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LIGHTWEIGHT AGGREGATE
Tapleys Hill Shale (2)

by

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SUMMARY

History

The results of previous work on Tapleys Hill shale showed that, while a light weight aggregate could be produced from it, the narrow bloating range made processing difficult owing to agglomeration of the material in the kiln. The investigation of sand injection to overcome this difficulty was recommended.

Objective

The object was to determine whether the tendency of Tapleys Hill shale to agglomerate in the rotary kiln during expansion could be overcome by the injection of sand into the kiln to produce a coated aggregate, and, if such a coated aggregate could be produced, to test it in concrete.

Summary of Work Done

Silica sand was injected at the burner end of the kiln during expansion of the shale, the behaviour of which was observed under various conditions of temperature, residence time, feed rate and feed size. The expanded product was used to prepare concrete cylinders which were tested for unit weight and compressive strength.

Conclusions

By injecting sand into the kiln to prevent sticking of the bloating particles it is possible to produce lightweight aggregate from Tapleys Hill shale by continuous expansion in a laboratory rotary kiln The product, though lacking in uniformity, is suitable for making lightweight concrete of structural grade.

Recommendations

It is recommended that the shale deposit should be further investigated to determine whether it contains more uniform and less weathered material, from which a more uniform expanded product might be obtained.

1. INTRODUCTION

This work had its origin in an investigation by Hosking and Sheridan in 1959 into the role of mica in the bloating of clays. Considerable quantities of fine mica were available from Radium Hill mill tailings, and it was hoped to find a use for this mica. The results of the investigations, which were reported by Hosking and Sheridan (1960)[1], showed that the addition of mica had little or no effect on the bloating characteristics of the clays examined, some of which however were found to have bloating properties. The authors accordingly recommended that no further work should be done on the use of mica as an additive, but that a survey should be made of the bloating properties of clays in the Adelaide area. This survey was carried out in 1961, when preliminary tests were made on 84 samples, of which 15 were selected as worth further examination. A detailed laboratory examination of these 15 clays (Madigan, 1962)[2] indicated that 4 of them should be submitted to pilot tests in a rotary kiln. The results of the rotary kiln tests are given by Madigan (1963).[3] These tests showed that a Recent clay from Section 3070, Hundred of Port Adelaide, could be bloated without difficulty in a rotary kiln to give a product of low bulk density but not particularly great strength. The red Marinoan slates and siltstones from Hallets Cove, Section 569, Hundred of Noarlunga, and the grey Sturtian slate from Section 1041, Hundred of Adelaide, were rejected as unsuitable for expansion in a rotary kiln. Tapleys Hill shale showed some promise, and preparation of sufficient product for testing in concrete was recommended.

The results of further work on Tapleys Hill shale (Madigan, 1965)[4] showed that if lightweight aggregate prepared from it was substituted for normal heavy aggregate in concrete, a weight saving of about 40% could result. The shale, however, had a marked tendency to agglomerate in the kiln during expansion, and it would be necessary to find a means of overcoming this before commercial exploitation of the deposit for the manufacture of lightweight aggregate could be recommended. One method of preventing balling and logging in the kiln that has been used commercially is to inject finely-divided silica sand or other refractory material into the kiln at the burner end. The injected refractory particles form a coating on the surface of the material being expanded and so prevent adhesion. The project was accordingly extended to allow an investigation of the application of this method to Tapleys Hill shale.

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1. HOSKING, P.K., and SHERIDAN, G.D., (1960), "Lightweight Aggregate - The Role of Mica in the Bloating of Clays", A.M.D.L. 44.
2. MADIGAN, D.C., (1962), "Lightweight Aggregate - Laboratory Testing of Clays and Shales", AMDL-191.
3. MADIGAN, D.C., (1963), "Lightweight Aggregate - Rotary Kiln Tests", AMDL Report 297.
4. MADIGAN, D.C., (1965), "Lightweight Aggregate - Tapleys Hill Shale", Amdel Report 431.

2. MATERIAL EXAMINED

The sample of grey laminated Tapleys Hill shale from Section 79, Hundred of Noarlunga, previously described (Madigan, 1963)[1] was used.

3. EQUIPMENT

The rotary kiln used for expanding the shale was 11 feet long, with a diameter inside the refractory lining of $8\frac{1}{2}$ inches, and was fired by an oil burner. Details of the kiln and burner have been given in previous reports (Madigan, 1963, 1965).[1]

Sand was injected into the burner end of the kiln through a sand-blasting hand-gun mounted adjacent to the oil burner. Air was supplied to the gun through a flow meter. At first the gun was used in the normal manner, sand being placed in the container, but a feed rate that was sufficiently low, and at the same time, constant, could not be achieved in this way. The gun was then inverted and the container removed. Sand was fed by gravity directly through the sand tube of the gun into the air stream. The vertical sand-tube of the gun was connected to a vertical glass tube drawn out to an internal diameter of 0.057 inch. The glass tube was connected to a glass funnel above it, which contained the sand. The flow of sand was maintained by bringing a small high-frequency vibrator into contact with the glass funnel. The rate of flow of sand was controlled by the diameter of the glass tube and was reasonably constant at about 1.25 lb per hour. The funnel that served as a sand reservoir was kept filled by hand.

