EFFECT OF ADMIXTURES ON CEMENT MORTARS AS SHOWN BY PHOTO-MICROGRAPHY

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE

Jack C. Mackie

1942

Effect of Admixtures on Cement Mortars as Shown by Photo-Micrography

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

by

JACK C. MACKIE

Candidate for the Degree of

Bachelor of Science

June 1942

THESIS

Acknowledgment

To Professor Mallman in the Bacteriology Department and Doctor Swanson of the Botany Department for their kind cooperation and the use of their photomicrographic equipment and to Professor Allen for his advice and consultation.

Introduction

The problem of the weakness of cement in tension has been known to exist for some time. It is hoped that this thesis will be a step in the direction of strength analysis of concrete by photo-micrography, as it is now being widely used in other fields of stress analysis. The scope of this thesis is necessarily limited due to lack of equipment and time, but since it is herein shown the reason for the failure of cement under stress, logical steps may be taken to prevent such failure.

An outline of the general procedure follows:

I A suspension of cement in water is photo-micrographed.

II To the above mixture of cement in water is added the the following admixtures and each one photo-micrographed separately,- Calcium chloride, red mineral oxide (pigment), pozzolith, and sugar.

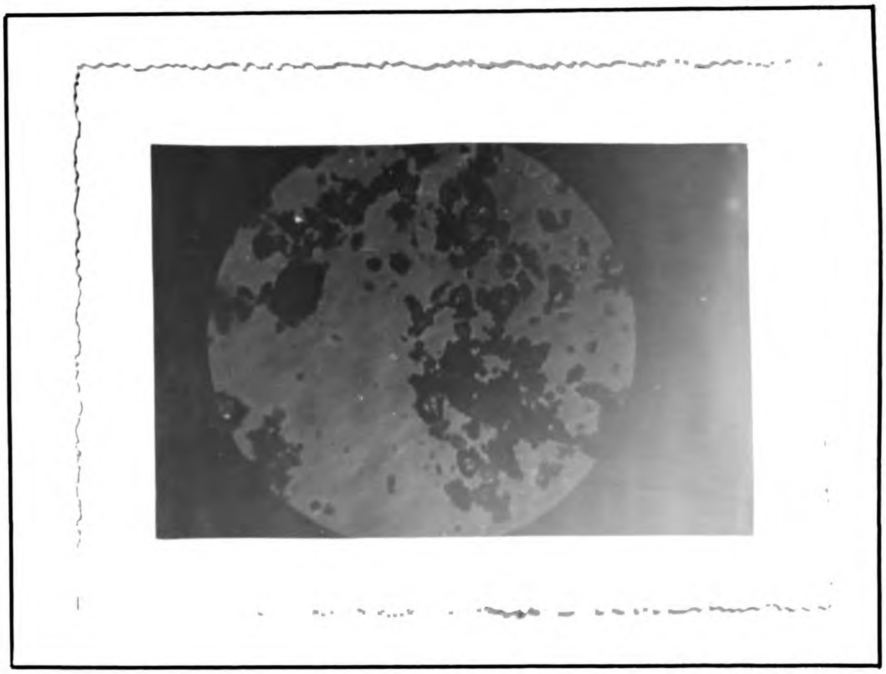
III Four briquets are molded of each type (admixture) and two of each type broken at the end of seven days curing in a moist closet, and a photo-micrograph made of each break.

IV The remaining two briquets of each type are subjected to a freezing and thawing cycle and then broken in tension.

