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PROCEEDINGS OF THE SOCIETY OF PUBLIC ANALYSTS.

SUMMER MEETING.

THIS took place on the afternoon of July 14, when about thirty members and their friends lunched together, and proceeded by steam-launch to the sewage outfall works at Barking, where a tour of inspection was made, under the guidance of Mr. W. J. Dibdin. The party afterwards returned to Greenwich, and dined at the Ship.

THE ANALYSIS OF MORTAR.

BY W. J. DIBDIN, F.I.C., AND R. GRIMWOOD, F.I.C.

(*Read at the Meeting, June 3, 1896.*)

The Legal Specification of Mortar.

IN the by-laws made by the London County Council, under Sect. 16 of the Metrop. Management and Building Acts Amendment Act, 1878, it is provided that the mortar used under that Act must be composed of freshly-burnt lime and clean sharp sand or grit, without earthy matter, in the proportions of one of lime to three of sand or grit.

In the case of cement-mortar, the cement to be used must be Portland cement, or other cement of equal quality to be approved by the district surveyor, mixed with clean sharp sand or grit, in the proportions of one of cement to four of sand or grit; also that burnt ballast or broken brick may be substituted for sand or grit, provided such material be properly mixed with lime in a mortar-mill.

In the by-laws made by the Council under Sect. 31 of the London County Council (General Powers) Act, 1890, it is provided that plastering or coarse stuff shall be composed of lime and sand, in the proportion of one of lime to three of sand, mixed with water and hair; but Portland, Keene's, Parian, Selenitic, or other cement or plaster of Paris, may also be used for plastering. The lime must be freshly-burnt lime; the sand must be clean sharp sand, free from loam or earthy matter; the hair must be good and sound, free from grease or dirt, and that one pound of hair to be used to every three cubic feet of coarse stuff. Fibrous material may be used instead of hair, and ground brick or furnace slag, each to the satisfaction of the district surveyor, may be used instead of sand; and the setting coat must be composed of lime or cement mixed with clean washed sand, or cement only.

Usual Character of Mortars.

Earthy Matter.

From these extracts from the by-laws relating to the use of building materials in the Metropolis, it will be seen that an analysis of lime-mortar or cement-mortar,

etc., can be conducted with a degree of accuracy sufficient to indicate very slight departures from the prescribed quantities of the materials used. Unfortunately analyses which have been made from time to time by us have shown distinctly that it is only under exceptional circumstances that mortars which come within these regulations are employed. To take one factor only, the earthy matter: analysis of samples of mortar, made with materials selected as coming within the definition of the by-laws, and in the proportions therein set out, shows that the earthy matter, as determined by us in the manner described hereafter, varied as follows: 1.5, 2.1, 0.14, 0.74, 0.81, 0.61, 0.64, 0.96, 0.85, and 0.70 per cent.; thus showing that the finely-divided matters which may be accidentally introduced by means of the broken brick or sand form but a very small proportion of the actual weight of the mortar. As compared with these, the following results obtained from the examination of a number of samples of mortars taken from a building in course of erection will indicate the great difference in this respect, viz.: 4.9, 3.8, 9.1, 3.4, 14.7, 13.7, 7.4, 10.4, 8.1, 12.3, per cent.

Soluble Silica.

Another factor of importance in estimating the quantity of cement in a genuine cement-mortar is that of the soluble silica. As is well known, the silica, soluble in hydrochloric acid, present in Portland cement will vary between 17 and 20 per cent.; but if the average is taken at about 18 per cent., it will form a fair basis for calculation.

If the cement-mortar is made with good Portland cement and clean, well-burnt brick or sand in the proportion of one of cement to four of the grit, there will be about $3\frac{1}{2}$ per cent. of soluble silica. In some samples of genuine cement-mortar, the soluble silica was found to be 3.25, 2.5, 3.25, and 2.25 per cent.; as against these samples of *genuine* mortar made with lime gave soluble silica equal to 0.9, 1.0, 0.6 traces, and 1.1. If we now turn to the analyses of *commercial* mortars (see Table V.) above referred to, we find that the soluble silica varied as follows: 0.9, 0.7, 0.7; thus showing a very marked difference between this factor under different circumstances.

