proportion to the quantity added. Therefore let the cement maker attend to the fine grinding of the cement, leaving the addition of the sand or any other adulterant to the engineer, who can regulate the proportion at his pleasure. I cannot agree with Mr. Potter's remarks that engineers should not interfere with manufacturers. I consider engineers are equally interested with manufacturers in the production of a good reliable article. By no means can I fall in with the statement that tensile and compressive tests alone are sufficient. Mr. Gibson showed us a cement which passes the tension tests; on analysis it proved to be injurious and even dangerous. Mr. Potter accuses engineers specifying too much lime in their analysis, but as a practical man he knows that this is not the case, and that such bodies as the Board of Works and Railway Department limit the per cent. of lime to the lowest at which it is possible to produce a cement clinker. After making this groundless assertion Mr. Potter jibes at engineers for insisting upon having cements matured. I ask him if he will accept and use or mixing with his sand a cement that is unmatured, or even a cement made with the minimum of lime, such as is preferred by the engineers of the Board of Works. I have good reason to believe that he prefers the highest test, and consequently the highest limed cement he can obtain. Mr. Potter knows as well as I do that if he were to grind an unmatured blowing cement with his sand the resulting compound would still be unmatured, and the blowing propensities would require to be matured as directed and desired by engineers, to whose interference in the manufacture he so strongly objects.

Prof. Kernot.—Regarding the appointment of a committee to go into this question, which Mr. Mountain favours, I think this should be done, and I will be prepared to give every assistance in my power.

Mr. Potter said he would like to make a few remarks regarding what Mr. Taylor had said, when

Mr. Anderson rose to a point of order, and stated that he thought it desirable that the discussion should be confined to members of the Institute.
DISCUSSION ON PORTLAND CEMENT ADULTERATION.

The rules having been referred to, Prof. Kernot ruled that it was quite in order for the gentlemen referred to to take part in the discussion, especially so, as they were present at the invitation of the Council.

Mr. G. S. Potter.—I have been connected with the cement trade for over 20 years, and our firm was the first to introduce fine grinding in England. Regarding Mr. Sandiman, he is a personal friend of mine, and our firm drew his attention to the advantages of this system. Samples of our Silicate Portland cement were submitted to him, and he said he was perfectly satisfied with the results obtained from it. On the strength of that, and of my own enquiries here, I introduced this particular business. I understood Mr. Mountain to say that the effect of fine grinding was to prevent a tendency to expand.

Mr. Mountain.—That is so. I quoted also from greater authorities in support of it.

Mr. Potter.—Experiments in Germany showed that so far from fine grinding preventing this, the actual effect was to make the cement more dangerous at the initial stages; but it is quite impossible to arrive at any definite conclusion in a discussion like this, and I agree that it would be much better if there were a properly recognised system of testing cement. In Sydney there was such a system, and if a manufacturer had 500 or 1000 casks he wished to put on the market it was placed in bond, the samples taken, the bond locked, and the Government inspector would supply a 28 days test in 30 days. They also had the Devais’ hot bath test, which he considered the safest and best. Testing of cement in Melbourne was not so satisfactory, being of a desultory nature—sometimes by weight, sometimes by measure, etc. In one instance it took eight months to supply a 28 days test. The main point is our cement is said to be adulterated; but no definite conclusion can be arrived at. On account of an engineer taking exception to our cement in Sydney, the whole question was submitted to the Under Secretary for Public Works. Four Chief Engineers of the Public Works Department and Prof. Warren represented us. He is one of the best authorities on this subject in Australia. I will read you his report:

The University of Sydney, 29th November, 1899.

The Manager, Federal Portland Cement Co. Ltd.,

Dear Sir,—I herewith state that I have made the following tests in order to ascertain whether the addition of sand to Portland cement is beneficial or otherwise in the proportions used, and the special process practised by your company in the manufacture of Silica Portland Cement. These tests were suggested by the New South Wales Government Board of Reference, consisting of the Under Secretary for Public Works and the Engineers-in-Chief of the four branches of the Public Works Department. The main question to be decided was:—Is the addition of sand in any sense an adulteration in the special process practised by your company in the manufacture of their Silica Portland Cement? Three series of tests were agreed upon which may be briefly described as follows:

Series a—Consisting of two parts of Surrey Hills sands, mixed with three parts of Portland cement (key brand). The sand and cement were
DISCUSSION ON PORTLAND CEMENT ADULTERATION.

merely mixed together, and were not subjected to any other treatment previous to testing.

