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PROPERTIES OF FIRED CLAY FOR USE AS CONCRETE AGGREGATE

by

H. S. Wilson

Mineral Processing Division

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SUMMARY OF RESULTS

The clay, extruded and cut into bars and cubes, was fired to five different temperatures between limits of 815 and 1035°C (1500 and 1900°F). Tests on the products of the firings showed that temperature had little effect on apparent specific gravity and absorption. Compressive strength of the fired clay increased from 3500 to 8400 psi when the firing temperature was increased from 815 to 1035°C. The moisture expansion of the fired products was negligible. Fired at 815°C (1500°F), the artificial aggregate would have an apparent specific gravity of 1.9 and an absorption of about 20 per cent. Because of the high absorption it would not be satisfactory in structural concrete but probably could be used in concrete block. The absorption might adversely affect the drying shrinkage and durability.

*Research Scientist, Construction Materials Section, Mineral Processing Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

INTRODUCTION

Edmontor Concrete Block Co. Ltd., Edmonton, Alberta, requested the assistance of the Mineral Processing Division in assessing the feasibility of producing an artificial concrete-sand aggregate by firing clay in a rotary kiln. The sand obtained locally is deficient in coarser particles, i.e., the 4-, 8-, and 16-mesh sizes. To have a suitably graded aggregate it is necessary to blend this too-fine material with a coarser sand that must be shipped a considerable distance. The company would like to produce an artificial aggregate similar to the coarser sand by firing the clay used by the company in the production of lightweight aggregate.

The company requested information on the temperature to which the clay would have to be fired to develop properties desirous in a concrete aggregate.

In commercial production of such an artificial aggregate, the company would crush the clay to the desired size range and pass it through the rotary kiln. The maximum temperature in the kiln would be kept below that at which lightweight aggregate is presently being produced.

This proposed method of production was not duplicated in the laboratory because all the desired measurements could not be made on granular material. Instead, the clay was extruded as a square column and cut into bars and cubes. Subsequent tests showed that the apparent specific gravity of the clay in the extruded state was comparable to that in the natural state (1.9).

PREPARATION OF TEST SPECIMENS

The clay used in this study was submitted to the Mineral Processing Division in 1968. It was from a deposit adjacent to the company's plant at Edmonton. It was the "lower" clay, which was evaluated as a raw material for the production of lightweight aggregate and reported in IR 69-3, "Comparison of Clays from Edmonton, Alberta, for Lightweight Aggregate".

The sample was in lumps of up to 4 in. and, for this study, it was crushed to minus 16 mesh in a laboratory jaw crusher. About 10 lb of the crushed clay was brought to the plastic state using 22 per cent water. The mixing was done in a single-paddle Hobart mixer. The plastic clay was extruded from a Midvale-Heppenstall hydraulic piston-type extrusion machine with a de-airing attachment. The de-aired clay was extruded through a 1-in. square orifice in the die. As it issued from the die, the column was cut into 6-in. bars and 1-in. cubes. All these test specimens were air dried for 24 hours and then placed in a dryer at 100°C (230°F) for an additional 24 hr. The ends of ten of the bars were ground flat and then tapered, resulting in specimens approximately 5 1/2 in. long with ends from 1/8 to 3/16 in. square. All bars and cubes were kept in the dryer until fired.

The prepared specimens were fired in an electrically heated stationary kiln to maximum temperatures of 815, 870, 925, 980, and 1035°C (1500, 1600, 1700, 1800, and 1900°F). Four bars, two with tapered ends and two with square ends, and two cubes were fired at each temperature. The test specimens were placed in the kiln at about room temperature and heated to the desired temperature in about 1 1/2 hr. The kiln was maintained at the desired temperature for an additional 1 1/2 hr to be certain that the heat had penetrated through the specimens. It was then allowed to cool normally to about room temperature before the specimens were removed. The lengths of the bars with the tapered ends were immediately measured, using a dial caliper that indicated length to 0.001 in.