All temperature measurements were made with an optical pyrometer.

4. EXPERIMENTAL PROCEDURE AND RESULTS

4.1 Sand Injection

Builders' sand screened to the required size was used for injection into the kiln. The first trials were made with the minus 120-mesh (BSS) fraction, but this material did not flow satisfactorily. The fines were then removed and the minus 120- plus 170-mesh fraction was used, but this still blocked the feed tube. A coarser fraction, minus 36 plus 120 mesh, was tried, which proved fairly satisfactory but occasionally blocked the feed tube. Finally the minus 36- plus 100-mesh fraction was tried. This was found to be a suitable feed and also formed a satisfactory coating on the bloated shale particles. Sand sized to this range was accordingly used for the rest of the experimental work, and its use made possible continuous processing of the shale under carefully regulated conditions, though constant attention was still necessary to prevent balling. Without the injection of sand the previous experience of ringing and balling in the kiln was repeated.

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1. loc cit.

4.2 Processing Details

Feed Rate. This was not very critical, and good results were obtained with feed rates of 20-30 lb per hour.

Residence Time. This can be controlled by variation of kiln speed and kiln slope. The kiln speed was kept constant at 6.79 rpm. The slope was varied between 2 and 5 in. per 10 ft. The best results were obtained with slopes of 4-5 in. Below 4 in. balling occurred, and this became marked when the slope was reduced to 2 in. Residence times were estimated to be approximately as follows for feed sized to minus $^3/_4$ plus $^3/_8$ in.

Slope in./10 ft	Residence Time, min	
	In Kiln	In Hottest Zone
4.9	10	3
4.0	14	5
2.0	22	7

Temperature. The optimum bloating temperature (temperature of shale in the bloating zone of the kiln) was about 1170°C. At 1190°C balling took place with feed sized to minus $^3/_4$ plus $^3/_8$ in., and became marked at 1200°C, though at these temperatures some well-bloated material was produced, whereas at the lower temperatures of 1170°C the degree of expansion was rather less. For feed containing minus $^3/_8$-in. material temperature control was more critical and balling took place at 1180°C even with sand injection.

Feed Size. Feed sized to minus $^3/_4$ plus $^3/_8$, minus $^3/_4$ plus $^1/_4$, minus $^3/_4$ plus $^1/_8$ and minus $^3/_8$ plus $^1/_8$ in. was used. Satisfactory bloating without balling was only achieved with the minus $^3/_4$ plus $^3/_8$ in. feed. When finer particles were present some balling always took place. With the minus $^3/_8$- plus $^1/_8$-in. feed balling was immediate when the temperature reached 1180°C, and occurred even at the lowest bloating temperature (1160°C). The temperature range for bloating of feed containing minus $^3/_8$-in. materials was too short for adequate control of the process in the laboratory kiln.

4.3 Product

The product was not uniform, and contained some poorly bloated and some unbloated material even under the best conditions of operation of the kiln. The average apparent specific gravity of the product from minus $^3/_4$- plus $^3/_8$-in. feed was 1.27, that from minus $^3/_8$- plus $^1/_8$-in. feed was 1.31. The average apparent specific gravity of the particles increased as the particle size decreased. A screen analysis of the product from minus $^3/_4$- plus $^1/_8$-in. feed gave the following results:

Size in.	% by Weight	Specific Gravity
+3/4	4	0.98
-3/4 +1/2	46	1.21
-1/2 +3/8	19	1.25
-3/8 +1/4	18	1.39
-1/4 +1/8	13	1.36

The upper limit of specific gravity for acceptable expanded shale is usually set at 1.3, hence the material smaller than 3/8 in. cannot be regarded as properly bloated, though of course it has undergone some expansion, since the apparent specific gravity of the raw shale is 2.21.

The product contained particles showing marked lamination. The most striking of these were white and refractory, and showed little or no evidence of expansion.

For making concrete, suitably graded fine and coarse aggregates are required. Fine aggregate was prepared by grinding the kiln product, screening the ground material, and combining the sized fractions as follows:

		% by Weight
-3/16 in.	+ 16 mesh (BSS)	45
-16	+ 52 "	40
-52	+100 "	10
-100	"	5

The bulk density of this material was 62.7 lb per cubic foot and the apparent specific gravity was 1.69. Coarse aggregate was prepared by screening the kiln product into two fractions, and recombining these in the following proportions:

	% by Weight
-1 +3/8 in.	75
-3/8 +3/16 in.	25

The bulk density of this material was 39.9 lb per cubic foot and the apparent specific gravity was 1.27.