Carbonic Acid.

A third factor is the quantity of carbonic acid. Genuine mortars made with good materials were found to contain, after the mortar had been made for some three months, carbonic acid equal to 1.02, 1.36, and 1.06 per cent. of carbonate of lime; and the cement-mortars to contain carbonic acid equal to 2.86, 2.86, 1.04, 1.87, 1.45 per cent. of carbonate of lime. Freshly prepared mortar made with good materials contained in two instances 0.3 and 0.4 per cent. carbonate of lime. Against these, the commercial mortars contained 6.42, 6.24, 7.39, 4.52, 8.9, 8.4, 8.0, and 4.5 per cent.; thus showing conclusively that this factor alone gave such marked indications of the character of the material that it would be almost impossible that a mistake should be made in estimating the character of a given sample of mortar or cement. It is to be noted that certain bricks contain carbonate of lime, and this should be determined before concluding that the mortar is made with old materials or insufficiently burnt limestone. In Table I. an instance is given of a brick containing 7.77 per cent. of carbonate of lime. The full details of these analyses are given in the tables at the end of the paper.

Relation of Weight to Volume (Lime-Mortar).

In the by-laws it is provided that the quantities are to be by volume, and not by weight; therefore the analysis, being stated by weight, must be converted into terms of volume. In order to show how this is arrived at, the following comparative analysis of a sample of mortar, specially prepared for this purpose, will make the point clear. The analyses of the lime and broken brick are given in Table I.; and, in Table II., that of the mortar made with one volume of lime and three volumes of brick. In this case the brick had some old mortar adhering to it, as would happen where old bricks are used.

TABLE I.

Sample of the Lime used in making Mortar.

Lime (CaO)	78.40 per cent.
„ carbonate... ..	3.22 „
„ sulphate	0.64 „
Soluble silica, iron oxide and alumina	12.85 „
Sand	4.80 „
Total	99.91 „

Sample of the Brick used in making Mortar.

	Per cent.
Moisture (loss at 212° Fah.)	1.27
Lime (CaO)	1.99
„ carbonate	7.77
„ sulphate	1.03
Soluble silica, iron oxide and alumina	3.60
Insoluble matter (crushed brick)... ..	78.77
Insoluble matter (fine)	1.69 { This had the appearance of having been burnt.
Total	96.12

TABLE II.

Sample of Mortar made with One Part by Measure of Lime and Three Parts Crushed Brick.

	Per cent.
Moisture, water of hydration, etc.	29.71
Lime (CaO)	12.85 = 16.06 commercial lime.
„ carbonate	4.47
„ sulphate	0.61
Crushed brick	46.03
Iron oxide and alumina	2.80
Soluble silica	1.85
Earthy matter	0.70 { This had the appearance of having been burnt.
Loss on ignition	0.98
Total	100.00
Commercial lime (containing 80 per cent. of CaO) to crushed brick, 1 to 2.29 by volume.	
„ „ „ „ „ to all other matters, 1 to 2.86 by volume.	

In this it will be seen that the earthy matter was 0·70 per cent. in the mortar, and the lime (as pure lime) 12·85 per cent., equal to 16·06 per cent. commercial lime of 80 per cent. pure CaO.

The brick (Table I.), as already mentioned, contained 7·77 per cent. of carbonate of lime. Another instance is given in Table III. of the analyses of lime and mortar made therewith and good brick. In this the carbonate of lime was only 1·97 per cent. on the mortar.

TABLE III.

Analyses of Stone-lime and Mortar made therefrom :

	Stone Lime.	Mortar. Lime 1 : Brick 3 parts by Volume.
Moisture, water of hydration, and loss	... 1·86	31·23
Lime (CaO)	... 78·63	10·89
Carb. lime	... 0·93	1·97
Sulphate of lime	... None	0·61
Iron oxide and alumina	... 4·30	3·55
Soluble silica	... 7·10	1·11
Sand and grit	... Trace	45·99
Earthy matter	... 6·20	1·37
Loss on ignition	... 0·98	3·28
	100·00	100·00

A large number of experiments on different samples of ground-up brick and various samples of lime, etc., have shown that it is a safe guide, in determining the volume of the materials from their weight, to increase the weight of lime found in the analysis by one-fourth in order to raise the lime (CaO) obtained to the relative quantity of *commercial* lime, on the assumption that the commercial lime originally contained 80 per cent. of pure oxide of calcium. The correction from weight to volume is then made by again increasing the weight by one-fourth.