TESTING AND RESULTS

The properties of a fired clay that are considered important if it is to be used as a concrete aggregate are: apparent specific gravity, absorption, compressive strength, and moisture expansion. This last property can be of considerable importance in fired-clay products such as brick and tile. It can create a problem if expansion occurs after the units are laid up in a wall. Moisture expansion is a continuous increase in volume of a clay body over an extended period resulting from absorption of moisture. Most expansion occurs in the first few days after firing.

The specific gravity of the product of each firing was determined by measuring the weight and volume of one cube. The weight was measured on a single-pan direct-reading balance, and the volume was measured by the mercury-displacement method. Readings were taken to 0.1 g and 0.1 cc respectively.

The absorptions of the fired products were determined by immersing one dried weighed cube, from each firing, in distilled water for 24 hr, 72 hr, and 3 wk. The cubes were reweighted in the surface-dry condition.

The compressive strengths were determined on 2-in. bars, cut from the longer 6-in. bars, and on 1-in. cubes. Two specimens were used for each strength determination.

The moisture expansion of the fired clay was determined in two ways. One of the two previously measured bars with the tapered ends was immersed in distilled water and the other was left exposed to the air. The lengths of the bars were measured every 24 hr until no further expansion was noted. To determine if the moisture expansion was reversible, the bar that was immersed in water, after it had been removed from the kiln, was placed in the dryer after 24 hr immersion. After 24 hr drying it was again immersed in water. This cycling of wetting and drying for 24 hr each was repeated until no expansion was noted. Inadvertently, the bars for the moisture expansion determinations, fired at 815°C, were destroyed; hence no measurements were available.

TABLE 1

Results of Tests

Firing Temperature °C / °F	815 / 1500	870 / 1600	925 / 1700	980 / 1800	1035 / 1900
Specific Gravity	1.9	1.7	1.7	1.7	1.7
Absorption (%):					
24 hr	19.1	19.9	18.9	17.9	16.6
72 hr	19.9	20.7	20.0	18.9	17.6
3 wk	21.4	22.0	21.5	21.4	20.2
Compressive Strength (psi):					
2-in. bars	3400	3800	4000	6100	9500
1-in. cubes	3500	4500	4500	7400	8400
Moisture Expansion (%):					
Exposed	-	0.05(8)*	0.06(9)	0.04(6)	0.05(6)
Wet/Dry cycling	-	0.09(8)	0.07(7)	0.07(6)	0.07(6)

*Bracketed figure is number of days between firing and maximum expansion.

DISCUSSION OF RESULTS

The various firing temperatures used in this investigation affected the specific gravities and absorptions within fairly narrow limits. The higher absorption and lower specific gravity of the cube fired at 870°C than that fired at 815°C indicates slight expansion between 815 and 870°C. Reductions of absorption at temperatures above 870°C indicate shrinkage, but not of such degree as to affect specific gravity appreciably. The compressive strengths did not follow a definite pattern, probably because only two specimens were used for each determination; hence averages of the two were reported. The moisture expansion figures indicate that this property is of negligible importance. On the basis of these tests, the maximum moisture expansion of a particle just passing a 4-mesh screen would be 0.00017 in., and would be less for smaller particles. The moisture expansion did not appear to be reversible when the bars were subjected to cycles of wetting and drying. Because the moisture expansion appeared to be complete in six to nine days, any expansion problem could be eliminated by leaving the aggregate exposed to moisture for several days before use.

The absorption of the fired clay is the property of greatest concern to the concrete manufacturer. Absorption of 15 to 20 per cent is excessive if the aggregate is to be used in structural concrete. The absorption of the aggregate would have to be satisfied before mixing is begun so that mixing water would not be taken up by the aggregate. It would be difficult to keep the water-cement ratio accurate under these conditions. The absorption would be less of a probelm if the aggregate is to be used in concrete block. The absorption would have to be satisfied with this type of concrete also, but less mixing water is used. Considering the large quantity of water required to satisfy the absorption of the aggregate, drying shrinkage of the concrete, either structural or block, might be a serious problem. Also, the durability of the concrete might be adversely affected by a highly absorptive aggregate.

CONCLUSIONS

Firing this clay in a rotary kiln to 815°C (1500°F) will produce an artificial fine aggregate having an apparent specific gravity of 1.9 and an absorption of about 20 per cent. It will have a compressive strength of at least 3000 psi.

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