Series b— Consisting of Portland cement (key brand) tested as received.

Series c— Consisting of ordinary Silica Portland Cement as made by your company containing two parts of Surrey Hills sand and three parts of Portland cement (key brand in this case). The sand and cement in this series were ground together by means of the special apparatus and process used by your company.

Each series consisted of tensile tests after three and seven days in cold water, and after seven days in Deval's hot bath; also when mixed with standard sand to form mortar in the proportion of one part of the cement or mixture to three parts of sand after seven days in cold water and seven days in Deval's hot bath. The standard sand used was river sand, obtained from the Emu Plains Gravel Company, sifted through a sieve of 400 and caught in one of 900 meshes per square inch. All the proportions mentioned in this report were determined by weight, and every care was taken to keep all the conditions uniform throughout the tests. The methods of forming the briquettes and testing them, also the apparatus used is in every respect the same as adopted in the principal European laboratories. The results are given in the following table:

<table>
<thead>
<tr>
<th>Name of Series</th>
<th>Tensile Strength Neat, Pounds per square inch.</th>
<th>Tensile strength of mortar, 3 to 1 lbs. per square inch.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 days cold</td>
<td>7 days cold</td>
</tr>
<tr>
<td>a</td>
<td>273</td>
<td>470</td>
</tr>
<tr>
<td>b</td>
<td>452</td>
<td>518</td>
</tr>
<tr>
<td>c</td>
<td>453</td>
<td>643</td>
</tr>
</tbody>
</table>

Conclusions on the results:—1. It will be observed that the results of testing the mixture of two parts of Surry Hills sand and three parts of Portland cement are inferior in every case to either the ordinary or Silica Portland Cement.

2. That as a material for making mortar or concrete the mere mixture of sand and cement as in Series A is decidedly inferior to either the ordinary or the Silica Portland Cement.

3. That the addition of sand to Portland cement as practised by the Federal Portland Cement Company Ltd. in the manufacture of their Silica Portland Cement is not an adulteration in any sense whatsoever, as it produces a stronger cement than the same Portland cement untreated.

I may add further that I have tested your Silica Portland Cement in tension, compression and cross-breaking, extending at present over six months; the twelve months' tests are not yet completed, and I have carefully observed its behaviour in the standard tests for soundness and constancy of volume. I consider that your Silica Portland Cement is a thor
DISCUSSION ON PORTLAND CEMENT ADULTERATION.

oughly sound and reliable material. I remain,

Yours faithfully,

W. H. WARREN,

(M. Inst., C.E., M. Am. Soc., C.E., Challis Professor of Engineering.)

There must be some chemical action going on in the cement when it sets; but although various theories have been put forth, nobody knows what the action is. I trust, in conclusion, that a committee will be delegated to go into this question, and some central authority appointed, so that tests can be made on a systematic basis, which will give reliable results, satisfactory to all concerned.

Mr. G. S. Potter (by correspondence).—Referring to the discussion on the "Adulteration of Cement," there were certain points raised to which I was unable to give an adequate reply, not having documents and figures at hand. As I understood Mr. Mountain, he suggested that in order to arrive at definite conclusions as regards the effect of adding sand, according to the process of our company, it would be advisable to compare Silica Portland cement with an ordinary Portland cement ground to the same degree of fineness as the Silica cement. This would appear to indicate the idea that the tests obtained from Silica Portland cement were due to fine grinding only. Now, as against that theory, it is fair to take the 34,000 mesh sieve as the finest standard that is known, and it will be conceded that all cement which passes through that sieve is effective," and all that is rejected is non-effective. In ordinary Portland cement, from 25 to 30 per cent is rejected on this sieve. Taking the sample of Silica cement, which was tested by Prof. Warren, and assuming that the whole of the original Portland cement was ground so as to pass through the 34,000 mesh sieve, and also assuming that the 40 per cent of sand added is inert, we get the following comparisons:—

<table>
<thead>
<tr>
<th></th>
<th>Ordinary Portland Cement</th>
<th>Silica Portland Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective</td>
<td>75 per cent</td>
<td>60 per cent</td>
</tr>
<tr>
<td>Non-effective</td>
<td>25</td>
<td>40</td>
</tr>
</tbody>
</table>

If it were simply a question of adulteration, counterbalanced by fine grinding, the Silica cement could not fail to give lower tests than the original Portland cement, more especially when tested 3 to 1. As Prof. Warren's tests show that the Silica cement is superior, the conclusion is inevitable that there is a definite combination between the finely pulverised Silica and the free lime present in the cement. I submit that this conclusion disposes of the contention that our Silica cement is adulterated, and meets the theory that the tests obtained are due solely to fine grinding.