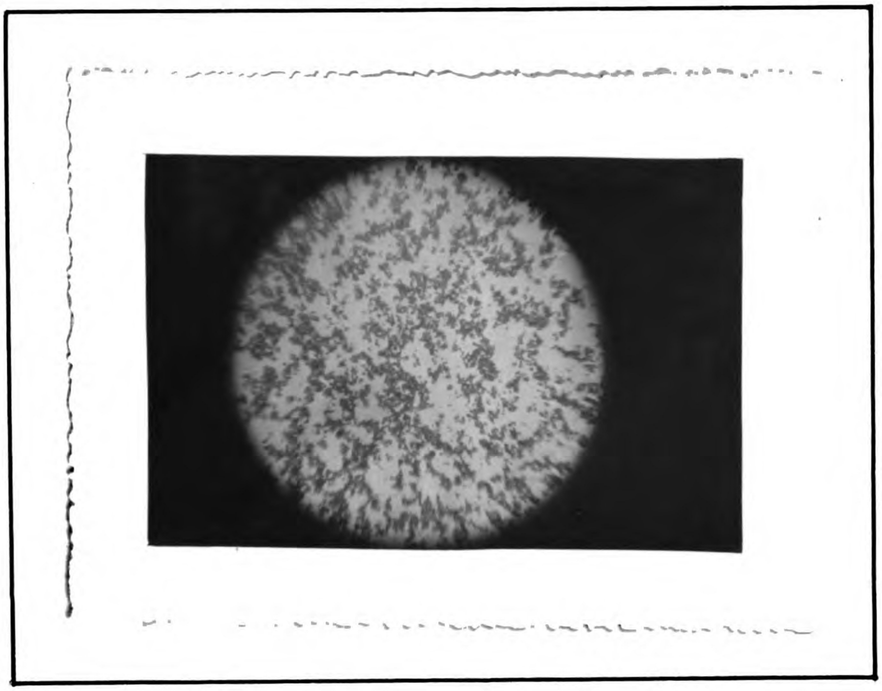
A mortar was chosen merely as a convenience, assuming that the same general theories evolved in this thesis will be applicable to concrete as well. A fine lake sand passing the number 30 sieve but retained on the number 50 sieve was used to insure uniformity in photographing. The mix used was 3 parts sand to one part cement with water added to produce a standard workable mix. Approximately 15% by volume of admixture was added in each case to insure positive results, the exact amount not being determined, as it is not within the scope of this thesis to determine or corroborate already established facts.

The calcium chloride was added by dissolving it in the mixing water, but the other admixtures were added in the dry state. In the case of the pozzolith, care was taken in regards to the amount of mixing water as a very plastic mix of standard quality was obtained with about half the quantity of mixing water used in the other samples. The sample containing sugar also produced an amazingly workable mix with small amounts of water.

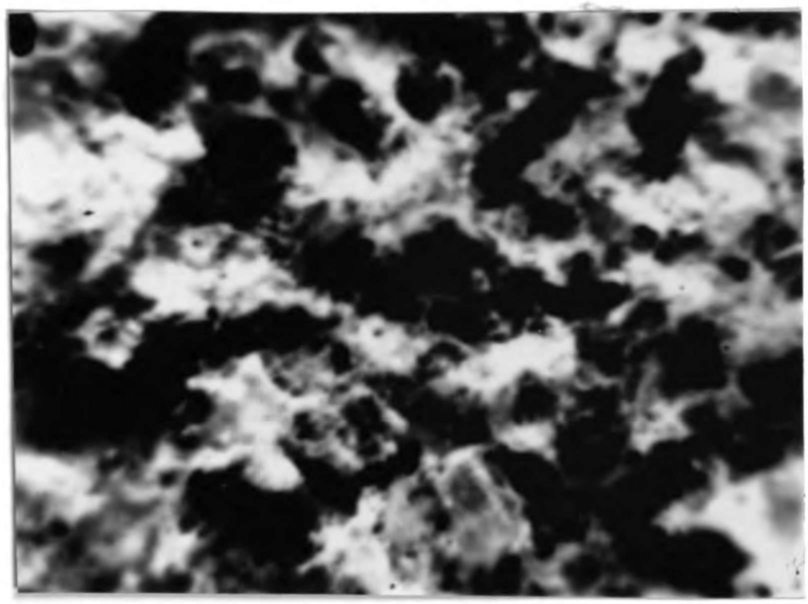
PLAIN CEMENT



This is a 450 diameter magnification of cement thoroughly mixed with water. The actual cement particle size is shown by the smallest particles floating in free suspension. The large masses or clusters are made up of hundreds of smaller individual particles, clinging together in such fashion by cohesive forces so that the water cannot penetrate or break up the cluster. This sample was thoroughly mixed and shaken, so on the average job with rapid or poor mixing, this condition is probably much worse. Of course each large cluster will act as a smaller particle and hydrate to a certain extent upon setting, but it is easily seen that the strength of the resulting concrete will be somewhat inferior to a properly hydrated cement.