The following will illustrate the method :

Equal volumes of stone-lime and of air-dry broken brick weighed as follows :

Lime		17·38 grammes per 18·5 c.c.
Brick		21·13 „ „ „

(1) To convert weight of commercial lime to equal volume of broken brick, add one quarter of the weight of lime found to itself, thus : $17·38 + 4·34 = 21·72$.

(2) By analysis, this lime contained 78·63 per cent. of real CaO, and a mortar made with this lime on analysis gave 10·89 per cent. of CaO ; therefore, to convert CaO in mortar into terms of commercial lime, for practical purposes add one quarter of the weight of CaO found to that quantity. Thus, CaO in mortar 10·89 per cent. + $2·72 = 13·61$ commercial lime.

(3) By No. 1, $13·61 + 3·4 = 17·0$ of CaO by volume.

(4) The ground-brick used in making the mortar (Table III.) contained 6 per cent. of matters soluble in weak acid ; therefore, to the weight of brick-grit actually found add 6 per cent., *i.e.*, sand and grit (brick), $45·99 (45·99 \times 0·06 = 2·76) = 48·75$.

(5) Lime to brick by volume : 17 : 49, or 1 : 3 nearly.

Relation of Weight to Volume (Cement-Mortar).

Equal volumes of washed and dried sand and of Portland cement of specific gravity 3.15 weighed 21.7 grammes and 19.3 grammes respectively. Therefore, the weight of cement found must be raised by one-eighth to equal the sand by volume.

Average Portland cement will contain from 17 to 20 per cent. of soluble silica. An average of 18 per cent. may therefore be taken, on which assumption the soluble silica formed may be calculated into terms of cement. Thus the 3.25 per cent. of soluble silica found in Sample No. 1, Table IV., would equal 18 per cent., or 19.25 per cent. corrected for volume. The sand and grit equalled 67.34 per cent.; therefore the ratio of cement to sand was 1 : 3.5. In sample No. 2 of the same table the soluble silica was 2.5 = 13.9 per cent. of cement = 15.6 by volume; the sand, etc., was 70.77 per cent.; the ratio consequently was 1 : 4.5. Sample No. 3 showed a ratio of 1 : 3.5, No. 4 of 1 : 5.6, and No. 5 of 1 : 4.8, the average being 1 : 4.4. The samples were stated to be from cement-mortars, made with 1 of cement to 4 of sand. Doubtless the difference is due to unequal mixing.

Absorption of CO₂ after Mortar is made.

The crushed brick (see Table I.), including some of the silica, iron oxide, and alumina, would amount to 48 per cent., or 51.77 per cent., including 3.74 per cent. of carbonate of lime found on analysis to be present in the brick. The commercial lime used contained 3.22 per cent. of carbonate of lime, so that the above 16.06 per cent. would contain 0.52 per cent. These together will account for 4.26 per cent. of the carbonate of lime in the quantity found in the above analysis, showing that only 0.21 per cent. of carbonate of lime was formed between the times when the mortar was made and analysed.

Analytical Methods.

Various suggestions have been made as to the best means of more or less rapidly arriving at a conclusion as to the quality of a mortar. Our own experience is against the adoption of any short cuts. However strong one's individual opinion may be, the evidence is incomplete unless the work is thoroughly done. It may be interesting here to shortly recite the outlines of the method adopted by us in these examinations.

