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Cellular Concrete Investigations for the Nova Scotia Department of Mines

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Cellular Concrete Investigations for the
Nova Scotia Department of Mines.

Work on the utilization of oil shale and limestone from Nova Scotia for the production of cellular concrete was undertaken on behalf of the Nova Scotia Department of Mines. This project was only started about the first of the year and this is intended to be purely a progress report describing the investigations so far completed and the nature of some of the problems encountered.

Cellular concrete has become a very common building material in Europe. Its properties of low unit weight, low heat conductivity, and excellent fire resistance places it at a distinct advantage in many applications in building construction. Such a material, particularly in Canada, should find a ready market. However, it does have two properties which create problems in usage, (1) high moisture absorption which results in serious failures under freezing conditions when the cellular concrete is not properly finished, and (2) friability, resulting in damage to blocks and panels when handled, particularly when inexperienced labour is involved. There are now two plants producing cellular concrete in Canada, one near Montreal, the other in Calgary.

The raw materials under investigation were obtained from deposits near New Glasgow. The essential constituents in cellular concrete are silica and lime. The oil shale furnishes the silica, and as well, at least a partial source of fuel; the limestone of course furnishes the lime.

Raw Materials.

(1) Shale - the shale is a black fissile variety containing three imperial gallons of oil per short ton with a calorific value of 1267 Btu per lb.

(2) Limestone - this is a very fine-grained, light-grey variety but mottled and non-uniform in appearance.

Chemical analysis.

CaO	-	46.84
MgO	-	1.59
SiO_2	-	6.46
Al_2O_3	-	1.99
Fe_2O_3	-	1.48
LOI	-	38.05

The shale and limestone as received occurred in pieces up to about eight inches in size.

Preparation of Materials.

For use in cellular concrete it is necessary to calcine both the limestone and shale. For this purpose both materials were crushed through two inches and the fines (-1/2 inch) screened out of the crushed product.

A number of calcining experiments were conducted to determine optimum temperatures and times of exposure, as well as size of feed to kiln, and the best type of equipment for firing.

Limestone.

For calcining the limestone only an electric globar furnace was used (stationary) and the size of lumps ranged from 1/2 to 2 inches. Three calcining temperatures were tried, 1900, 1950, and 2000°F for a period of two hours each. Calcination appeared to be complete in all cases and no marked difference in activity was noted. within this temperature range. The limestone after firing had a brownish colour, again non-uniform, varying between light and dark browns.

Shale.

Initially the shale was fired up to two inches in size in both the globar furnace and rotary kiln. However, even at retention times up to four hours in the Globar and up to 1950°F, and 15 minutes in our short rotary kiln up to 2025°F, combustion was incomplete, i.e., much of the interior of the shale particles remained black. The raw shale was then reduced further in size to a maximum of 1/2-in. down to dust. The rotary kiln proved the most effective, but even under the best of conditions sufficient carbon remained to colour the ground product black. A sintering grate was next tried and proved to give a product similar to the rotary kiln. It did however, have the advantage of making use of the oil in the shale as a source of fuel which the other types of kilns did not.

The problem thus remained with us in that a very dark or black product was obtained when the calcined shale was ground for use in the mixes. Further work will have to be done in an attempt to remove all carbon during the calcining period.

Preliminary Experiments with Dense Mixtures.

The cementitious material in cellular concretes is principally a hydrated calcium silicate. Some preliminary tests were made to determine optimum ratios of lime to shale to obtain maximum strength. These tests were made with dense mixtures. In addition to the screened shale other varieties of silica were used for comparison purposes.

A commercial high grade hydrated lime was used in these mixtures and enough water to produce normal consistency (a very stiff plastic state).

Each combination of materials was mixed dry and sufficient water added to attain normal consistency, about 40-45 per cent by weight of dry constituents. Two 2 x 4-in. cylinders were molded from each mix and allowed to cure at room temperature for 24 hours and then autoclaved at 120 psi and 350°F. The autoclave cycle consisted of four hours raising temperature from 70° to 350°F, 16 hours at 350°F, and four hours lowering temperature.

Compressive Strengths of Dense Mixtures.