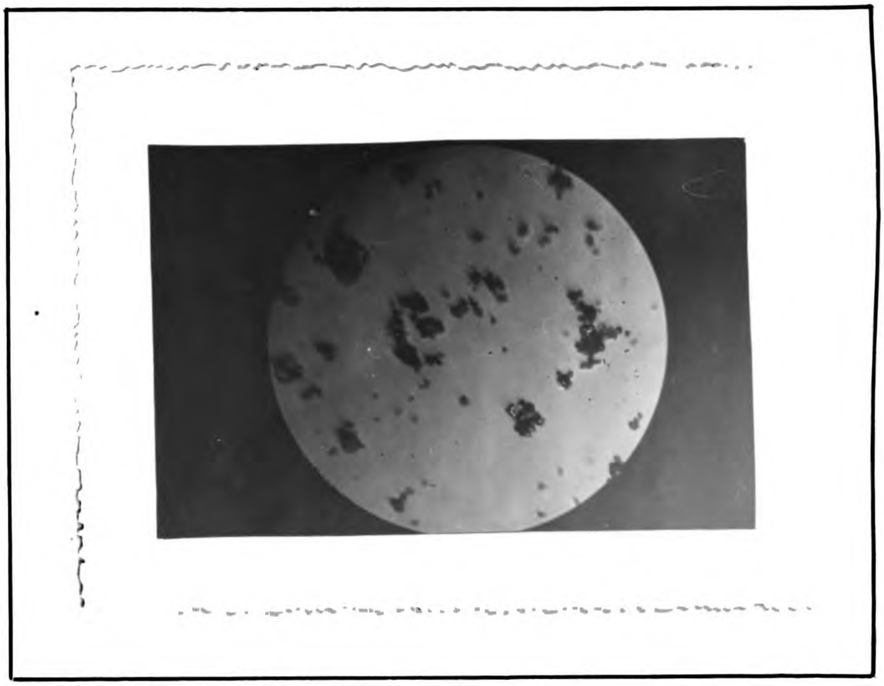


The above photograph is of the same subject, but of lower power magnification,-100 diameters. It covers a much broader field, showing that the tendency for cement particles to cluster is a general rule rather than the exception, each spot on the photograph being a separate cluster at low power magnification, except those in free suspension which are protected by a surrounding film of water. When these clusters are broken up or dispersed, the resulting concrete will be much superior in strength.



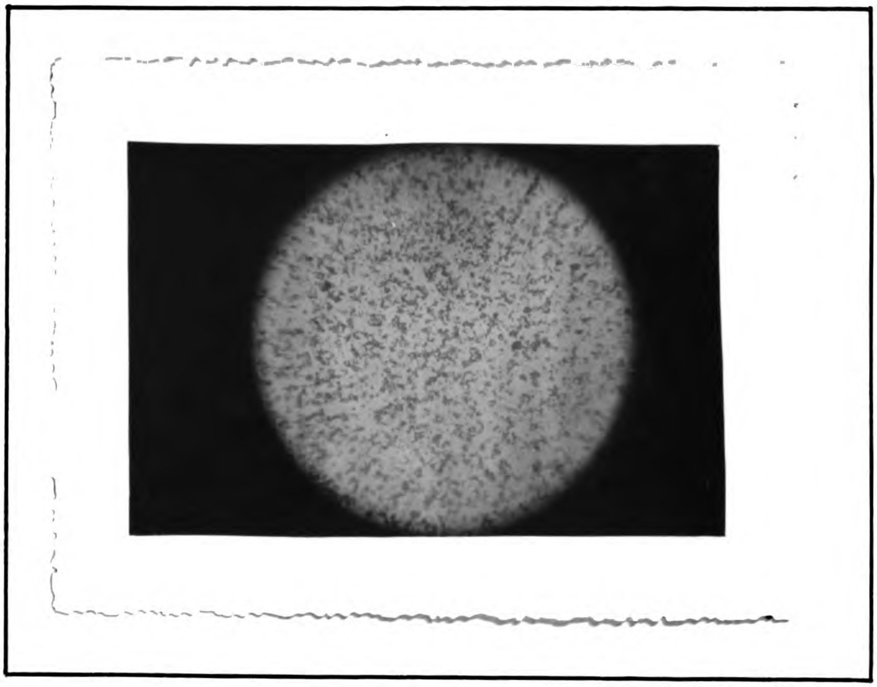
The above is a photo-micrograph taken at the break of a plain cement mortar briquet. Due to the extremely small depth of focus on the high powered lens, the focus is not too sharp, so it is slightly clearer at arms length. The general structure has a tendency to be rather coarse and honeycombed as shown by the black portions which are deep shadows. There were no cracks caused by breaking, but the effect is that it is splotchy and non-homogeneous, indicating a loose structure.