First, the sample, having been thoroughly well broken up and mixed, is placed in a suitable bottle, from which 10 grammes are weighed in a platinum dish and placed on the water-bath for the estimation of moisture, the drying being continued in the usual way until no further loss is found. Objections may be made to the adoption of this system, in so far as it may be assumed that carbonic acid will be absorbed by the mortar during the process of drying; but a large number of experiments have shown that such absorption, if any, makes a difference so little in degree that it obviously falls within the limits of the allowable quantity in good samples of mortar. A further portion, weighing 10 grammes, is placed in a beaker, stirred up with 10 per cent. hydrochloric acid, and allowed to stand for one minute, when the fluid is decanted, and with it all the fine earthy matter held in suspension. This process is repeated until the supernatant water at the end of one minute is clear. The cleaned, washed sand and grit or broken brick is then dried and the weight ascertained. The earthy matter is filtered from the washings and

weighed; a known portion of the filtrate is taken for the estimation of the silica, iron, alumina, and lime, the latter being weighed as sulphate.

The sample taken for moisture after weighing is ignited at a dull red heat, insufficient to decompose the carbonate, and the loss on ignition so found recorded.

The ignited mortar is then treated with a small quantity of water to completely hydrate the lime, dried at 220° Fahr. and weighed. The loss on ignition is thus obtained. If found necessary, the carbonic acid may be again taken on the dried mortar as a control.

It is obvious that the analysis may be more or less complete according to the character of the information required.

The appended tables, Nos. IV. to VII., contain the results of the analyses of some typical samples analysed by us.

Table No. IV. shows the results of the analyses of five samples of cement mortar.

Table No. V. shows the results of the analyses of three samples of bad mortar.

Table No. VI. shows the results of partial analyses of fifteen samples of very bad mortar; in these the analyses were carried only far enough to show that all the samples contain excessive quantities of earthy matter and old mortar; and also that they were deficient in freshly burnt lime.

In contrast with these, Table No. VII. shows the result of the partial analyses of a sample of good mortar taken from a public building in course of erection. In all the following tables the results are stated in percentages.

TABLE IV.

Analyses of Samples of Cement-mortar.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Moisture, water of hydration, etc.	7.50	6.12	7.72	7.26	9.68
Lime (CaO)	11.80	10.87	11.97	9.20	11.24
„ carbonate	2.86	2.86	1.04	1.87	1.45
„ sulphate	0.20	0.30	0.99	0.84	0.71
Iron oxide and alumina	4.35	3.75	4.00	4.95	4.00
Soluble silica	3.25	2.50	3.25	2.00	2.25
Earthy matter	0.61	0.64	0.96	0.85	0.70
Loss of ignition	2.09	2.19	2.42	2.50	2.02
Sand and grit	67.34	70.77	67.65	70.53	67.95
Total	100.00	100.00	100.00	100.00	100.00

Ratio of Cement to Sand, etc.

Calculated on the Soluble Silica.

1 : 3.5 ... 1 : 4.5 ... 1 : 3.5 ... 1 : 5.6 ... 1 : 4.8

Calculated on the Lime.

1 : 2.7 ... 1 : 3.0 ... 1 : 2.9 ... 1 : 3.0 ... 1 : 3.0

The average total lime in cement may be taken as 60 per cent.; therefore, the lime found, including that carbonated, may be corrected to volume of cement thus :

Sample No. 1—CaO = 11·8 + 1·6 carbonated = 13·4 = 22·3 of cement ; add one-eighth for correction to volume = 25·1 vols. of cement to 67·34 of sand, or a ratio of 1 : 2·7.

It will be noticed, however, that the calculation of cement from the lime found is unsafe, as the mortar might be sophisticated with lime, and therefore not *cement-mortar*. The soluble silica is the only reliable indicator.

TABLE V.
Bad Lime-mortars.

