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AN INVESTIGATION INTO THE CONCRETE-MAKING PROPERTIES OF MILL TAILING SAND FROM SIGMA MINES (QUEBEC) LTD., BOURLAMAQUE, QUE.

by

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CONCRETE-MAKING PROPERTIES OF MILL TAILING SAND

SIGMA MINES (QUEBEC) LTD., BOURLAMAQUE, QUE.

A sample of 295 lbs mill tailings was received here for investigation on concrete-making properties for use in the mine. These tailings are separated by cyclone at the mill and used for backfill purposes underground.

The mine management inquired on the possibility of making concrete mill-holes and manways in the stopes with this material. The concrete should have sufficient abrasive resistance to withstand the passage of 5000 to 6000 tons of ore through a mill hole.

It is desired to make the maximum possible use of the tailings in the concrete. The object of the investigation is therefore to proportion a concrete to meet the above requirements which will contain a minimum of additional coarse aggregate.

1. Physical properties of Sigma Mines mill tailings.

A. Sieve analysis.

Sieve No.	% by fractions retained	Cum. % Passing
16	0.0	100.0
30	1.0	99.0
50	7.0	92.0
100	35.5	56.5
200	35.0	21.5
-200	21.5	

Fineness modulus of sand - 0.52

CONCRETE-making

B. Bulk Specific Gravity on saturated surface-dry basis, as per ASTM C127-42

G = 2.61

C. Absorption of sand, per cent, as per ASTM C127-42

A = 1.2%

D. Unit weight of sand, dry rodded as per ASTM C29-55T

Wt = 101.0 lb/cu. ft.

2. Petrographic analysis show the following compositions of the sand:

Feldspar	42%
Quartz	33%
Carbonates	13%
Hornblende, dark	12%
	100%

3. Comparison of mortar-making properties.

To evaluate the mortar-making properties of Sigma Mines (SM) mill tailings, test mixes were made according to the ASTM Standard Method C87-52. For comparison purposes the fine sand under test was compared in mortar with graded standard Ottawa sand, manufactured limestone sand, and natural sand. In this test the water-cement ratio was maintained at 0.60, and the consistency of mortar was held constant at a flow of 100±5% on a standard flow table for all mixes. The results are compiled in Table No. 1.

TABLE 1 - Evaluation of Mortar-making Properties of Different Types of Sand.

Test Nos:	97	98	99	100
Type of sand:	Ott. graded std. sand	Manufactured limest. sand	Natural sand N.Hayley,Ltd.	Sigma Mines Mill Tailings
Sieve No.	% Retained on Sieves			
4		0.0	0.0	
8		10.0	10.0	
16	0.0	32.5	32.5	0.0
30	46.0	57.5	57.5	1.0
50	84.0	80.0	80.0	8.0
100	100.0	94.0	94.0	43.5
200		100.0	100.0	78.5
Fin. Mod.:	2.30	2.74	2.74	0.52
W/C ratio:	0.60	0.60	0.60	0.60
Flow %:	100+4.7	100-3.1	100+1.6	100+3.2
Cem. fact.: (bag/cu.yd.)	9.6	10.5	9.7	14.1
Physical properties of hardened mortars.				
Density: (lbs/c.ft.)	141.0	144.8	142.2	133.5
Absorption %	3.3	4.4	4.5	6.2
28-d. Compr. Strength-psi.: (2x2x2 cubes)	4170	7700	5615	5775

Comparing natural, well-graded sand with the mill tailings, we can see that the latter need 50% more cement per cu. yd. to obtain same strength of mortar as produced by the natural sand.

4. Improvement of sand grading.

The mill tailings have a high amount of material passing No. 200 mesh sieve. Efforts were made to improve the grading of the sand by reduction of fines. The tailings were screened, separated into fractions and reblended in 3 gradings with decreased amount of fines.

To evaluate the mortar-making properties of the improved samples of sand, another series of mortar mixes with same w/c ratio and same consistency were prepared. Results of these tests are compiled in Table No. 2.

Test results show, that reduced amount of fines in the tailings increase the compressive strength of the mortar. Improved tailings with only 5% left of material passing 200 mesh sieve (third improved grading in Table 2) have increased strength by 13%, saving at the same time 1.3 bags of cement per cu. yd. of mortar.

5. Proportioning of concrete mixes.

Mortar tests have shown that a plain cement mortar with fine mill tailings would require very rich mixes, using over 14 bags of cement per cu. yard of mortar.