CALCIUM CHLORIDE

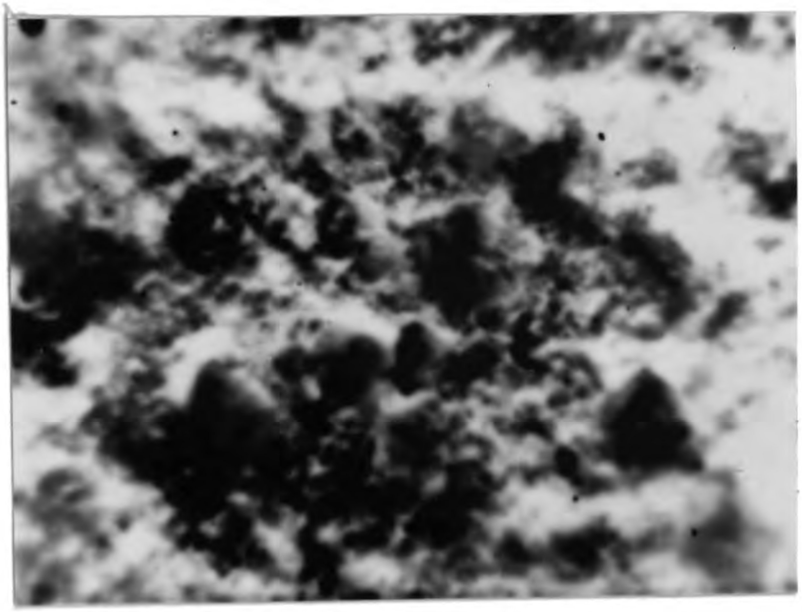


The above is a 450 diameter photo-micrograph of a solution containing water, cement, and calcium chloride. The general tendency is the same as that of cement,-to form clusters, but on careful scrutinization it will be seen that each particle is protected from becoming united with any other by a layer of calcium chloride. Although they still tend to group together by cohesive forces, each particle is permitted to hydrate thoroughly since it cannot combine with other particles in one large lump, therefore its ability to produce high early strength. The clusters in general seem to be smaller than those in the plain cement, exhibiting a mild tendency toward diffusion.

Perhaps the main reason for all this high early strength is the fact that since each particle is surrounded with a layer of calcium chloride, upon drying of the cement, the calcium chloride will effloresce, supplying more water for the cement particle to hydrate, thusly producing the high early strength.

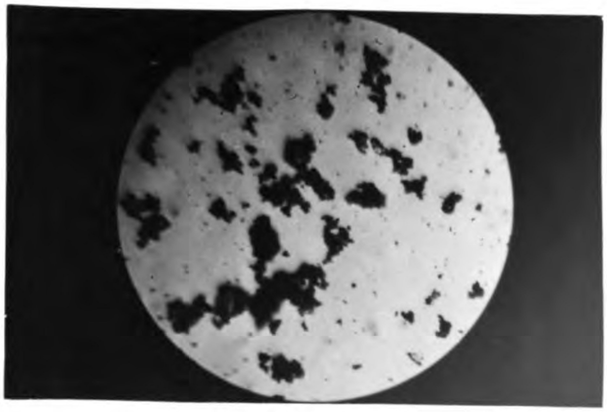


The above is also calcium chloride, but magnified only 100 diameters to cover a broader field of which the preceding photo-micrograph shows the detail.