	No. 1.	No. 2.	No. 3.
Moisture, water of hydration	17·1	21·1	15·1
Lime (CaO)	5·9	6·0	6·2
„ carbonate	8·9	8·4	8·0
„ sulphate	1·8	1·7	2·0
Sand, grit, broken brick, etc.	51·5	46·3	53·4
Iron oxide and alumina	1·6	1·4	1·5
Soluble silica	0·9	0·7	0·7
Earthy matter	7·4	10·4	8·1
Loss on ignition	4·9	4·0	5·0
Total	100·0	100·0	100·0
Commercial lime (CaO) to sand and grit, etc., by volume	1 to 5·5	1 to 4·9	1 to 5·5
„ „ to all other matters by volume	1 to 8·3	1 to 7·7	1 to 8·1

TABLE VI.
Partial Analyses of very Inferior Mortars.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Moisture	3·13	3·61	3·42	2·80	2·79	3·00	3·22
Lime (CaO)	7·48	8·72	5·68	7·71	6·11	6·00	6·73
Lime carbonate	12·61	13·18	15·45	11·36	15·79	14·66	16·34
Sand, grit, etc.	58·90	54·85	57·14	58·76	59·09	55·36	55·84
Earthy matter	8·44	7·39	8·68	7·57	7·65	9·94	9·27
Iron oxide, alumina, and soluble silica	3·75	2·90	3·00	4·50	3·30	2·60	3·20
Commercial lime (CaO) of 80% to all other matters of volume	1 to 5·0	1 to 4·2	1 to 6·4	1 to 4·8	1 to 6·1	1 to 5·9	1 to 5·3
Commercial lime (CaO) of all other matters by volume	1 to 7·6	1 to 6·4	1 to 10·2	1 to 7·4	1 to 9·5	1 to 9·7	1 to 8·5

	No. 8.	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.	No. 15.
Moisture	3·87	10·28	4·64	3·68	3·93	7·97	3·15	6·32
Lime (CaO)	9·97	9·00	7·50	12·01	7·63	10·29	8·34	5·96
Lime carbonate	11·25	11·13	15·11	8·86	15·80	8·63	16·70	20·95
Sand, grit, etc.	57·00	50·96	50·35	55·27	50·60	54·27	50·35	52·05
Earthy matter	8·10	8·78	9·30	8·63	8·78	8·70	10·41	8·23
Iron oxide, alumina, and soluble silica	4·50	3·60	3·80	4·15	4·70	3·70	4·20	3·30
Commercial lime (CaO) of 80% to sand, grit, broken brick, etc., by volume	1 to 3·6	1 to 3·6	1 to 3·9	1 to 2·9	1 to 4·1	1 to 3·3	1 to 3·8	1 to 5·5
Commercial lime (CaO) of 80% of all other matters by volume	1 to 5·5	1 to 5·6	1 to 6·9	1 to 4·4	1 to 7·2	1 to 5·0	1 to 6·7	1 to 9·4

TABLE VII.

Sample of Good Mortar taken from a Public Building in Course of Erection.

Moisture	17.84
Lime (CaO)	14.43
Lime carbonate	0.97
Sand, grit, etc.	59.15
Earthy matter	1.05
Iron oxide, alumina, and soluble silica...	3.75

Commercial lime (of 80 per cent. CaO) to sand, grit, etc., by volume, 1 to 2.6.

„ „ to all other matters (dry), 1 to 3.0.

DISCUSSION.

The PRESIDENT said that it was seldom the Society had the pleasure of Sir Charles A. Cameron's presence at their meetings, and he was sure he only echoed the sentiment of all members present in asking Sir Charles to open the discussion.

Sir CHARLES A. CAMERON said he was afraid he could not add anything to the very valuable information that had been laid before the Society by the authors of this paper. He occasionally had specimens of cement submitted to him which, although apparently having a correct composition—according to what was laid down in the text-books—nevertheless would not adhere to the surface of bricks. As a matter of fact, disputes were constantly arising in connection with cement, mortar, and concrete, and there was a very large field open to workers in the direction of obtaining information which would enable such disputes to be settled on a scientific basis.

In Ireland he did not think it was customary to use ground bricks in place of sand to such an extent as appeared to be the case in England.

He believed the authors had mentioned the case of a mortar in which the proportion of lime to sand was as low as 1 : 9. He had himself once examined a sample containing almost as much sand, viz., 86 per cent.

