THE USE OF HAYDITE AS A CONCRETE AGGREGATE

THESIS FOR THE DEGREE OF B. S.

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THESIS

The Use of Haydite as a

Concrete Aggregate

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THESIS

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To the Civil Engineering Faculty
of Michigan State College, who
have so ably assisted us in gain-
ing our education in Engineering,
we do hereby dedicate this
Treatise on Haydite--P.B. A.J.

Manufacture and Uses of Haydite.

Haydite is a light weight, burned clay aggregate, manufactured for use in concrete products in place of sand, gravel, stone, slag or cinders. This aggregate is manufactured from clay which is taken from the pits and ground to a maximum size of 1½ inches. The ground clay is then delivered to, and burned in, a rotary kiln of the same type as used in the manufacture of Portland cement, the kiln revolving as the clay is being delivered to the upper end.

The clay travels continuously through the kiln, passing a preliminary heating stage and finally reaching a zone of highest near the discharge end of the kiln. The temperature at this point is about 2000 degrees Fahrenheit. In this zone incipitent fusion takes place, the carbon content oxidizes forming gases, resulting in the clay expanding into a light, cellular structure. This expansion process is so complete that the finest particles show a cellular structure when magnified.

The resulting product, called Haydite, is a series of air cells, the partitions of which are vitrified fused clay, which has a high structual strength. The product, after being discharged from the kiln in clinker form, is screened and graded into standard sizes used in concrete, as shown in the table on the following page.

Standard sizes of Haydite aggregate.

Size of Screen	Screen Analysis Standard Grading Accumulated Per Cent Retained Aggregate Sizes		
	$\frac{1}{4}$"x 0"	$\frac{1}{2}$"x $\frac{1}{4}$"	$\frac{3}{4}$"x $\frac{1}{4}$"
100	85	100	100
48	75	100	100
28	60	100	100
14	40	100	100
8	10	100	100
4		75	95
3/8		[illegible]	25
$\frac{3}{4}$		0	0
F.M.	2.70	6.10	6.70

Properties of Haydite

Haydite is a light aggregate having a specific gravity of 2.52. The coarse size (¾"x ¼") weighs about 48# per cubic foot. (Natural sand, which is used the same as the fine Haydite aggregate, weighs about 100# per cubic foot.) Haydite will resist acids and is completely inert. It fuses at a temperature of 2000 degrees Fahrenheit. The aggregate resembles cinders somewhat in appearance except that it is light gray in color.

Due to the cellular structure of Haydite it is necessary to pre-wet the aggregate when making a concrete mix. This is necessary because part of the Portland, when mixed with the dry aggregate, will work inside the aggregate and part of its effectiveness in binding the particles together will be lost. Pre-wetting will cause a film of water to form around the aggregate and prevent the Portland from entering the particles of aggregate during the mixing process. Experiments show that if the aggregate is not pre-wetted there is about a 25% loss in strength. In practice 25 to 50% of the required amount of water is mixed with the aggregate before the Portland is added.

A chemical analysis of Haydite shows the following: Loss on ignition .40%; Silica 65.4%; Alumina 12.3%; Iron Oxide 13.3%; Lime 5.2%; Magnesia 2.77%; Sulphur 0.0% and Alkalies 0.65%.

Compressive Strength of Haydite

A 2500# mix was arbitrarily selected and cylinders were made up for a 28 day compression test. From tables in "Design and Control of Haydite Mixtures" it was found that a 1-1¾-2½ mixture, with a water cement ratio of 8¾ gallons per sack, would give this strength.

Twenty cylinders were made of pure Haydite, using the ¾"-¼" size for coarse aggregate and the ¼"-0.0" size for fine aggregate. Reinforcing steel was placed in four of these cylinders to be used in a test for bond. The slump test on this mixture showed 6 inches. The Haydite was pre-wet as described in page on "Properties of Haydite." About 25% of the water was added before the Portland was mixed in. In placing the concrete in the cylinders (6"x 12" were used) the concrete was placed in layers approximately 4 inches thick and each layer puddled 25 times. The cylinders were allowed to dry in moist air for 24 hours, then placed in water till they were used i in tests.