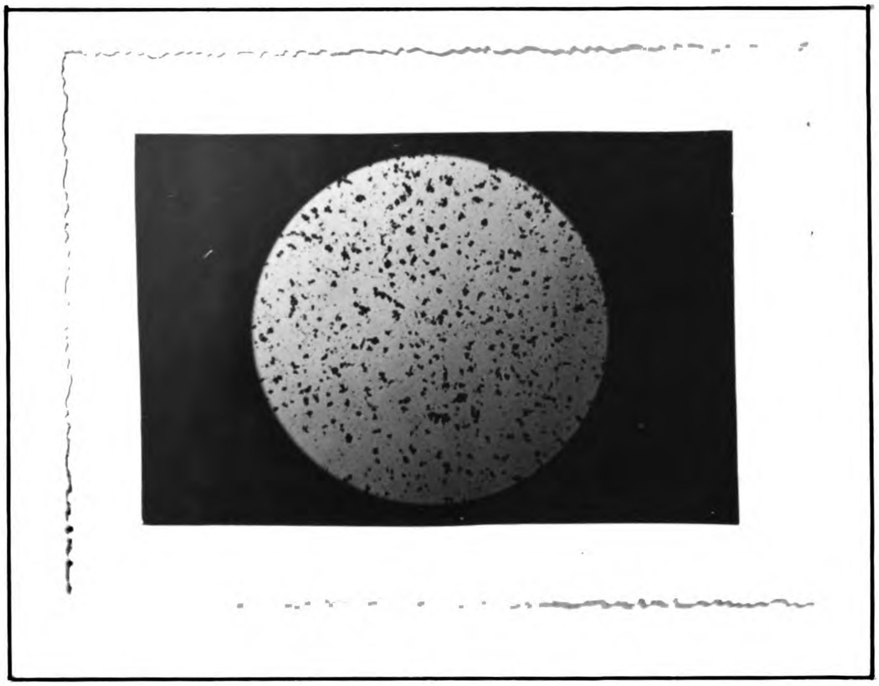


This is a photo-micrograph of a mortar briquet containing calcium chloride, broken at the end of seven days curing in a moist closet. There are several cleavage cracks, but the mix appears to be quite smooth comparatively,- more homogeneous, anyway, than the plain cement mortar. The black portion is shadow, indicating a depression at that point. When the photograph is splotchy, it indicates that large clumps, or clusters of the material have pulled out under tension instead of failing on a single plane as should a true homogeneous mix.

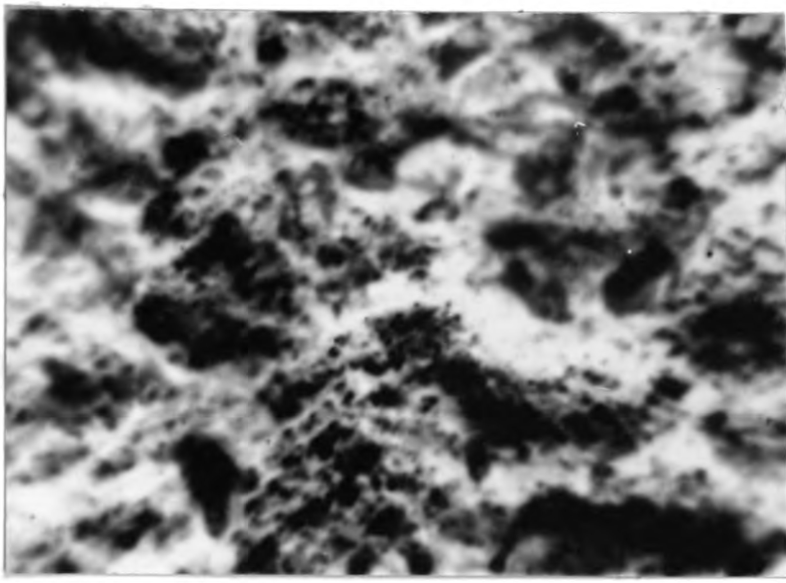
PIGMENT



The above is a photo-micrograph of pigment (mineral oxide) mixed with cement and water. A panchromatic film was used in photographing, so the colors are all equally represented although the pigment particles cannot be distinguished from the cement particles. This photo is characterized not by the dispersion effect, but by the density of the clusters. These smaller clusters are more compact than those of plain cement and do not string out in chains nearly so much showing the condensing effect of the pigment producing a higher strength concrete as shown by the graph drawn upon testing the briquets in tension.