TABLE 2 - Effect of Improved grading on Mortar Strength Properties

Test Nos:	101	102	103	104	105
Type of sand:	Ott. graded std. sand	Sigma Mines Mill Tailings	Improved 1 Mill Tailings	Improved 2 Mill Tailings	Improved 3 Mill Tailings
Sieve No.	% Retained on Sieves				
100	100.0	43.5	60	70	80
200		78.5	82	89	95
	% Passing No. 200 Mesh Sieve				
-200	nil	21.5	18	11	5
W/C ratio:	0.60	0.60	0.60	0.60	0.60
Flow % :	100-1.6	100+0.8	100+3.1	100-3.1	100-1.6
Cem.factor: (bag/cu.yd.)	9.6	14.4	13.6	13.28	13.1
Compressive Strength of 2-in. Mortar Cubes					
3-d. psi.:	1775	2320	2350	2520	2625
7-d. psi.:	2604	3219	3467	3589	3638

Addition of coarse aggregate to the mortar can improve the product and save cement. For our trial mixes of concrete, 1/2-inch gravelstone was used, graded as follows:

Fraction -3/4" + 1/2" - 10%
-1/2" + 3/8" - 35%
-3/8" + No. 4 - 55% by weight

To find the optimum proportion of coarse to fine aggregates, three trial mixes were prepared, using 30, 40 and 50% tailings of the total amount of aggregate, with 6 bags of cement per cu. yd. and 4 inches slump. From each batch 3 cylinders 6 x 12 in. were molded for 7 and 28-day tests. Mix proportions and test results are shown in Table No. 3. Results of these proportioning studies indicate that maximum amount of tailings to be used in 6 bag concrete mixes is 30% of the total aggregates. Such mix will produce good workable concrete with a 28-day strength over 3000 psi.

6. After the best sand-gravel ratio was established, comparison mixes were designed with mill tailings and natural, well-graded sand. In both mixes 6 bags of cement were used per cu. yard of concrete and both were of the same consistency - 3½ inch slump. From each batch 3 standard 6 x 12 in. and one 4 x 8 in. cylinders were molded for 7 and 28-day compressive strength and abrasion tests.

Batch proportions and test results are shown in Table No. 4.

TABLE 3 - Concrete mixes with Sigma Mines mill tailings as fine aggregates

Test No.	PLASTIC CONCRETE MIX								HARDENED CONCRETE			Notes
	Mix proportions per 1 cu.yd.					Unit Weight lbs/c.ft.	Slp in.	Air %	Density (SSD) lbs/c.ft.	Compressive Strength		
	Cement lbs	Sand lbs	Gravel lbs	Water lbs	W/C ratio					7-d. psi	28-d. psi	
106	528 6 bg.	924 30%	2118 70%	380	0.72	146.0	4	2.0	149.0	2440	3650	Good workability
107	524	1167 40%	1712 60%	427	0.81	142.0	4	2.5	144.5	1780	2740	Oversanded mix
108	525	1361 50%	1361 50%	473	0.90	137.7	4	3.0	141.1	1310	2102	Very oversanded. Sticky mix.

TABLE 4 - Concrete mix (6 bg. cem) with natural sand vs. mill tailings

110	526	1309	1888	302	0.57	149.1	3½	2.0	151.5	2880	Absorpt. % 6.5	Excellent concrete
111	525	911	2129	370	0.71	146.2	3½	1.9	149.6	2370	8.0	Good concrete

Note: Table 1.

(a) Sand used in test Nos. 106, 107 and 108 is Sigma Mines mill tailings, as received.
(b) Gravel used is the 1/2-inch natural gravelstone.

Table 4.

(a) Sand used in test No. 110 is natural, well-graded sand, and in test No. 111 - Sigma Mines mill tailings, as received.
(b) Gravel used is the same 1/2-inch natural gravelstone.

7. To obtain some information on the abrasion resistance of concrete made with mill tailings compared with natural sand concrete, tests were conducted on concrete samples Nos. 110 and 111. Eight slices of each type of concrete were subjected to high velocity air jet fed by standard silica sand. Loss of weight indicates the abrasion effect on the concrete specimens.

The average abrasion loss on concrete made with mill tailings No. 111 was about 20% higher than the loss on concrete made with natural sand, as represented by sample No. 110.

Conclusions.

1. To produce 3000 psi concrete with mill tailings alone will require at least 12 bags of cementper cu. yd. of concrete.

2. Concrete mix with 30% mill tailings and 70% 1/2 in. gravelstone will cut down the cement requirement in half, using 6 bags of cement for 3000 psi concrete mix.

3. Improvement could be obtained by eliminating a portion of fine material in the mill tailings, cutting down the amount of -200 mesh size from 25 to 5%.

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