With a view to further elucidating this point, I have pleasure in giving some results which I obtained about five years ago, when I went very fully into the question of fine grinding. The absolute tests are not high, the percentage of water added was rather excessive, and the machine used was a long beam Adie, which, from my experience, does not permit of such high tests as the modern short lever machines. In these tests the same cement was used in every case, the only difference being in the fineness of grinding. The percentage of residue rejected on the various sieves used was as follows:—
DISCUSSION ON PORTLAND CEMENT ADULTERATION.

<table>
<thead>
<tr>
<th></th>
<th>2500</th>
<th>5776</th>
<th>14,400</th>
<th>34,225</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>nil</td>
<td>nil</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>No. 2</td>
<td>nil</td>
<td>.5</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>No. 3</td>
<td>5</td>
<td>14</td>
<td>25</td>
<td>32</td>
</tr>
</tbody>
</table>

Tests.—3 of standard sand to 1 of cement.

| No. 1 | 190 | 277 | 315 | 370 | 380 |
| No. 2 | 157 | 226 | 265 | 302 | 368 |
| No. 3 | 116 | 183 | 214 | 254 | 264 |

Another series of tests was made to prove the point that cement rejected by the 34,000 mesh sieve is inert. No. 2 cement had added to it fine sand, passed through a 50 x 50 sieve, so as to bring the percentage in the 34,000 sieve up to 32, the same as No. 3. The tests were:

1 Week. 4 Weeks. 8 Weeks. 12 Weeks. 12 Months.

| No. 1 | 474 | 514 | 315 | 370 | 280 |
| No. 2 | 466 | 534 | 571 | 578 |
| No. 3 | 433 | 520 | 573 | 606 |

These are almost the same as in the case of No. 3.

The neat tests are, in my opinion, of minor importance as compared with the 3 to 1 tests, but it may be of interest to some of your readers to have them:

| No. 1 | 190 | 277 | 315 | 370 | 380 |
| No. 2 | 157 | 226 | 265 | 302 | 368 |
| No. 3 | 116 | 183 | 214 | 254 | 264 |

These show that the advantageous effects of fine grinding are not apparent when the cement is tested neat.

The following tests were made from various samples of different brands. The first two columns give the percentage of residue on the 14,400 and 34,000 sieves:

<table>
<thead>
<tr>
<th></th>
<th>14,400</th>
<th>34,000</th>
<th>1 Week.</th>
<th>4 Weeks.</th>
<th>8 Weeks.</th>
<th>12 Weeks.</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>30</td>
<td>122</td>
<td>220</td>
<td>255</td>
<td>315</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>32</td>
<td>145</td>
<td>185</td>
<td>255</td>
<td>275</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>27</td>
<td>170</td>
<td>211</td>
<td>222</td>
<td>252</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>37</td>
<td>100</td>
<td>147</td>
<td>170</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>36</td>
<td>110</td>
<td>140</td>
<td>180</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>39</td>
<td>132</td>
<td>145</td>
<td>190</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>40</td>
<td>67</td>
<td>117</td>
<td>150</td>
<td>167</td>
<td></td>
</tr>
</tbody>
</table>

Comparing the 3 to 1 tests with those made by Prof. Warren, and taking the 7 days Deval's hot bath test as being approximately equivalent to the 28 days cold test, we have:

Finely Ground Cement.  
| No. 3 | 116 | 188 | 175 | 252 |
| No. 1 | 190 | 277 | 263 | 335 |
DISCUSSION ON PORTLAND CEMENT ADULTERATION.

Percentage of increase.

64 per cent. 51 per cent. 50 per cent. 33 per cent.