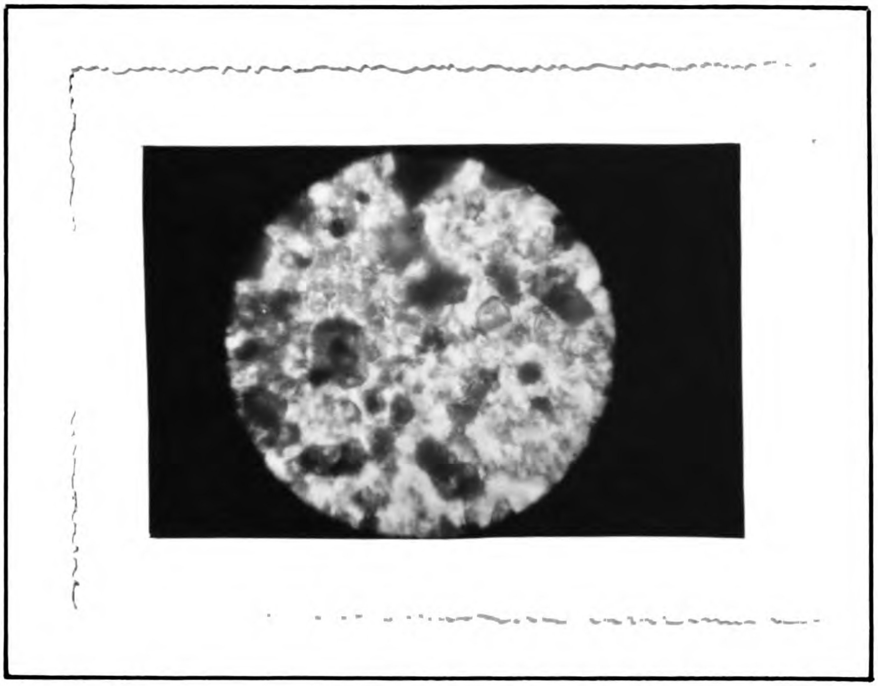


This 100 diameter photo-micrograph of the pigment is again reduced in power to cover a much broader field. Again the small clusters are shown to be concise and compact and not nearly as chain-like or stringy as the plain cement particles. The smallest specks on the photo are free pigment particles which when upon subsequent mixing with aggregate will condense to fill in the voids, producing a more dense mix resulting in a higher strength concrete.



This is a photo-micrograph of 100 diameters, of cement mortar containing mineral oxide pigment. This structure produced higher strength than did the structure of the plain portland cement mortar. There is less splotchiness, showing greater homogeniety, especially in the upper center of the photograph. The density appears to be greater also as evidenced by the closely packed particles indicating a tendency to get away from clumping of the mix as shown in the photo-micrograph of the plain mortar briquet.