Silica Source	Proportions CaO/silica source,	Compressive Strength psi
No. 1 Ground silica	2:1	3920
2 "	3:1	3500
3 Diatomite	2:1	716
4 "	3:1	637
5 Rotary kiln		
6 burned shale	2.5:1	955
7 Sintered shale	2.5:1	1450

By way of interest the sintered shale was compared with the rotary kiln product using a standard pozzolanic activity test which consists of curing sand-lime-siliceous material mortars at 55°C for 6 days. Results again indicated a greater activity between the lime and sintered product which confirms the autoclave method results.

As previously mentioned the limestone was calcined at 1900°, 1950°, and 2000°F for two hours in a globar furnace. In testing the activity of the products the ground silica used in the previous test described as No. 1 was combined with the different limes in a ratio of 1:3 = lime to silica. Again a normal consistency was used to mold 2 x 4-in. specimens.

Reactions - Calcined limes
with ground silica

Temperature of calcining limestone	Compressive strength psi
1900°F	2840
1950°F	2770
2000°F	2570

Cellular Concrete Investigations.

There are a number of variables in the production of cellular concrete which require detailed investigation before a satisfactory product can be produced. The principal factors are correct ratio of lime:burned shale, consistency, curing cycle, amount of gasifying agent (aluminum in this case), and other additives required to produce a light, strong, and uniform product. The literature on this subject is meager and in any case each particular combination of raw materials presents a separate and unique problem. The work thus far has been of a very exploratory nature. A number of combinations of lime and siliceous materials along with additives have been tried in the attempt to produce a uniform cellular product which would not slump, or shrink prior to autoclaving. These will not be described in detail but some general comments follow on the factors investigated.

Proportions of Materials.

From the work with dense mixtures at least an idea of the approximate ratio of lime to shale and other sources of silica was obtained. A ratio of 1:3 lime to shale was used in most of the mixes, but indications were noted that in fact the optimum ratio may depend on the degree of fineness of the shale or silica.

Water:solids ratio.

Various combinations of materials were used at water:solids ratios between 0.5 and 1.1. It was found that the finer the ground shale or silica the more water is necessary to produce a given consistency. In order to obtain a cellular product it is also necessary to use a slurry which will readily flow. However, as the water is increased the greater is the tendency for the cellular product to slump before autoclaving, or before it has had a chance to set. It is therefore desirable to use as little water as possible to obtain a slurry of the required consistency. One way of doing this is to avoid excessive grinding of the raw materials - only sufficient to obtain the required degree of reaction.

To illustrate; a silica ground through 200-mesh required a water solids ratio of 1.0 compared to 0.75 for a silica ground through 100-mesh to produce a slurry of the consistency of thick cream. The 0.75 ratio showed practically no slump; the 1.0 ratio slumped about 20 per cent.

The burned shale used was combined with both hydrated lime, and the calcined lime. In all cases very appreciable slumps resulted, apparently from excessive water content. In future work the shale will not be ground so fine, and it is hoped to achieve better results.

Aluminum powder.

A number of different types of aluminum powder were obtained for the investigation, however, until now only one variety has been used. Amounts used have been varied between 1.5 and 4.5 lb per ton of dry materials. It was found that 1.5 lb per ton was quite adequate to produce a highly porous product which if it had set in the "risen" state would have been satisfactory.

Order of mixing.

After some experimentation it appeared likely the calcined lime should be mixed with water for a period of time before the other constituents were added to permit complete hydration. This was subsequently done and the burned shale then added followed by any additives and last of all the aluminum powder. The merits of this procedure have by no means been established and probably further work will be required on this aspect of the problem.

Additives.

In addition to the aluminum, some constituent or combination thereof is required to stabilize the cell structure once it has formed to prevent slumping prior to autoclaving. Although it would also be desirable to use an agent to accelerate the reaction between the lime and silica, none is presently known. Although a number of stabilizing agents have been tried, nothing very definite has been established. Water glass appears to be one of the better additives although it seems to produce a very coarse and non-uniform texture.

Discussion.

The work completed to date on the Nova Scotia cellular concrete investigation has been briefly reviewed. It is certainly too early to come to any conclusions on the probable success or failure of such a project. It is apparent now however, that the colour of the calcined limestone is a serious handicap. If the shale can be burned to complete combustion it will probably be suitable, otherwise it too would result in an objectionably coloured product. Another problem which exists is a method of burning the shale so as to make use of the oil fuel present. Some method of sintering appears to offer the best possibility. A very lengthy program of work is indicated at present before the usefulness of the shale and limestone, under investigation for production of cellular concrete, can be established.