A PRELIMINARY STUDY OF PORTITE AS AN ADMIXTURE FOR CONCRETE

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S. W. Curtiss

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A Preliminary Study of Portite as an Admixture for Concrete

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S. W. Curtiss

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"The question uppermost in the minds of engineers and contractors is whether the use of admixtures is the cheapest way to secure the desired results."

Edward E. Bauer

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Introduction

The use of cementing material dates back to the time of the ancient Egyptians, but portland cement, as known now, is a comparatively recent discovery. The first modern development of cement began in the early 18th century. In 1824, Joseph Aspdin, a bricklayer of Leeds, England was granted a patent for a product he called "portland" cement for its resemblance in color to a building stone found on the isle of Portland.

With the discoveries of Aspdin and others, by the middle of the 19th century portland cement was advanced to basically the same product it is today. It was first imported to this country in 1865, and manufactured here shortly after that time. Since then the manufacturers have concentrated their research on new methods of production. The result has been lowered costs of production and lowered selling prices, thus greatly increasing the use and importance of concrete.

Originally, strength was the major consideration in good concrete, and the concrete mixtures were designed with that aim predominate. However, as concrete was adapted to more and more uses, other requirements grew in importance. Today, the durability, the workability, and the economy of the concrete are considered fully as important as the strength. Strength, of course, must always remain a very important design factor. A means has been sought, therefore, to provide the most economical concrete mix that includes the maximum durability and workability without sacrificing the desired strength.

Research on this subject in the last decade led to the investigation of the use of admixtures in concrete. At the present time there are many admixtures on the market. Rather than attempting to describe all admixtures produced, the author has chosen to investigate the possibilities of just one. It is the purpose of this thesis to conduct a preliminary study of the general practicability of Portite, manufactured by Hopper Products, Inc. of New York City. In view of the limited time and facilities, no attempt will be made to verify all the claims made by the manufacturer concerning the performance of Portite.

Admixtures in General

A brief background of the subject at hand is in order to give the reader a broader understanding of the purpose of this thesis. The following definition is used to clarify the meaning applied to admixtures. An admixture is defined as a substance other than portland cement, aggregate or water that is used as an ingredient for concrete.

Usually the purpose of using an admixture is to modify the properties of the concrete in such a way as to make it more suitable for a given job. Under certain conditions, the use of a suitable admixture may impart desireable characteristics which cannot be secured as economically by other methods. It is emphasized, however, that no amount or kind of admixture should be considered as a substitute for the use of structurally sound well-graded concreting materials or good concreting practice.

From the time admixtures were first promoted for use in concrete, two schools of thought have arisen regarding their value.

Many engineers argue that admixtures of any form are not worthwhile. They point out the fact that the mixer operator, or even a special hand, must take the time to add the substance at the mixer. In addition some means must be made to store, deliver the material to the construction site, and in some cases, even prepare it in the proper form before it can be used. Further, there is the basic fact that it takes additional money to buy the admixture.

The testing engineer points out the fact that many admixtures tend to decrease the ultimate strength of the slab. Since strength will always be the major design factor, this argument receives justifiably strong support. In order to be truly practicable any admixture that reduces the strength of the hardened concrete must offer sufficient advantages to warrant redesign of the mixture to reach the desired strength.

The idea of increasing the general utility or life of a concrete structure, or of decreasing the amount of labor necessary in the molding or finishing process sounds like a vague promise to many field engineers. Anyone who has ever worked with an experienced concrete construction engineer is well aware of his inherent suspicion of new building technique developed in the laboratory. This suspicion is readily understandable, when one considers the fact that a good field man works with so many different mixes, he feels he completely understands concrete. This prejudice has long been a strong obstacle to admixtures.

Probably the greatest single objection to admixtures, however, comes from the group that considers admixtures a substitute for cement or a proper mix. It is true that additional cement can provide many of the advantages offered by admixtures. The general effects of increasing the cement ratio are: increased strength, workability, impermeability, frost resistance, heat development, volume change, and increased surface crazing if the placed concrete receives much manipulation.

