The total downward shear deflection of the amidship frame and the total rotation of the end frames in the ship are the sum of the respective deflections of all the frame sections on one side of amidships.

[1] A more detailed account will probably appear in *Trans. Institution of Naval Architects*, London, 1927.
[2] *Proc. Nat. Acad. Sci.*, **12**, No. 6, June, 1926.

INFLUENCE OF IRON CONTENT ON MORTAR STRENGTH

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Those most intimately concerned with the use of concrete for bridges, highways or other work freely admit that the most important problem is the variation in mortar strength developed by mixtures of different kinds of sands. This variation in actual test conditions lies between 100 and 600 pounds per square inch in the 28-day tension test. In the attempt to find the cause for some of this variation and, therefore, its control the authors have been investigating several different elements of sand and mortar structure, chemical content, etc., which might lead to or influence mortar strength. One of the elements which has come under consideration is that of the iron found in the native sand. This element is usually present as an oxide, due to the weathering or disintegration of some of the component materials found in the sand aggregate. The iron may be present as a disintegration of several of the common component minerals or due to the leaching of ferruginous material from other sources into the sand. It should be noticed that the makeup of the sand aggregate with regard to iron is quite different under these two methods of allocating the iron in the aggregate. It is, however, difficult to differentiate between iron derived from one source as contrasted with that derived from the other. The material will, therefore, be treated as though the iron content came from the same source.

After some experiment a delicate test for determining the presence and the approximate amount of iron was developed in this laboratory.[1] Through the use of this test it is possible to arrange sands on the basis of the amount of iron present in them and to contrast this with the strength developed by these sands in the ordinary mortar test. While the amount of the iron detected in this manner is extremely small in total amount the data show that its effect on strength is significant for the 284 native Maine sands involved. The percentages of the sand's iron content are arranged on a geometric basis.

Table 1 shows that there is a slight but consistent increase in the strength developed by mortars on the 28-day test as the content of the iron found in the native sand increases. This increase amounts to about 100 pounds over the whole range, an increase well worthy of consideration.

TABLE 1

AVERAGE 28-DAY TENSILE STRENGTH OF MORTARS IN RELATION TO THE IRON CONTENT OF THE SAND

RELATIVE IRON CONTENT	NUMBER OF SANDS	MEAN MORTAR STRENGTH (1:3 MIX)
Trace	18	282
0.00022%	55	284
0.00044%	81	306
0.00088%	65	298
0.00176%	28	322
0.00352%	11	332
0.00704%	26	388

Attention may now be turned to the variations in the strength for any given iron class. These variations are shown in the correlation tables 2 and 3. Table 2 for 28-day tensile strength and table 3 for 7-day tensile strength.

COLOR TEST FOR IRON-PLATE NO.

28-DAY TENSION—AVE. OF 3 BRIQUETTES

	0	0+	1	1+	2	2+	3	3+	4	4+	5	5+	6	6+	7	TOTALS
140							1									1
160		1		2	1				1							5
180			1			1	2	2								6
200		5		2		3	1	2		1	1					15
220			2	6	2	7	2	2			1					22
240			3	5	3	5	5	7	1	1						30
260		3	2	6		5	1	4	3	1	1					26
280		2	1	5	2	6		3	1	1				3		24
300			4	1	2	11	2	4	4		2		1			31
320		5	1	3	4	4	4	5	1	2				1		30
340	1		1	5		10	4	3	2	2			1	2		31
360			1	1	2	1	1	2	2	1	3		1	3		18
380			1	1		9	2		1		1		1	4		20
400				1		3	3					2	2			11
420								1		1				1		3
440		1						1	1				2			5
460								1						1		2
480		r = 0.377 ± 0.034								1			1	1		3
500														1		1
520																
TOTALS	1	17	17	38	16	65	28	37	17	11	9	2	9	17		284

TABLE 2

Correlation Table showing the relation between iron content and 28-day tensile strength.

COLOR TEST FOR IRON-PLATE NO.

7-DAY TENSION—AVE. OF 3 BRIQUETTES

	0	0+	1	1+	2	2+	3	3+	4	4+	5	5+	6	6+	7	TOTALS
100							1									1
120		1			1		1	1								4
140		1	1	2												4
160				1		2		1								4
180		2		4	1	1	1		1				1		1	12
200		4	6	4	4	9	5	7	2	1					1	43
220		4	7	13	4	9	5	12	4	2				1		61
240	1	5	3	7	4	14	7	5	1	2	3			2		54
260		2	1	5	1	6	6	5	2	1	2	1	1	1	1	35
280		2	1	4	4	11	2	3	2	1	1	1	3	1	1	37
300		1	2	2		5		1	1	2	1	1	2	1		19
320			1			1			1	1	1	1	1	1		8
340				1		2		1			1		1	3	2	11
360							1							1		2
380								1		1				1		3
400		r = 0.371 ± 0.034														
420													1			1
440																
TOTALS	1	22	22	43	19	60	29	37	14	11	9	4	10	12	6	299

TABLE 3

Correlation Table showing the relation between iron content and 7-day tensile strength.

It will be noticed from tables 2 and 3 that the tensile strength increases as the iron content of the sand increases. This increase when the iron is plotted in the geometric manner is linear. The correlation coefficients for these relationships are 28-day tensile strength 0.377 ± 0.034, 7-day tensile strength 0.371 ± 0.034. The correlations are, therefore, significant. There is, as will be noticed, a considerable range of breaking strength for any given iron content class. Thus while the iron content significantly increases the strength, it does not account for all of the variability in tensile strength by any manner of means. The amount of the variation which is controlled by limiting the iron content to one given class is equivalent to about 7% of the total variation. The iron content of a sand, therefore, is an important consideration in bringing about a control of the variation in the sand strength but is by no means the only cause of this variation.

The fact that the correlation coefficients are the same for the 7-day and 28-day periods indicates that the effect of iron on a mortar strength is essentially the same for each period.

In an earlier paper[2] the authors showed that the tension test and the compression test measured different attributes of the strength-giving properties of mortar mixtures. Comparison of the iron content in the sand shows that apparently this element is one of the properties of the sand measured by the tension test which does not influence the compressive strength of the mortar. Thus while the correlation between iron content and 28-day tensile strength is 0.377 ± 0.034, a very significant correlation, that for compressive strength is 0.084 ± 0.040, not a significant correlation. The important fact coming from this relationship is that iron content is important to tensile strength and unimportant to compressive strength. This further substantiates our earlier conclusion that both the tensile and compressive strength tests should be performed on the mortar as they show different properties of the sand.

Summary.—The evidence presented indicate that the chemical constituent of the sand, iron, is an important factor in influencing the tensile strength of mortar; the larger the amount of iron the greater the average tensile strength.

[1] This test utilizes ammonium thiocyanate as the reagent. A description will appear elsewhere.

[2] "The Significance of the Common Test Method for Determining the Strength of Mortars," by John W. Gowen and H. Walter Leavitt, *Proc. Amer. Soc. Testing Materials*, **25**, Part II, 218–227, 1925.