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INFLUENCE OF ALUMINIUM ON MORTAR STRENGTH

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The writers have for some years been analyzing the variation in the strength developed by mortars made from native sands and common commercial cements. This variation in actual test condition lies between 100 and 600 pounds per square inch in tension and 2500 to 9000 pounds in compression. Among the constituents shown to account for part of this variation in strength is the amount of native iron* found in the sand, a correlation of 0.38 ± 0.03 existing between the content of this native iron and strength. In this paper another sand constituent, aluminium, is studied and its relation to the strength developed by the mortar containing it.

Table 1 shows that there is a consistent increase in the tensile strength developed by mortar on the 28-day test as the content of aluminium found in the native sand increases. This increase amounts to more than 100 pounds over the whole range of variation in the native sands' aluminium content.

TABLE 1

AVERAGE 28-DAY TENSILE STRENGTH OF MORTARS IN RELATION TO THE VARIATION IN ALUMINIUM CONTENT OF THE NATIVE SANDS

ALUMINIUM CONTENT, %	NUMBER OF SANDS	MEAN MORTAR STRENGTH, 1: 3 MIX
0.25–0.50	17	298
0.50–0.75	28	339
0.75–1.00	15	333
1.00–1.25	17	379
1.25–1.50	15	385
1.50–1.75	11	399
1.75–3.75	14	418

The amount of variation which exists for any one class and the degree of correlation which exists between the aluminium content and strength may be seen in tables 2 and 3. Table 2 represents the 28-day tension results and table 3 the 7-day tension results.

Tables 2 and 3 show that as the amount of aluminium in the sand increases the breaking strength increases. The straight lines on the tables show the general trend in the relationship. The correlation coefficients for aluminium and strength are: 7-day, 0.36 ± 0.05, and 28-day, 0.41 ± 0.05. The correlation is, therefore, significant. It will be further noticed that within any given class of aluminium per cents, breaking strengths still have a fairly wide variation. Thus while the aluminium content significantly affects strength it is clearly not the only limiting variable. In fact, we already know another chemical constituent which also plays a part, namely, iron. The part which this iron content plays in relation to the aluminium content will be analyzed in the succeeding paper.

% Aluminium

$r = 0.412 \pm 0.052$

28-Day Tension	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	Totals
160		1																1
180																		
200		1		1														2
220			1															1
240			4	3		2												9
260		5	1		2													8
280		3	4	2			1		1									11
300		1	5	2	2	1												11
320		1	1		2	1	2	1	1									9
340		3	2		4		2		1						1			13
360		1	2	2		1												6
380				1	3	2			1									7
400		1	4	2		3	1	1										12
420			1	1		2	2	1	2									9
440				1		2	1											4
460			2		1													3
480					1	1	1	1										4
500			1		1													2
520							1	1						1				3
540																		
560									1									1
580					1													1
Totals		17	28	15	17	15	11	5	7					1	1			117

TABLE NO. 2

Relation between aluminium content and 28-day strength.

% Aluminium

$r = 0.362 \pm 0.054$

7-Day Tension	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	Totals
100																	
120		1															1
140																	
160																	
180		1	2	2													5
200		2	4	2	1	1			1								11
220		6	4	2	3	3											18
240		3	2	2	3	1	2										13
260			2	1	3	1	2		1						1		11
280		1	2	2				1									6
300		2	2	1	3	3	3		1								15
320		1	5	1		3	1	1	2								14
340			3	1	1	1	1	1	2								10
360			1	1	1	1	1	1									6
380							1	1									2
400			1		2	1											4
420														1			1
Totals		17	28	15	17	15	11	5	7					1	1		117

TABLE NO. 3

Relation between aluminium content and 7-day tensile strength.

The amount of variation in the strength for which the variation in aluminium content is responsible is shown by the correlation coefficients to be about 8% of the total variation in mortar strength. The fact that the correlation coefficients are approximately the same for the 7-day and 28-day tests shows that the aluminium content continues to be equally effective in raising or lowering the tensile strength throughout this duration of life of the mortar.

Aluminium content does not have the same marked effect on the compression strength of these mortars. In fact, the correlation between aluminium content and compression strength for these 117 sands is only 0.115 ± 0.062, scarcely significant. Thus again we have called to our attention a fact emphasized elsewhere in our papers, i.e., that the tensile test for mortar strength measures different attributes of the mortar strength than the compression strength.

Summary.—The evidence presented clearly indicates the importance of another chemical element of native sand in affecting mortar strength. Aluminium in these native sands affects 7-day and 28-day tensile strength in such a manner that the larger its amount the greater is the tensile strength. Aluminium does not materially affect the strength of the test cylinders in compression.

* "Influence of Iron Content on Mortar Strength," by H. Walter Leavitt and John W. Gowen, *Proc. Nat. Acad. Sci.*, **13**, No. 4, pp. 263–265, April, 1927.

ON THE JOINT INFLUENCE OF IRON AND ALUMINIUM IN NATIVE SANDS ON MORTAR STRENGTH

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In the preceding papers the influence of iron and aluminium content of native sands on the strength of these sands in mortar has been analyzed separately. In this paper the joint influence of these elements on strength will be shown in its true perspective. Table 1 shows the relation of the iron content to the aluminium content of these 117 sands. Measured in terms of correlation this relation is 0.384 ± 0.054. The effect of the iron content on mortar strength has been indicated elsewhere[1] to be 0.377 ± 0.034 for the 28-day period. A rapid digestion technique was used for the determination of the iron in the 284 sands involved. For the 117 sands here utilized the relation was 0.323 ± 0.055 where the iron content was determined by a digestion test of 5 hours in hot HCl. The results are essentially the same. The aluminium content in relation to strength is shown in the preceding paper to be 0.412 ± 0.052.

From these three possible correlations the influence of any one of the elements on another with the third constant may be found. Thus the correlation for aluminium and strength with the amount of iron constant is 0.330 ± 0.055, for aluminium and iron for strength constant is 0.291 ± 0.051, and for iron and strength for aluminium constant is 0.196 ± 0.058.