It can readily be seen, therefore, that an increase in cement content would not always be entirely satisfactory. An admixture, on the other hand, may be beneficial in one or more of the following ways; it may improve the texture of the mix; it may have cementitious properties of its own; or it may be pozzolanic. It is with the first of these refinements, this thesis is most concerned. The most common textural improvements are achieved by increasing the fines or by increasing the entrained air.

The apparent result of the improved texture is increased durability, workability, homogeneity, and waterproofness. The need for increased durability is most urgent in concrete that is exposed to severe climatic conditions. In northern states many concrete pavements, for example, have undergone surface scaling caused by severe frost action, by direct applications of flake calcium chloride or rock salt to remove ice, or by repeated applications of granular materials impregnated with these salts. Increasing public demand on highway departments to keep roads open to traffic and to provide safe traveling conditions during winter months has in recent years led to widespread use of such salts, a practice which has been primarily responsible for the development of this scaling problem.

In the last few years a comprehensive program of research has been carried on to solutions to this situation. A means was sought to develop concrete which would have high resistance to severe frost action, and immunity to the action of sodium chloride and calcium chloride as commonly employed on rural roads and urban streets. It has been conclusively demonstrated that concrete having excellent durability to withstand such hazards can be produced with air-entraining agents.

An air-entraining agent, when combined with cement, water, and aggregates in the process of mixing, introduces into the resulting concrete minute and well-distributed air bubbles and imparts other characteristics not found in normal concrete.

The need for durable concrete is not, by any means, limited to pavements or to frost and salt resistance. Durability of concrete is affected also by alternate wetting and drying, heating and cooling, capillary water, deposition of salts by percolating water, dissolving of certain products by the percolating water, and by the dissolving of the cement by certain acids. The water-cement ratio of the mix influences the permeability of the paste, and, in turn, the durability of the concrete. An admixture, therefore, that can effectively reduce the water-cement ratio of the mix, all other factors being equal, will definitely increase the durability.

At times it may be desireable to increase the workability of a concrete mixture (a) if the concrete is harsh because of aggregate grading or aggregate characteristics; (b) if the concrete must be placed around closely spaced reinforcement or in difficultly accesible sections; (c) where special means of placement are required, such as with tremie or pumping methods. The desired results may be obtained by redesigning the mix or by the use of admixtures.

Although air-entraining agents are considered primarily for use because of their effect on the durability of concrete, their effect on the workability of leaner mixes is so pronounced as to merit mention as workability agents. The incorporation of numerous small well-distributed air bubbles in the concrete acts as a lubricating medium, generally increasing the "fatness" of the mix and markedly improving the placeability of otherwise harsh concrete.

Certain organic compounds or mixtures increase the slump of concrete of a given water content and, therefore, permit concrete of a given slump to be produced at a reduced water content. These agents, in many cases, do much to increase the workability of the mix.

Admixtures can variously be used to increase homogeneity and waterproofness; and to decrease porosity and absorption, bleeding, and segregation. These factors were grouped together because of the general correlation to one and another. In turn, these factors are often related to general durability and workability. In some cases even a well-designed mix fails to provide satisfactory control over the above factors.

Basically, these admixtures improve the mix by increasing the density of the concrete. They may accomplish this by increasing the fines, by decreasing the water content, by increasing the fluidity without increasing the water, or by a combination of these techniques.

From the preceeding remarks, it can readily be seen that admixtures can be an asset to concrete construction if used intelligently. The use of an admixture may increase the cost of the concrete. Therefore, even though a given admixture may produce a desireable effect, the value of that effect should be weighed against its cost. Moreover, the effect of a given admixture can usually be obtained, at least in some degree, by other means or by other admixtures. Hence, whenever possible, the cost of an admixture should be compared with that of alternate materials or methods for getting the desired result.

Description of Portite

Portite is a reddish brown liquid of about the consistency of light machine oil. It is readily soluble in water, dissolving with very little agitation. When rubbed between the fingers, it feels very much like liquid soap. Drying somewhat sticky, it is readily removed with water. It is somewhat alkaline and has a slight odor not unlike that of fish oil. This odor is not noticeable in the finished concrete, and it does not discolor the mix.