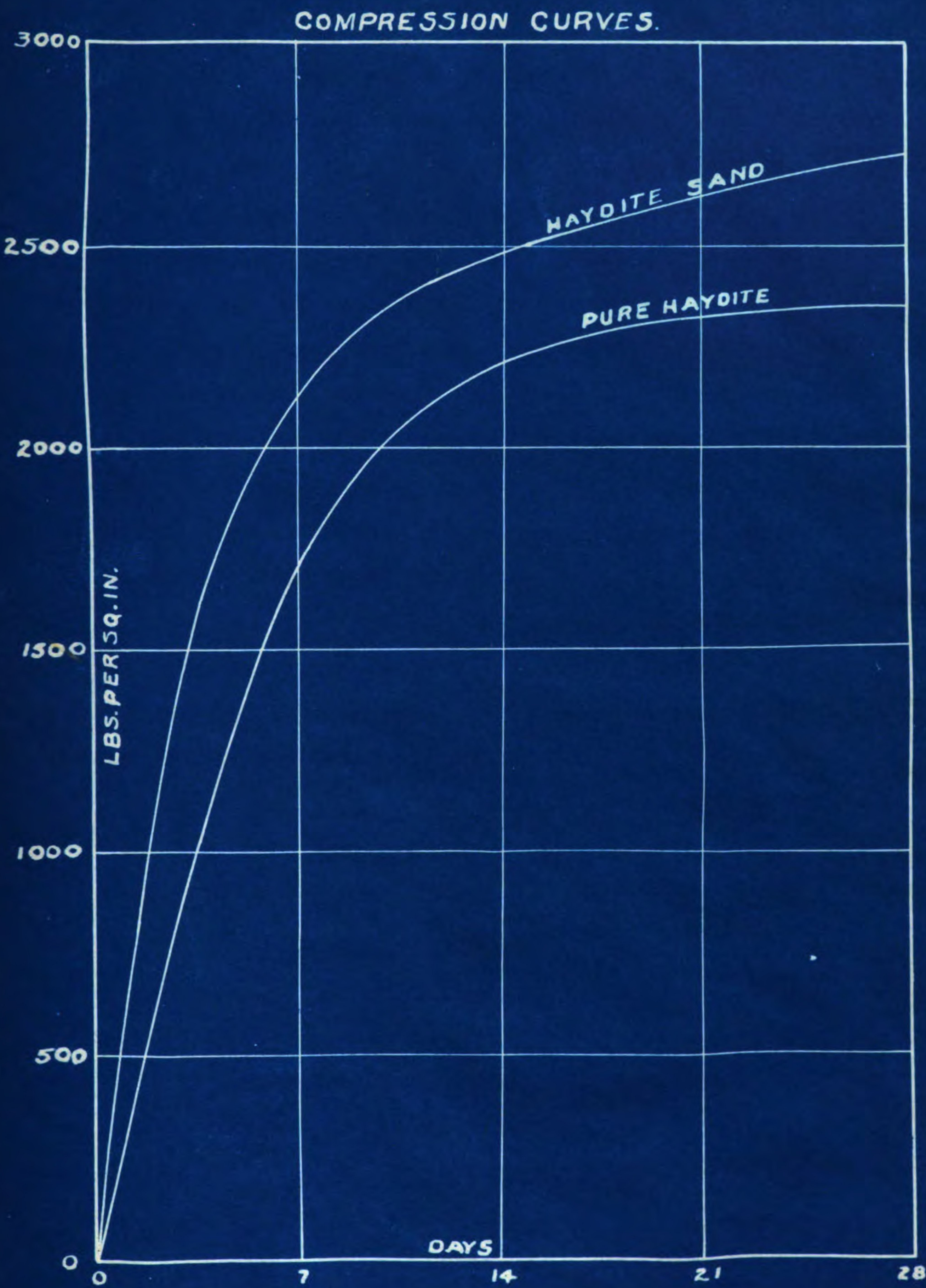
A similar set of cylinders was made using a 1-1¾-2½ mixture of Haydite and natural sand. The ¾"-¼" Haydite was used for coarse and the natural sand was used for fine aggretate. This mixture called for a water cement ratio of 7¾ gallons per sack. The slump test for this mix was 4 inches.