Both fine and coarse aggregates were prepared from the kiln product without any attempt to segregate well-bloated from partly-bloated material. A sample was cut from the prepared coarse aggregate and separated into 2 fractions, lighter and heavier than water, by flotation. The heavier-than-water fraction was then separated by hand-picking into 3 portions; expanded, partially expanded, and unexpanded, as judged by eye. The apparent specific gravity of each of these fractions was then determined, with results as follows:

Fraction	% by Weight	Specific Gravity
Lighter than water	13	0.88
Heavier than water:		
Expanded	15	1.14
Partially expanded	20	1.26
Unexpanded	52	1.45

Calculating the apparent specific gravity of the original mixtures from these results gives 1.26.

4.4 Compressive Tests

As in previous tests, proportions were calculated on the basis of 2 volumes of fine aggregate to 3 volumes of coarse aggregate and 7 bags of Portland cement per cubic yard. A bag of cement has been taken as 94 lb or 1 cu ft, and it has been assumed that 32 cu ft of dry loose aggregate (the sum of the uncombined coarse and fine aggregate volumes) are required to produce 1 cu yd of concrete. On this basis the requirements per cubic yard of concrete are:

	cu ft
cement	7.0
fine aggregate	12.8
coarse aggregate	19.2

and the proportions became:

	Proportions	
	by Volume	by Weight
cement	1.00	1.00
fine aggregate	1.83	1.22
coarse aggregate	2.74	1.16

The samples of fine and coarse aggregate were sent to the Institute of Technology with a request that concrete cylinders should be cast using the above proportions, and tested for unit weight and 28 day compressive strength.

The tests were carried out under the supervision of Mr M. G. Symons using the mixing procedure previously described (Madigan, 1965)[1]. The average density of the cylinders was 103.9 lb per cubic foot and the average compressive strength was 4225 lb per square inch. Details of the tests are shown in Table 1. Mr Symons reported that his observations made on the previous tests were found to be relevant in the present series of tests. He further reported that the fractured surfaces of the cylinders were found to contain coarse aggregate particles which had not failed, whereas in previous tests the fractured surfaces contained a major proportion of sheared coarse aggregate particles. This would indicate that concretes of higher strength could be produced from the present coarse aggregate by using richer cement pastes and lower water-cement ratios.

1. loc cit.

5. CONCLUSIONS

By injecting sand into the kiln to prevent sticking of the bloating particles it was found possible to produce lightweight aggregate from Tapleys Hill shale by continuous expansion in a laboratory rotary kiln. The product was suitable for making lightweight concrete of structural grade.

It cannot however be pretended that the material examined was ideal for the manufacture of lightweight aggregate. The bloating range was narrow, so that even with the use of sand very careful temperature control was necessary to maintain expansion yet avoid sticking. The product was not uniform, but consisted of particles covering a considerable range of apparent specific gravity. The particles at the lower end of this range conferred strength and those at the upper end conferred lightness on the concrete containing them. The lack of uniformity in the product appears to be due at least in part to variation in the feed, some particles of which exhibited marked banding. The strongly banded pieces appeared to be more refractory than the less banded material, and showed little tendency to bloat.

The work done on Tapleys Hill shale is sufficiently promising to suggest that the deposit is worth further investigations to determine whether it contains more uniform and less weathered material, from which a more uniform expanded product might be obtained.

TABLE 1

TABLE 1: COMPRESSIVE STRENGTH TESTS
Date cast: 24.6.66
Date tested: 22.7.66

Cylinder No.	Height in.	Diameter in.	Sectional Area sq in.	Maximum Load lb	Weight lb	Age Days	No. Caps	Density lb/ft³	Water Cement ratio	Compressive Strength lb/in²
1	12.0	5.97	28.0	119,200	20.18	28	1	103.8	0.63	4250
2	12.0	5.97	28.0	108,000	20.06	28	1	103.1	0.63	3850
3	12.0	5.98	28.1	115,600	20.25	28	1	103.8	0.63	4100
4	12.0	5.97	28.0	125,000	20.19	28	2	103.8	0.63	4450
5	11.9	5.98	28.1	124,000	20.31	28	1	105.0	0.63	4400
6	11.9	5.99	28.2	121,000	20.21	28	1	103.9	0.63	4300
								Av. 103.9		Av. 4225

Note: 1. Cylinders were stripped from the moulds 24 hours after casting and cured in water until tested.

2. Cylinders were capped, as indicated, with sulphur compound for standard testing.