The following is a description of the advantages of this product as claimed by the manufacturer. As mentioned before, the author has made no attempt to substantiate all these claims. The author has merely attempted to formulate an unbiased preliminary study of this agent.

Portite is described by Hopper Products, Incorporated, its manufacturer, as a stable, neutral, organic compound, made and supplied as a concentrated liquid. In the recommended amount of 4 ounces per bag of cement, it acts as a physical and dispersing agent to produce highly homogeneous cement mixtures and to bring out the best qualities inherent in any aggregate.

This product does have a definite tendency to reduce the required water content by increasing the slump of a normal mixture. Reduction of the water-cement ratio is recognized as being conducive to concrete improvement.

One of the advantages of a reduced water content is a reduction in the percentage of shrinkage. Shrinkage may be

Portite-improved concrete being placed for floor of new garage to house U. S. Post Office trucks at Yonkers, N. Y.

an important consideration in the design of large sections or precise work. In many cases, consistently smaller shrinkage and greater climatic stability would permit fewer expansion joints in the design of the structure.

Concrete, with the subject added, does have increased workability from the workman's viewpoint. The mix has a jelly-like appearance or buttery consistency. All tests made in this study were with a constant water-cement ratio for the sake of comparison. It was noted, however, that the water content very well could have been reduced in the mixes containing the admixture without loss of workability. The slumps were from $1\frac{1}{2}$ to 2 inches greater than those of the normal mixture.

The Newark Testing Laboratories, Newark, New Jersey, reported definite air entrainment characteristics in their tests and examination of Portite for Hopper Products. The entrainment of air would be an important contributing factor to the increased workability and other refinements to concrete wrought by this material.

Another advantage is greater homogeneity with no dusting of the concrete surface, better internal physical balance, and virtually no segregation. The test cylinders made in connection with this report seemed to verify this. After rupture, the internal structure of the cylinders was closely examined under a magnifying glass. It was found that the samples containing the test liquid showed more uniform deposits of fines on the larger sections of coarse aggregate than in the normal mix samples.

When required, absolute integral waterproofness is claimed by the use of 8 ounces of Portite per bag of cement. It is also reputed to have the property of unusual adhesion to brick and old concrete, but these characteristics were beyond the scope of this thesis. They were mentioned merely to include the full range of its uses.

But more important to the builder are the statements that the agent is non-contaminating, non-irritating, non-toxic, unreactive, does not affect the time of set, and has no bad after effects. Also, the Newark Testing Laboratories reported that bond to steel was appreciably increased, while absorption and porosity was definitely decreased.

Regardless of the advantages of an admixture, a contractor should first determine its economy of use. The manufacturer points out the economy of this product by emphasizing simplicity of use and high effeciency. It entails no special handling, is concentrated in form, and stable in storage. Further savings are made by its ease of use,

Driveway at Refined Sugars and Syrups plant at Yonkers, N. Y. Local ground and chemical conditions had always caused serious surface difficulties. Portite-improved concrete laid in 1946, showed no signs of deterioration over one year later.

increased ease and speed of placement of the concrete, and easier and quicker finishing. Further discussion of the economy of the agent may be found farther along in this report.

Because of unfortunate results in the past, it would be wise to investigate the effect of any admixture considered for use upon the ultimate strength of the structure. Irregardless of other beneficial changes an agent may give to concrete, if it requires counter-active increases of cement, the resulting cost may make its use prohibitive. It is for this reason the author determined to check the effect of Portite on the compressive strength of the batch. The following portion of this report is devoted primarily to simple strength tests.

Laboratory Tests

The laboratory tests made in connection with this study were comparitively simple and brief, since this was a preliminary study aimed at investigating the practicability of this product.