These percentages are worked out on a comparative basis, and not as regards absolute results, and although the improvement in the case of the Silica cement is not as great as in the case of the very finely ground Portland cement, still it is sufficiently substantial to prove its superiority over the original Portland cement treated. Furthermore, with due deference to Mr. Mountain, I submit that the comparison asked for is beyond the question at issue. The effect of the addition of Silica should be considered in its bearing on cements that are on the market, and not on a cement that is ground to a degree of fineness that is practically uneconomical. In the case of a Portland cement ground to a minimum residue of 5 or 6 per cent. on a 34,000 mesh sieve, the cost to the consumer would certainly be not less than 2s. per cask more than the ordinary cements on the market; and, in order to use it economically, it would be necessary to make a mortar of 5 or 6 parts of sand to 1 part of cement. The mixing would certainly be defective, and consequently the mortar or concrete would be far from uniform. In practical work—"on the board"—the mixture of 4 of sand to 1 of cement is generally considered the limit at which it can be properly done by hand. In my opinion, 3 to 1 is the outside limit. In these mixtures I refer only to the addition of sand or fine screenings; the admixture of metal or large stones is another matter altogether. Therefore, even granting that a Portland cement ground to the same degree of fineness as the silica cement might show a greater strength than the latter, yet its cost is so much higher that it is uneconomical to use. I contend that the only fair comparison is as between Silica Portland cement and Portland cements which are on the market, and if it is conceded—as Professor Warren has proved—that the former is superior to the latter, and as it can be obtained at a rather lower cost, then there is every reason why engineers should use it.

The whole matter has been gone into very fully by the Board of Reference, Department of Public Works, Sydney, consisting of Mr. Robt. Hickson, Mr. C. W. Darley, Mr. W. L. Vernon, Mr. H. Deane, and Mr. J. Davis, who are respectively Under Secretary, Engineer-in-Chief for Public Works, Government Architect, Engineer-in-Chief for Railway Construction, and Engineer-in-Chief for Sewerage Construction. In a minute dated 7th December, 1899, they report as follows:

USE OF SILICA PORTLAND CEMENT.

"With reference to the minute of 28th ult., in which it is set out that, before finally dealing with this matter, the Board had decided to await the result of the 28 days' cold tests of cement. Mr. Roberts, the officer in charge of cement testing, to-day submitted the following results:

Twenty-eight Days Cold Tests.

Neat. 3 Sand to 1 Cement.

No. 1—2 parts Surrey Hill Sand, 3 parts " Key " brand. 486 108
DISCUSSION ON PORTLAND CEMENT ADULTERATION.

"No. 2—Portland cement "Key" brand 661 250

"No. 3—Silica cement 2 parts ground Silica 664 261 3 " cement, "Key" brand.

Mr. Roberts also submitted three cubes composed as stated above, each 1500 grains in weight. Also "No. 4" cube, composed of lime 2 parts and ground silica 3 parts, 1500 grains in weight. All the cubes were subject to a pressure of 1400 lbs. per sq. inch, and, under that pressure allowed to absorb what water they would.

"The mixture of cube No. 4 hydrated with 22.4 per cent. of water under a pressure of 1400 lbs. per sq. inch, forming an hydraulic cement which hardened under water. It seemed as if the result of mixing ground silica was to give opportunity to chemical action, and it was not, therefore, a mechanical mixture. This view is borne out by the action of the ground silica in the case of No. 4, as when mixed with lime it made the latter hydraulic. The Board, after much careful consideration of these tests and those referred to in the minute of 28th ult., came to the conclusion that the admixture of the ground silica could not be deemed an adulteration, seeing that the compound was not inferior, but rather better than the original article, and recommended that silica cement be allowed on Government works.

"With regard to the future, it was considered that the omission from specifications of the word "Portland" where reference is made to cement would admit silica cement, and the Government would get the advantage of the lower price.'

Seeing that the Chief Engineers in the New South Wales Government Departments have, after a most careful investigation, pronounced that Silica Portland Cement is not an adulteration, and have recommended it for use by the Government, it seems to me that all the points raised—even that of chemical combination—are fully answered by this report, and by that of Professor Warren.

Should your Institute desire any further investigation, I shall have great pleasure in assisting them by giving any information in my power.

Mr. Percy Oakden (Institute of Architects).—I came here to listen and learn, and am not prepared to discuss this question; but our Institution thoroughly endorses the idea of having some central authority for testing these cements, and we will be glad to co-operate with the Institute of Engineers. To make comparative tests complete we want also the test of the neat cement finely ground to add to the others.

Mr. H. C. Mais.—It would be a good thing if we were to follow the example of the American Society of Engineers, and lay down rules for the guidance of all concerned in the matter—proper and scientific methods of testing all cements. There is an interesting discussion in the July number of the Engineering News for 1898 on the chemical action between silica trass or other form of silica. The author of the paper has gone carefully into the question, and the results of his experiments tend to show that there is a chemical combination between the silica and the free lime. This...
DISCUSSION ON PORTLAND CEMENT ADULTERATION.

question has also been taken up by the German scientists. Also in the Engineering News, April 6th, 1896, there is a very interesting article on the manufacture of what is called sand cement. Enormous quantities of it have been used on one of the largest buildings in New York with entire success.

