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R.663 Regeneration of moulding sand

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Messrs Johns Phoenix submitted samples of spent moulding sand and requested that a method be found to clean and regenerate the moulding sand. At present, fresh moulding sand is mixed with approximately 5% sodium silicate and subjected to a carbon dioxide atmosphere prior to casting. The spent moulding sand is then dumped.

SAMPLES

Fresh moulding sand.

Sizing analysis of the fresh moulding sand is given below.

Fraction (µm)	*% Mass*	*Cumulative % Mass*
+600	0.1	0.1
+300	0.6	0.7
+250	0.7	1.4
+212	4.5	5.9
+180	47.9	53.8
+150	15.4	69.2
+125	24.2	93.4
+106	3.3	96.7
+ 75	2.7	99.4
+ 38	0.5	99.9
- 38	0.1	100.0
Head	100.0	

Chemical analysis of the fresh sand showed that it contained 0.02% of sodium.

Spent moulding sand.

This sample consisted of large lumps of hardened sand and very minor amounts of metal and iron oxide particles mixed with silica. The total sample weight was approximately 268 kg. Chemical analysis gave the following results

Sodium, as sodium silicate	Nil
Sodium, as sodium carbonate	0.57%
Sodium carbonate	1.31%

Spent moulding sand washed in a concrete mixer (by Johns Phoenix) for 5 minutes.

The sizing analysis of the dried product was as follows

Fraction	*% Mass*	*Cumulative % Mass*
+4.75 mm	4.5	4.5
+2.36 mm	1.4	5.9
+1.18 mm	1.2	7.1
+600 µm	0.5	7.6
+300 µm	3.6	11.2
+250 µm	3.9	15.1

Fraction	*% Mass*	*Cumulative % Mass*
+212 µm	9.8	24.9
+180 µm	29.5	54.4
+150 µm	11.1	65.5
+125 µm	27.1	92.6
+106 µm	4.8	97.4
+75 µm	1.9	99.3
+38 µm	0.5	99.8
-38 µm	0.2	100.0
Head	100.0	

Chemical analysis of the sand gave the following result.

Sodium, as sodium carbonate	0.24%
Sodium carbonate	0.55%

Spent moulding sand washed for five minutes in a concrete mixer and screened (riddled) at 1 inch (by Johns Phoenix).

A sizing analysis of the sand gave the following result.

Fraction (µm)	*% Mass*	*Cumulative % Mass*
+600	0.4	0.4
+300	4.1	4.5
+250	4.4	8.9
+212	9.6	18.5
+180	28.9	47.4
+150	15.0	62.4
+125	30.1	92.5
+106	4.9	97.4
+75	2.0	99.4
+38	0.4	99.8
-38	0.2	100.0
Head	100.0	

Chemical analysis of the sand gave the following results.

Sodium, as sodium carbonate	0.18%
Sodium, as sodium silicate	Nil
Sodium carbonate	0.42%

Spent moulding sand washed for five minutes in a concrete mixer and then washed for a further 5 minutes (by Johns Phoenix).

Sizing analysis gave the following result.

Fraction	*% Mass*	*Cumulative % Mass*
+19.05 mm	3.2	3.2
+9.53 mm	0.2	3.4
+4.75 mm	2.0	5.4
+2.36 mm	2.3	7.7
+1.18 mm	1.2	8.9
+600 µm	0.4	9.3
+300 µm	2.2	11.5

Fraction	*% Mass*	*Cumulative % Mass*
+250 µm	2.5	14.0
+212 µm	5.7	19.7
+180 µm	34.7	54.4
+150 µm	21.5	75.9
+125 µm	14.9	90.8
+106 µm	6.3	97.1
+75 µm	2.2	99.3
+38 µm	0.5	99.8
-38 µm	0.2	100.0
Head	100.0	

Chemical analysis of the sand gave the following result.