Previous to the strength test a simple experiment was conducted showing the presence of and general effect of air entraining properties. Similar samples of the sand, used as fine aggregate in the strength tests, were placed in three identical beakers. Enough water was added to all three beakers to make a harsh, semi-mobile mixture. Portite was added to the second and third beakers, with suction applied to the second beaker to withdraw the air. As a result; the first mixture was harsh; the second mixture, containing sand and water plus the admixture minus air, was also harsh; but the third mixture, containing sand and water plus the admixture with any air it produced remaining, was noticeably more plastic.

Thus, it seems that entrained air in sand improves its placticity. It would seem that this action is due to a reduction of particle interference. This improvement would, similarly, react primarily upon the sand constituent of concrete. It is readily seen that lean mixes will entrain correspondingly more air than rich mixes since the fine aggregate is in relatively high proportion to the total. Therefore, as the cement content increases, the advantage gained by the use of an air entraining agent decreases. The need for improvement in consistency is decreased by the action of the surplus cement, while the percentage of air entrained decreases with the decrease in total proportion of sand.

Consequently, when so few test cylinders are made, it is desireable to make them of a near-average richness. In a problem of the sort there can be only two variables. One of the variables is the constituents, naturally the other is the result which would be the dependent variable.

Since this admixture was advertised as a water-reducing agent, was known to entrain air, and the comparative strength was the unknown; it was decided to vary only the quantities of admixture used. A reduction of the water-cement ratio will generally increase the strength, but many air-entraining agents tend to decrease that important item.

Two sieve analyses were conducted on both the fine and coarse aggregates, and an average value was taken. An average of two dry-rodded unit weight measurements gave a unit weight for sand of 107.5 pounds per cubic foot and a unit weight for gravel of 101.5 pounds per cubic foot.

Several trials showed that the mix that would most nearly approach a theoretical yield of 5.5 bags of cement per cubic yard as well as good grading was a mix of 1:2½;3¼ by volume with a water-cement ratio of eight tenths, or a mix by weight of 1:2.86:3.51 with a water-cement ratio of fifty three one hundredths.

One slump test was made for each differeht percentage of admixture. Each cylinder tested was made in a seperate batch to serve as a check on errors.

Since the degree of workability varies to some extent with the mixing time, it was important to keep the mixing time as near constant as possible. Each batch was mixed by hand for 2 to $2\frac{1}{2}$ minutes, at which time the workability seemed to remain constant.

All of the aggregate needed for the test was spread out and allowed to air dry over night. Corrections were made for the moisture content of both fine and coarse aggregate.

The results of these tests appear in tabular form on the following pages.

Material	Fine Aggregate
Date	April 22, 1948
Type of shaker	Machine
Time of shaking	15 minutes
Weight of sample	1000 grams

Sieve	Total weight retained	Total percent retained	Total percent passing	Fractional percent passing
First Sieve Analysis				
# 4	7.8 gms.	0.78 %	99.22 %	10.01 %
# 8	107.9 gms.	10.79 %	89.21 %	19.34 %
# 16	301.3 gms.	30.13 %	69.87 %	20.95 %
# 30	510.8 gms.	51.08 %	48.92 %	30.18 %
# 50	812.6 gms.	81.26 %	18.74 %	16.33 %
# 100	975.9 gms.	97.59 %	2.41 %	2.41 %
Passing	1000.0 gms.	100.00 %	0.0 %	0.0 %
Second Sieve Analysis				
# 4	4.6 gms.	0.46 %	99.54 %	10.37 %
# 8	108.3 gms.	10.83 %	89.17 %	18.92 %
# 16	297.5 gms.	29.75 %	70.25 %	20.99 %
# 30	507.4 gms.	50.74 %	49.26 %	29.34 %
# 50	800.8 gms.	80.08 %	19.92 %	16.95 %
# 100	970.3 gms.	97.03 %	2.97 %	2.97 %
Passing	1000.0 gms.	100.00 %	0.0 %	0.0 %
Average Sieve Analysis				
# 4	6.2 gms.	0.62 %	99.38 %	10.01 %
# 8	108.1 gms.	10.81 %	89.19 %	19.13 %
# 16	299.4 gms.	29.94 %	70.06 %	20.97 %
# 30	509.1 gms.	50.91 %	49.09 %	29.76 %
# 50	806.7 gms.	80.67 %	19.33 %	16.64 %
# 100	973.1 gms.	97.31 %	2.69 %	2.69 %
Passing	1000.0 gms.	100.00 %	0.0 %	0.0 %