At the end of seven, fourteen, twenty-one and twenty-eight days, four each of the two types of cylinders were tested for compressive strength. (The Reihle Universal testing machine was used.)

The results of the compression test are shown on the following page. It is seen that the Haydite-Sand concrete gave a higher compressive strength than the clear Haydite.

The data obtained in the compression test is as follows:

Clear Haydite	7	Days 14	21	28
1	50,000	60,000	62,500	64,400
2	52,500	64,000	64,500	66,000
3	49,000	66,000	64,500	68,500
4	49,500	62,000	63,500	63,400
Haydite-Natural Sand				
1	60,000	67,500	78,000	78,750
2	65,000	67,500	72,000	76,000
3	61,000	69,600	75,000	76,800
4	64,000	65,000	72,500	78,000


COMPRESSION CURVES.
3000
2500
2000
1500
1000
500
0
LBS. PER SQ. IN.
HAYDITE SAND
PURE HAYDITE
DAYS
0
7
14
21
28

Bond Strength of Haydite

This experiment was merely for the purpose of determining whether the Bond strength of Haydite was satisfactory. (Mr. A.M. Rouse investigated Bond strength thoroughly in his thesis, "Bond Strength of Haydite on Painted and Unpainted Steel.")

Four cylinders of each type of concrete were used for this test. One-half inch reinforcing rods were imbedded into the 6 x 12 inch cylinders, 8 inches. The cylinders were dried in moist air for 24 hours and then cured in water 28 days before being tested. (The bars used were plain round bars.)

At the end of 28 days the reinforcing rods were pulled out, using the Reihle Universal testing machine. The Haydite sand concrete gave the highest bond strength, as seen in the following data.

Bar No.	Clear Haydite	Haydite Nat. sand
1	4770	6500
2	4845	6670
3	4560	6300
4	4890	6835
Average	4766	6626

Bond strength/ sq. in. $= \dfrac{4766}{\frac{1}{2} \times 3.1416 \times 8} = 380\#$ / sq. in. For clear Haydite

Bond strength / sq. in. $= \dfrac{6626}{\frac{1}{2} \times 3.1416 \times 8} = 524$ for Haydite natural sand

Driving and pulling Nails in Haydite

Haydite has the same bond strength for nails as it does for reinforcing steel. However, it is difficult to use nails on account of the difficulty in driving. Nail driving tests were tried on 7 and 28 day old concrete.

Results on 7 day old Haydite: Nails were first driven through a $\frac{3}{4}$" board and then on into the piece of Haydite concrete. The board was used to make the test as near like ordinary conditions as possible. Six and eight penny nails were used. An ordinary carpenter's hammer was used for driving. By using much care it was possible to drive this concrete. The pulling test was tried after the concrete had cured for 28 days and was satisfactory. It required as much force to pull a nail out of the Haydite as it did to pull one out of a yellow pine two-by-four with nails of the same size driven to the same depth.

Results from driving nails in 28 day Haydite: The test was the same as used on the 7 day Haydite Concrete. Here it was almost impossible to drive a nail of any kind. About nine out of ten nails would bend before before they could be driven to a depth of one inch. The concrete would crumble for a distance of about one sixteenth of an inch around the nail as it was being driven. Tests on older Haydite concrete would doubtless prove less satisfactory.

Heat Resistability of Haydite

This test was carried out with the object of determining the heat resistance of Haydite concrete and comparing its heat resistance with that of ordinary concrete. Three 6" x 12" cylinders were used for this test; one cylinder made of ordinary concrete-no.4 to $\frac{3}{4}$" gravel for coarse aggregate and natural sand for fine; the other two being the same as used in the compression test, one made of pure Haydite and the other of Haydite and natural sand.

The three cylinders were placed in a gas fired furnace and held at a temperature of 1900 degrees Fahrenheit for three hours. The cylinders were allowed to come up to heat with the furnace and after the test were allowed to cool off in the furnace.