Sodium, as sodium carbonate	0.27%
Sodium carbonate	0.62%

METHOD AND RESULTS

Jaw Crushing

The spent moulding sand was crushed in a 5 inch (125 mm) x 5 inch Denver jaw crusher, and then mixed. A sizing analysis of the mixed crusher discharge was as follows:

Fraction	*% Mass*	*Cumulative % Mass*
+19.05 mm	2.9	2.9
+9.53 mm	10.6	13.5
+4.75 mm	11.4	24.9
+2.36 mm	5.8	30.7
+1.18 mm	2.2	32.9
+600 µm	1.0	33.9
+300 µm	3.2	37.1
+250 µm	3.3	40.4
+212 µm	6.6	47.0
+180 µm	26.9	73.9
+150 µm	5.1	79.0
+125 µm	16.8	95.8
+106 µm	2.1	97.9
+76 µm	1.4	99.3
+38 µm	0.5	99.8
-38 µm	0.2	100.0
Head	100.0	

Autogenous ball mill grinding - N1

Portion of the jaw crusher discharge was autogenously ground in a 12-inch (305 mm) x 36-inch (914 mm) ball mill in closed circuit with a 600 µm Sweco vibrating screen. Water added during grinding was removed by decantation after the -600 µm material had settled. The ball mill was operating at approximately 60 rpm.

Fraction	% Mass	% Na	% Na_2CO_3	Na_2CO_3 Units	% Na_2CO_3 Distribution
+600 μm	1.1	0.25	0.58	0.638	0.5
-600 μm	98.9	0.25	0.58	57.368	43.8
Jaw crusher discharge	100.0	0.57	1.31	131.000	100.0

This method resulted in the removal of 55.7% of the original sodium carbonate present. The material lost as +600 μm constituted 1.1% of the mass of the sample.

A sizing analysis of the -600 μm sand produced gave the following result.

Fraction	% Mass	Cumulative % Mass
-600 μm +300 μm	1.2	1.2
+260	1.4	2.6
+212	3.7	6.3
+180	20.7	27.0
+150	12.2	39.2
+125	48.4	87.6
+106	8.1	95.7
+75	3.0	98.7
+38	0.8	99.5
-38	0.5	100.0
Head	100.0	

Filtration tests

One kilogram samples of -600 μm sand (a product of autogenous grinding) were agitated with one or two litres of fresh water prior to filtration in a 9.5-inch (241 mm) diameter Denver laboratory filter using a coarse silk cloth as filter cloth. Filtration rates are unavailable as the rate of filtration was very slow due to the presence of some slime material. Each sample was washed with a further litre of fresh water during the filtration process.

After filtration, the sand was found to contain 0.07% sodium (using one litre of water for agitation) and 0.06% sodium (using two litres of water).

Of the sodium carbonate present in the -600 μm sand 74% was removed by filtration. Therefore, 88% of the sodium carbonate in the original spent sand could be removed by autogenous grinding followed by filtration.

Fraction	% Mass	% Na	% Na_2CO_3	% Na_2CO_3 Distn
-600 μm filtered sand	98.9	0.065	0.15	11.3
-600 μm sand	98.9	0.25	0.58	43.8
Jaw crusher discharge	100.0	0.57	1.31	100.0

Cyclone test

The -600 µm sand produced by autogenous grinding was fed at approximately 10% solids to a Warman 3-inch (76 mm) cyclone fitted with a 0.25-inch (6 mm) diameter orifice and a 0.5-inch (13 mm) vortex finder. Water was removed from the settled cyclone products by decantation.

Fraction	*% Mass*	*% Na*	*% Na_2CO_3*	*% Na_2CO_3 Distn*
Cyclone O/F	0.6	0.35	0.81	0.4
Cyclone U/F	98.3	0.05	0.12	9.0
-600 µm sand	98.9	0.25	0.58	43.8
Jaw crusher discharge	100.0	0.57	1.31	100.0

Of the sodium carbonate present in the -600 µm sand (produced by autogenous grinding) 80% was removed by cycloning. Therefore 91% of the sodium carbonate in the original spent sand could be removed by autogenous grinding followed by cycloning.

A sizing analysis of the cyclone products was as follows.

Fraction	*Cyclone Overflow*		*Cyclone Underflow*	
	% Mass	*Cumulative % Mass*	*% Mass*	*Cumulative % Mass*
-600 +300 µm	Nil	Nil	0.9	0.9
+250 µm	Nil	Nil	1.1	2.0
+212 µm	1.2	1.2	3.1	5.1
+180 µm	5.4	6.6	30.8	35.9
+150 µm	4.6	11.2	15.9	51.8
+125 µm	14.3	25.5	38.3	90.1
+106 µm	4.2	29.7	5.5	95.6
+75 µm	1.1	30.8	3.3	98.9
+38 µm	2.3	33.1	0.8	99.7
-38 µm	66.9	100.0	0.3	100.0
-600 µm	100.0		100.0	

Roll crushing of jaw crusher discharge

Direct roll crushing of jaw crushed spent moulding sand through 600 µm produced material with the following sizing analysis.