Material	Coarse Aggregate
Date	April 22, 1948
Type of shaker	Manual
Time of shaking	25 times
Weight of sample	3000 grams

Sieve	Total weight retained	Total percent retained	Total percent passing	Fractional percent passing
First Sieve Analysis				
1 "	390.0 gms.	13.03 %	86.97 %	20.42 %
3/4 "	1003.6 gms.	33.45 %	66.55 %	25.34 %
1/2 "	1763.8 gms.	58.79 %	41.21 %	40.26 %
# 4	2971.4 gms.	99.05 %	0.95 %	0.95 %
Passing	3000.0 gms.	100.00 %	0.0 %	0.0 %
Second Sieve Analysis				
1 "	393.5 gms.	13.12 %	86.88 %	16.18 %
3/4 "	879.1 gms.	29.30 %	70.70 %	25.83 %
1/2 "	1654.0 gms.	55.13 %	44.87 %	43.77 %
# 4	2967.1 gms.	98.90 %	1.10 %	1.10 %
Passing	3000.0 gms.	100.00 %	0.0 %	0.0 %
Average Sieve Analysis				
1 "	392.2 gms.	13.07 %	86.93 %	18.31 %
3/4 "	941.4 gms.	31.38 %	68.62 %	25.58 %
1/2 "	1708.9 gms.	56.96 %	43.04 %	42.02 %
# 4	2969.3 gms.	98.98 %	1.02 %	1.02 %
Passing	3000.0 gms.	100.00 %	0.0 %	0.0 %

Characteristics of Mix

Cylinder number	1 & 2	3 & 4	5 & 6
Cement, grams	2,000	2,000	2,000
Fine Aggregate, grams	5,720	5,720	5,720
Coarse Aggregate, grams	7,020	7,020	7,020
Water, grams	1,086	1,086	1,086
Portite, grams.	-0-	6.7	13.3
Portite, ozs./bag	-0-	4	8
Average Slump, inches	1½	2½	3
Workability	Good	Very good	Very good
Segregation	Slight	Negligible	Negligible
Distribution of Aggr. (after breaking)	Varied	Uniform	Uniform
Surface of cylinder (after set)	Smooth	Smooth	Smooth
"Pulling" of gravel (in rupture)	Normal	Normal	Normal

Compressive Strength

Cylinder	Portite/Bag	Force	Strength
7 day strength			
1	-0-	52,500 lbs.	1,857 p.s.i.
2	-0-	51,000 "	1,811 "
3	4 ozs.	58,000 "	2,052 "
4	4 "	56,000 "	1,988 "
5	8 "	64,000 "	2,263 "
6	8 "	65,500 "	2,317 "
Estimated 28 day strength			
1	-0-	78,750 lbs.	2,886 p.s.i.
2	-0-	78,500 "	2,717 "
3	4 ozs.	87,000 "	3,078 "
4	4 "	84,000 "	2,982 "
5	8 "	96,000 "	3,395 "
6	8 "	97,750 "	3,476 "
Average 7 day strength			
1 & 2	-0-	51,750 lbs.	1,834 p.s.i.
3 & 4	4 ozs.	57,000 "	2,020 "
5 & 6	8 "	64,750 "	2,285 "
Average estimated 28 day strength			
1 & 2	-0-	77,625 lbs.	2,802 p.s.i.
3 & 4	4 ozs.	85,500 "	3,030 "
5 & 6	8 "	96,875 "	3,436 "

Conclusions

Within the scope of these tests conducted as a part of this report, the agent showed sufficient merit to warrant further study of its capabilities. It not only did not reduce the ultimate strength in compression, but actually showed an increase for this particular mix. The mixture, even without any addition of admixture, was designed by proper, accepted methods. The author does not believe that any admixture should be used as a substitute for good design techniques.