The cylinders were removed from the furnace at the end of forty-eight hours and examined. The pure Haydite seemed to be in the best condition. It had only a few hair line cracks and appeared to be intact. The cylinder made of Haydite and natural sand was in nearly as good condition, except that the fine cracks were a little larger. The cylinder made of ordinary concrete was in bad condition. It was cracked badly and crumbled easily, breaking under its own weight.

A compression test was made on the two remaining Haydite cylinders. They were of the same strength, each testing 37# per square inch.

Specific Gravity of Haydite

The unit weights of the aggregate used in the experiments were determined. These weights were determined in the following manner. A ½ cubic foot measure was calibrated and found to be accurate. The measure was filled one third full with the aggregate to be tested and tamped 25 times with a pointed rod. It was then filled two thirds full and again tamped 25 times. Then it was filled to overflowing and tamped as before, the surplus struck off, and the net weight determined. The course Haydite weighed 44 pounds per cubic foot-(¾"-¼" size) and the fine weighed 61 pounds per cubic foot-(¼"-00"size). The natural sand was also weighed, being much heavier than the Haydite sand. The natural sand weighed 105 pounds per cubic foot.

The weight per cubic foot of the clear Haydite concrete and of the Haydite-natural sand was determined. Cylinders of each type of concrete were carefully weighed and the dimensions measured. The clear Haydite cylinders weighed 18¾# and the Haydite-natural sand cylinders 21¾# each. All cylinders measured 6" diameter and 12" high.

$$\text{Wt./cu. ft. of pure Haydite} = \frac{1728 \times 18\tfrac{3}{4}}{6 \times 6 \times .7854 \times 12} = 95.5\#$$

$$\text{Wt./cu.ft. of Haydite Sand} = \frac{1728 \times 21\tfrac{3}{4}}{6 \times 6 \times .7854 \times 12} = 110.8\#$$

Porosity of Haydite

The object of this experiment is to determine the ability of Haydite to absorb water. A cylinder made of clear Haydite and one made of Haydite and natural sand was carefully weighed. They were then placed in water for a period of 2 hours. After taking them out they were carefully wiped off and reweighed. There was no noticeable change in the weight of either cylinder. This was to be expected as the surface of the Haydite concrete was quite smooth and appeared to be quite impervious.

An example of the imperviousness of Haydite concrete was noticed at the Hay-Con Tile and Brick plant on Greenfield Avenue in Detroit. Here they have a steam room made of Haydite Concrete in which the green tile are subjected to a steam bath during the curing process. The walls were made of eight inch thick Haydite tile and the ceiling of flat Haydite slabs four inches thick. This steam room is in operation eight hours a day. The outside of the walls were inspected very carefully. They did not show a trace of moisture anywhere, which clearly demonstrates the imperviousness of Haydite concrete.

Comparative cost and Availability of Haydite

Haydite is very expensive compared with standard aggregate. Its initial cost is about 2½ times that of gravel or crushed stone.

Haydite is manufactured at only two plants, one at South Park, Ohio and the other at Saint Louis, Missouri. Haydite is available at these plants in almost any desired quanity.

Freight is a large item in the cost of Haydite. The cost of the aggregate increases as the distance from the manufacturing plants increases. The cost of ordinary aggregate is fairly constant as it can be obtained in quanities almost anywhere in the United States.

Summary

Haydite compares quite favorably with ordinary concrete in all respects. Its outstanding feature is its light weight. The clear Haydite concrete weighs 36% less than ordinary concrete and the Haydite natural sand concrete weighs 26% less. Because of its light weight Haydite might be used advantageously in tall buildings where the dead load is a controlling factor in its construction. In this case Haydite would not only permit the construction of a taller building, but it would also save steel. It is claimed that the saving in steel will more than make up for the extra cost due to the high cost of Haydite aggregate. This has not been proven as a fact.

In strength Haydite seems to be the equal of ordinary concrete. Referring to the tables in, "Concrete Practice" by Hool and Pulver, on proportions for different strength concrete it is found that a 1-1¾-2½ mixture of ordinary concrete (using the same size aggregate as used in the Haydite mixes) would give a 2500 pound concrete. The compression curves show that the Haydite concrete tested very close to 2500 pounds per square inch.