Fraction	*% Mass*	*Cumulative % Mass*
-600 +300 µm	5.6	5.6
+250 µm	5.9	11.5
+212 µm	8.1	19.6
+180 µm	23.3	42.9
+150 µm	10.1	53.0
+125 µm	37.2	90.2
+106 µm	4.8	95.0
+75 µm	2.7	97.7
+38 µm	1.5	99.2
-38 µm	0.8	100.0
-600 µm material	100.0	

This test was carried out on a Denver laboratory roll crusher, 10-inch (254 mm) diameter x 6-inch (152 mm) face operating at approximately 250 rpm.

A further 0.05% Na was added to this material prior to its use as moulding sand in a trial casting.

Magnetic separation of -600 μm sand

The -600 μm sand, (produced by autogenous grinding) was magnetically separated on a Rapid, high intensity dry magentic separator giving the following results.

Fraction	*% Mass*	*% HCl soluble Fe*	*% Fe Distribution*
M/S M/Al	1.38	11.8	81.4
M/S N	98.62	0.62	18.6
-600 μm sand	100.00	(0.20)	100.0

Trial casting using regenerated sand

The -600 μm sand, produced by autogenous grinding and containing 0.25% sodium as sodium carbonate (0.58% Na_2CO_3) was used by Johns Phoenix in a trial casting. A further 0.44% sodium as sodium carbonate was added for bonding prior to casting.

It was stated that the trial casting appeared normal and that the regenerated sand had identical moulding properties to fresh sand. After casting, the spent moulding sand was found to contain 0.69% sodium as sodium carbonate (1.59% Na_2CO_3). The spent sand, after jaw crushing, was autogenously ground in a laboratory ball mill in closed circuit with a 600 μm screen. The following results were obtained.

	Jaw crusher discharge		*Autogenously ground through 600 μm*	
Fraction	*% Mass*	*Cumulative % Mass*	*% Mass*	*Cumulative % Mass*
+19.05 mm	Nil	Nil	-	-
+9.53 mm	28.4	28.4	-	-
+4.75 mm	22.2	50.6	-	-
+2.36 mm	6.2	56.8	-	-
+1.18 mm	2.7	59.5	-	-
+600 μm	1.5	61.0	-	-
+300 μm	3.8	64.8	3.7	3.7
+250 μm	2.8	67.6	3.8	7.5
+212 μm	4.0	71.6	7.0	14.5
+180 μm	9.2	80.8	26.8	41.3
+150 μm	3.9	84.7	15.0	56.3
+125 μm	11.0	95.7	32.1	88.4
+106 μm	1.9	97.6	4.8	93.2
+75 μm	1.2	98.8	3.6	96.8
+38 μm	0.9	99.7	2.1	98.9
-38 μm	0.3	100.0	1.1	100.0
Head	100.0		100.0	

Fraction	*% Mass*	*% Na*	*% Na_2CO_3*	*% Na_2CO_3 Distn*
+600 µm	5.5	0.06	0.14	0.5
-600 µm	94.5	0.25	0.58	34.5
Jaw crusher discharge	100.0	0.69	1.59	100.0

Of the spent moulding sand 5.5% by weight has been lost as +600 µm material. In producing -600 µm sand, 65.0% of the original sodium carbonate present has been extracted.

CONCLUSIONS

This preliminary investigation has shown that the extraction of sodium carbonate from spent moulding sand can be relatively easily achieved through the use of autogenous grinding or intense agitation followed by cycloning and, or filtration. The regenerated sand should have a sizing analysis within an acceptable range, for re-use as moulding sand.

All sodium present in the spent moulding sand exists as sodium carbonate and no sodium silicate is present.

A determination of the highest concentration of sodium carbonate that can be tolerated in moulding sand should be made. The major problem then becomes to produce free running moulding sand rather than sodium carbonate free sand.

The production of free running moulding sand will depend entirely upon the method of drying the washed sand, and its sodium carbonate content.

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