Mr. McKenzie.—It is very probable that some such chemical action, as that described by Mr. Mais, of the Silica and free lime compound, does take place. My own experience in this matter has made me think that too much reliance is placed on these briquette tests, concerning which I have had some very anomalous results.

When I commenced the docks at Sydney, I was the first to introduce cement testing, which has been carried on efficiently ever since. With briquette tests, however, I obtained some inexplicably anomalous results. The varying and delicate conditions of the amount of water, temperature, preparing of the briquettes, the testing, machines, &c., all these affected the results. I, therefore, made some beams, 9in. x 9in. and 4ft. 6in. to 12ft. long, with fixed ends, and some beams with free ends, with spaces left at their ends; also some arches 16ft. span, and other sizes of the same sectional area as the beams, and these tests did not at all agree with the briquette tests, and as an engineer I would place much more reliance on the beam tests. When I first went to New South Wales I had no experience of bluestone dust, but after some briquette tests, which gave astonishingly good results, I allowed it to be inserted in the specifications and the contractors to use a certain proportion of it. Sir John Goode came to see me shortly afterwards, and was much surprised at seeing this dust used. As an English engineer, he thought it a very pernicious thing; but on seeing the results of the briquette tests, he said I was amply justified in using it. When in England a few months afterwards I took part in a discussion at the Institute of C. Engineers, and to the astonishment of the members, advocated the use of this material. I am not ashamed to say now that I would gladly recall the remarks made on that occasion, as from my beam tests I am now convinced that this dust is of very inferior quality and should not be used, and I have been careful to exclude it since. I have seen some cubes with this dust in tested for compression, and was told that they gave wonderfully good results. My experience with the beam and the arch, tested with a centre load, showed that the dustless material was much better. With tests of cement made under salt-water, the strength of the material was found to be only \( \frac{1}{4} \) of that made in air, under similar conditions. These were 9 months' tests.

It was agreed that the question of appointing a Committee be left in the hands of the Council.

Mr. J. T. N. Anderson in reply.—Several questions were particularly directed to the explanation of terms which are used. As these are quoted I am not responsible for them and do not propose to answer them. Re remarks as to quotations from Mr. Roberts' papers, not agreeing, I may state that the article quoted by me was given in full, without any alteration whatever. In using the word "adulteration" I was following a good precedent, viz., the London Chamber of Commerce. In an investigation on this subject by leading British experts from 1896 to 1898, nearly two
years, the result was that any extraneous matter added to the Portland cement can be counted an "adulteration." I did not so condemn all as adulterations, but quoted several of them; silica Kentish rag stone, silicate, puzzuolana, &c. Regarding Professor Warren's report on the use of silica in Portland cement, it may be that in a few years he may change his opinion, just as Mr. McKenzie stated he has done concerning the use of the bluestone dust. The advocates of the silica cement may now be strongly convinced of the utility of their article, but we have nothing to show that they may not take a similar stand to Mr. McKenzie in the future, and think they had been too sanguine as to the advantage of their process. For myself I can only rely on the records I have read and to the fact that the leading experts in England and Germany practically condemn it, which will make me diffident in the use of the silica cement. We certainly think Prof. Warren's report worthy of the closest attention. He admitted to me a day or two ago that the comparison of the silicate cement was not with cement ground to the same degree of fineness, and that some of the strength might be due to the fineness of grinding. He did not think it necessary to compare the results of the finished article as turned out by Mr. Potter, with anything from the raw article from which it had been made, from a commercial point of view. He also admitted that he did not ascertain how much free lime was present in the "Key" cement before testing; also that a good deal of the strength in the finished article might have been due to the free lime in the "Key" cement. I am anxious to see this question thrashed out to a finality, if possible, and am still continuing my experiments with some of the articles furnished by Mr. Potter, on a small job under exactly similar conditions, but it will be a long time before they will be of any practical value. It is to collect the results of such tests that I recommend a committee be appointed, so that recommendations can be made as to standard methods of testing, such as mentioned by Mr. McKenzie. If the use of the word "adulteration" has hurt anybody, I sincerely apologise, but I still maintain that any cement not pure Portland cement should be so branded, so that the public may know exactly what they are purchasing.
Notes on the adulteration of Portland cement (Paper & Discussion)

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