With the additional strength taken into consideration, the results of a test made with reduced water-content and reduced cement ratio would be the next natural step in the investigation of the practicability of this product. It would be interesting, indeed, to see if the normal strength and the added workability and reduced water content could be maintained in a leaner mixture. That is, replace a small amount of cement with the admixture.

A theoretical example of the cost of using Portite appears on the following page. It would be impossible to obtain accurate cost figures without determining the size and location of the work as well as the cost and availability of all ingredients. Transportation costs figure so highly in the cost of both the cement and the aggregate only a comparative figure can be obtained for the general cost of the agent. It is readily apparent, therefore, that under one set of conditions, only, are these figures correct.

Illustrative Example

Yield

Cement, 1 sack of 94 lbs.	$\frac{94}{3.1 \times 62.4}$	= 0.486 cu. ft.
Sand	$\frac{94 \times 2.86}{2.65 \times 62.4}$	= 1.624 " "
Gravel	$\frac{94 \times 3.51}{2.65 \times 62.4}$	= 1.988 " "
Water, 6.7 gal.	$\frac{6.7 \times 8.33}{62.5}$	= 0.888 " "
Absolute volume of one-sack batch		= 4.986 " "

Quantites Required for One Cubic Yard of Concrete

Cement = $\frac{27}{4.986}$ = 5.42 sacks = 1.33 bbl. = 4[illegible]9 lb.

Sand = 5.42 x 94 x 2.86 = 1,457 lbs. = 0.729 ton

Gravel = 5.42 x 94 x 3.51 = 1,788 lbs. = 0.894 ton

Water = 5.42 x 6.7 x 8.33 = 302 lbs. = 36.3 U.S. gal.

Portite = 5.42 x 4 = 21.68 ozs.

Example Costs

Cement	= $3.00 x 1.33	= $3.99	per cu. yd.
Sand	= $2.00 x 0.729	= $1.46	" " "
Gravel	= $2.25 x 0.894	= $2.01	" " "
Total without Portite		= $7.46	" " "
Portite	= $0.023 x 21.68	= $0.50	" " "
Total with Portite		= $7.96	" " "

In the above illustrative example, the cost of Portite, used in 4 ounces per sack doses, would be $0.50 per yard or 6.7% of the total cost of all other ingredients.

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This study is by no means a complete investigation of the subject. On the basis of the characteristics of Portite as demonstrated by test or by observation, however, a few general uses of the product present themselves.

The advantage gained runs in an inverse proportion to the richness of the mixture. As a converse theory, it is to be expected that the agent might well be a desireable addition to a lean mixture that exhibited harsh characteristics.

The water-reducing factor could be put to good use to reduce bleeding and to decrease the amount of time required for finishing work. One contractor stated that this water reduction made it possible to trowel-finish floors 2 to 2½ hours earlier than before. On an average pour for that particular structure that meant a saving of approximately $ 1.10 per yard in concrete finishing time.

The reduction of segregation is most important on those jobs where chutes are used. This can mean an appreciable lowering of handling costs. Further, considerable effort can be eliminated on intricate form pours by the increased workability.

The reader will find no evaluation of these qualities in the theoretical example. No two jobs would present the same difficulties, so no comparison is possible in the time allowed. The author suggests consideration of the use of Portite in the danger of segregation or excessive labor costs and time delays on finishing work. If subsequent tests show that this admixture is a consistent air-entraining agent, its field of use could be broadly expanded. It is wholeheartedly recommended, therefore, that the subject of the air-entraining characteristics of this agent be considered as a worthwhile future thesis.

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T. C. Powers

Materials

The Portite used in this experiment was furnished by Portite Division of Hopper Products, Inc., 12 East 41st Street, New York 17, New York, through the courtesy of Mr. Edward T. Campbell. All cement and aggregate was provided by the cement laboratory of Michigan State College.

ROOM USE ONLY