Mr. ALLEN said that one problem which he had been called upon to solve was how much road-sweepings a particular sample of mortar contained, and what was the proportion of "clean, sharp sand." Road-sweepings seemed to be a very indefinite article, and he thought that if the authors could indicate how to ascertain the quantity present, it would be of great service to others as well as to himself.

It seemed to him, if he had understood that part of the paper correctly, that it was a little questionable whether it was fair to deduce the amount of cement in a cement mortar from the amount of soluble silica. This surely must be a very variable quantity.

There was no doubt that the Society was very much indebted to anyone bringing forward figures on such a difficult subject, as they would at least afford something like a basis for further investigations.

Mr. BODMER remarked that where broken bricks were used in substitution for sand, the by-laws, although providing for the proper grinding up of the bricks, did not specify distinctly that they should be well burnt. Badly-burnt bricks might be

used, and in that case the amount of earthy matter present would be considerable. He thought it desirable that either the use of bricks should be altogether prohibited, or that some more definite limit should be laid down as to their employment.

The proportion of quicklime contained in the lime used was also a matter upon which disputes often arose, but it was hardly possible to suggest any definite standard, for in some kinds of lime which were really very good for mortar-making the percentage of actual quicklime was comparatively low.

Mr. JOHN HUGHES said that the by-laws of the London County Council in regard to the composition of mortar were far too vague. Nothing is mentioned respecting the quality of the lime, except that it should be "freshly burnt," its richness in CaO and soluble silica is entirely omitted, as well as its weight per cubic foot, which may vary considerably. The sand must be sharp and clean, "without earthy matter," but there is no definition of what constitutes earthy matter.

In making mortar it is usual to specify quantities by measure rather than by weight, consequently the respective amounts of lime and sand, or substitutes for sand, must vary in proportion to their gravity. Therefore mortar, though made according to the strict reading of the by-laws, may contain as little as 10 parts of lime (CaO) by weight in every 100 parts of the perfectly dry mortar. Thus, taking a cubic foot of gray lime containing 80 per cent. CaO, and weighing (according to Hurst's "Architectural Hand-book") 44 lbs., and 3 cubic feet of clean sand weighing 100 lbs. per cubic foot, we have a mixture in the dry state which contains only 10·23 CaO in every 100 parts by weight. On the other hand, if a substitute for sand, such as broken brick, having a less gravity, be used, the percentage of CaO in the mortar would be increased.

Some years ago he devoted considerable time to the examination of old mortar obtained from numerous old abbeys and castles, and the results of the analyses were published in *The Builder* during the years 1892 and 1893. These analyses corroborated Mr. Bodmer's observation, that the percentage of actual quicklime was really no criterion of the quality of the mortar. The lime rapidly becomes converted into carbonate, especially in the smoky atmosphere of towns, and in the case of good building-lime the CaO is associated with soluble silica in the same form as it exists in Portland cement, so that the total lime in its various combinations, rather than the caustic lime alone, should be considered before condemning a mortar.

He would mention that, according to his researches, the average amount of caustic lime in ancient mortar did not exceed 0·5 per cent. Further, within certain limits the actual percentage of total lime was no reliable indication of the quality of the mortar. Thus, the mortar from Rochester Castle (of which only the keep remains), contains as much as 28·67 CaO, while that from Tintern Abbey, in Monmouthshire (which was remarkable from the fact that the four gable ends were still standing), contains only 18·84 CaO per cent. The mortar from the leaning tower of Caerphilly Castle, in Glamorganshire, contains as little as 13·49, associated, however, with 9·85 of soluble silica.

He could not agree with Mr. Dibdin in calculating the probable amount of cement present in a mortar from the figures for soluble silica. Limestones contain varying quantities of gelatinous or hydrated silica, which after calcination forms a natural

cement, and it is to the presence of this cement that the durability of ancient mortar largely depends.

Greystone lime contains 9 per cent. of this soluble silica; Aberthaw lime contains as much as 15, while the best Portland cement contains not more than from 20 to 22; consequently limestones are suitable for making mortar in proportion to their richness in this so-called soluble silica.

In conclusion he would say that some of the best and most durable of these old mortars contained as much as 4 to 5 per cent. of oxide of iron and alumina.