The heat resistability test showed Haydite to be superior to concrete. It stood up well under a test that far exceeded the heat that a wall would receive during an ordinary fire. Ordinary concrete completely disintrigated under the same test. Haydite also proved to be a good concrete for water proofing jobs as seen in the discussion on Porosity.

The unit bond stress in the clear Haydite concrete was 380# per square inch and the unit bond stress in the Haydite-Natural sand concrete was 524# per square inch. A factor of safety of 5 is used in finding the allowable bond stress. This would give an allowable bond stress of 76# per square inch in the clear Haydite and 105# per square inch in the Haydite-natural sand concrete. This allowable bond stress would be satisfactory as the allowable bond stress usually used in concrete design is from 60 to 80# per square inch.

From the preceding described experiments we would conclude that Haydite would be satisfactory for use as a concrete aggregate.

Suggestions for Haydite Concrete Specifications
(From pamplet by Hydraulic-Press Brick.Co.)

It is suggested that the water-cement ratio principle be followed in the design of Haydite concrete mixtures. The water-cement ratio curve published by the Portland Cement Association is applicable to Haydite concrete providing allowance is made for the absorption of the Haydite aggregate. The effective absorption of Haydite aggregate is approximately 7% moisture by weight. This absorbed water is not liberated in the mix by the Haydite aggregate and therefore does not become a part of the water-cement ratio.

Unless otherwise specified or indicated, all concrete shall be made of Portland cement, Haydite aggregate and water.

The Haydite aggregate shall consist of Haydite Sand, Size ¼"-00", and Haydite Coarse, Size ¾"-¼", or Haydite Special, size C-X, which shall be so graded that all particles of the Haydite sand will pass a ¼" square mesh, and 95% of the coarse Haydite will pass a ¾" mesh, with no appreciable amount of dust.

Cement and aggregate shall be stored at the works in a manner to prevent deterioration, the intrusion of foreign matter, or the mixing of the fine and the coarse aggregate.

Water used in mixing concrete shall be clean and free from strong acids, alkalies, oil of organic materials.

The strength of concrete shall be fixed in terms of the water cement ratio, which shall not exceed the values shown in the following table:

Assumed Strength of Concrete

Actual W-C Ratio, U.S. Gal. Per Sack of Cement	Assumed Compressive Strenght at 28 days in pounds/ sq. in.
6	3000
6¾	2500
7½	2000
8¼	1650

The strengths indicated above are for average job specimen, cured damp at a temperature of 70 degrees F.

The proportions of Haydite aggregate to cement for concrete of any water-cement ratio shall be such as to produce concrete that will work readily into corners and angles of the form and around the reinforcement without excessive puddling or spading and without permitting the material to segregate or free water to collect on the surface. The combined aggregate shall be of such composition of sizes that when separated by the No. 4 standard sieve the weight retained on the sieve shall not be less than 1/3, nor more than 2/3, of the total, nor shall the amount of coarse material be such as to produce harshness in placing or honeycombing in the structure.

All concrete throughout shall be mixed in an approved type of power operated batch mixer which will assure a uniform distribution of the materials throughout the mass. The Haydite aggregate, both sand and coarse sizes, shall be thoroughly wetted down in the pile before going to the mixer, and the mixing must continue for at least ~~fx~~ one full minute after all ingredients, including water, are in the drum, and until concrete of a uniform consistency and color is produced.

All materials, including water, shall be measured in a manner that will insure accurate and uniform proportions of each of the materials at all times.

Concrete shall be handled from the mixer to the final place of deposit as rapidly as practible by methods which will prevent segregation ,separation or loss of ingredients, excepting that chuting will not be permitted at any time.

Under no circumstances shall concrete which has partially hardened be deposited in the work.

Concrete shall be thoroughly compacted by puddling with suitable tools during the operation of placing, and thoroughly worked around the reinforcement, around the embedded fixtures, and into the corness of the forms. The use of the vibrator is recommended as an aid in placing Haydite concrete.

When it is desirable to include field test of concrete, curing, depositing in cold weather, or forms details.

and details of construction, it is suggested that the specifications as recommended by the Portland Cement association in their booklet, "Design and Control of Concrete Mixtures," be incorporated, and when admixtures are used, include the manufacturer,s directions.