Mr. B. E. R. NEWLANDS said he presumed this paper was intended to refer only to cases occurring in those districts in which the by-laws referred to had been adopted; but there were districts where the by-laws had not been adopted, and a still greater number where they had not been enforced.

In Manchester, and other large towns, mortar was manufactured as an industry by the Corporation, and this mortar was generally made with the cinders and clinkers from the Corporation's destructors. This mortar—which was sold to the general public by the Authorities—would yield very different analytical results from the mortars dealt with in the paper.

Mortar made with furnace clinker was also used to a considerable extent in the Metropolitan area, most frequently, perhaps, in the case of buildings erected by work's proprietors, whose furnaces supplied the clinker; and this mortar, although of a very high standard as far as hardness and setting power were concerned, would not satisfy the tests given in the paper.

Dr. M. A. ADAMS said, that from the local experience he had gained in the midst of the cement district, where there was an abundance of materials for making lime from both white and gray chalk, he could confirm the remark made by Mr. Hughes, that alumina was often a somewhat important constituent of commercial lime.

It was customary in his neighbourhood to look upon the lime made from gray chalk (which contained a large proportion of silicates and 3 or 4 per cent. of alumina) as almost equal in quality to Portland cement. Certainly, it was a fact well-known to all practical builders in the district, that they could use far less of such lime than was required if they employed lime made from the upper layers of the chalk, which was nearly pure calcium carbonate.

Mr. DIBDIN said that he and his colleague congratulated themselves on having raised such an interesting discussion. He sincerely hoped that the paper would be the forerunner of several others on the same and kindred subjects.

Mr. Newlands was perfectly correct in his remarks as to the scope of the paper. The question had been dealt with entirely as under the by-laws relating to London. As a matter of fact, these by-laws contained the only statement or definition of mortar having legal weight of which he was aware. If they were wrong, it was without doubt desirable that they should be amended as soon as possible, but as they existed, a considerable amount of work had been done under them, and it was just as well that they should be thoroughly understood.

The subject, taken in its industrial aspect and as ranging over the ground of all kinds of mortar, both ancient and modern, was of course a very large one, and to treat it exhaustively would require a great deal more than the hour or so available at one

of the Society's meetings, and he and his colleague looked upon this paper rather as an index for pointing out that a large amount of valuable work could be done by those who took up the subject in detail.

With regard to the adulteration of mortar, it was seldom that a sample was found which really complied with the specification contained in the by-laws, a common adulterant, in London at any rate, being dust-bin refuse.

Mr. Allen had asked for information as to the best mode of estimating road-sweepings. In many cases road-sweepings consisted largely of sharp sand mixed with organic matter. The only way to deal with them was to separate the organic from the mineral matter and estimate them in the ordinary way. Of course quite a cursory observation would indicate whether the organic matter was in the form of horse-dung or the like.

With regard to Mr. Bodmer's remarks, he did not think much difficulty would be found in differentiating between properly burnt earthy matter and clay that had merely been warmed up. The by-laws appeared to be perfectly definite in their references to the ballast or bricks that might be used in making mortar. They stated that burnt ballast or broken brick might be substituted for sand or grit. Now, earthy matter that had merely been warmed could not properly be described as "burnt ballast," and unless a brick had been fired—and properly fired—it could not, according to his (Mr. Dibdin's) idea, be regarded as coming within the meaning of the term "brick," any more than partially heated chalk could be regarded as lime.

Mr. Hughes had remarked that the amount of lime present was no criterion of the quality of a mortar, and had referred to the mortar of Tintern Abbey as containing 16 per cent. of lime. Now, assuming 16 per cent. of caustic lime to be equivalent to 20 per cent. of commercial lime, and adding one-fourth to correct for the difference in specific gravity between the lime and sand, the volumetric proportion of lime to sand worked out in this case to 1:3, or exactly the same as laid down in the by-laws.

With regard to clinker-mortars, these were not comprised in the present paper, which dealt only with good brick, grit, or clean, sharp sand, and lime or Portland cement. In the case of mortar made with other materials, other data must be obtained as a basis of calculation.