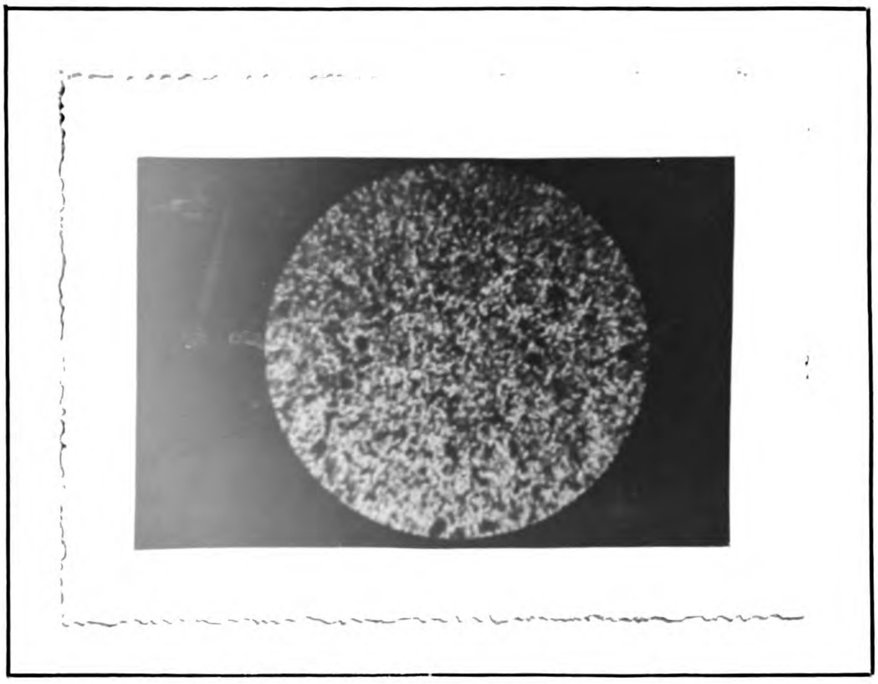
POZZOLITH



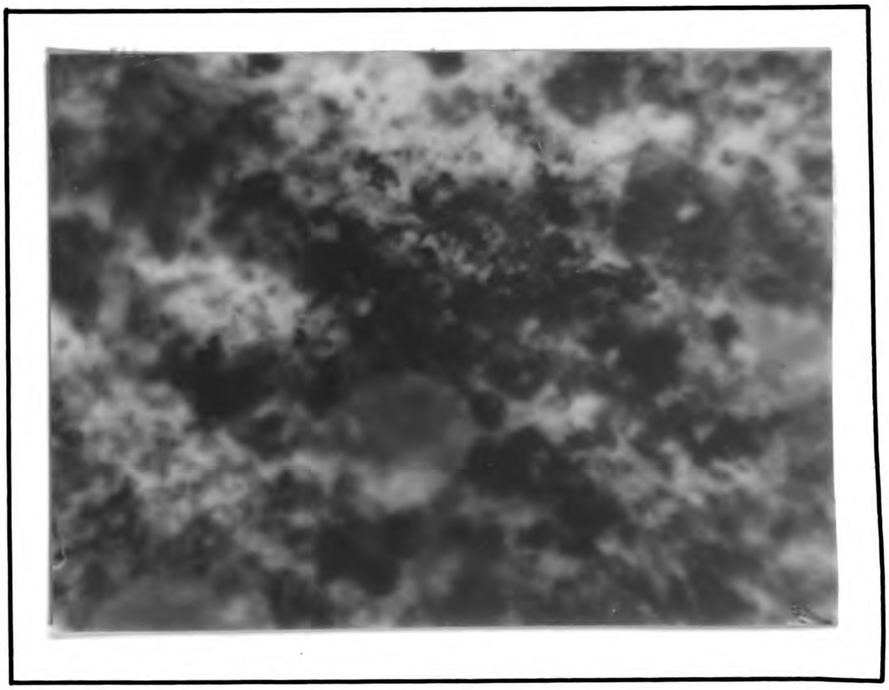
This is a high power (450 diameter) photo-micrograph of a suspension of cement in water with pozzolith added. This photograph is remarkable in comparison with the plain cement. The larger, dark particles are cement whereas the light grey fine ones are the minute pozzolith particles. Due to the near-transparency of the pozzolith, it does not show up too well in the photograph, but the principle is there.

The pozzolith particles are practically spheroids in shape contrasted with the highly irregular shape of the cement particles. Pozzolith in the dry state practically seeks its own level much as a pile of fine buckshot would, being almost frictionless, but much lighter in weight than the buckshot. The pozzolith, being so free-flowing, upon mixing, penetrates the cement clusters and breaks them up allowing for more thorough hydration of the particles and at the same time, the fine pozzolith tends to fill the voids producing a more dense mix.

While being viewed under a microscope, the slide was moved slightly and the very small pozzolith particles were observed to flow very freely, due to the lack of friction as before stated. It was this motion which caused the agitation and wearing on the clusters until they were thoroughly broken up, producing complete dispersion.

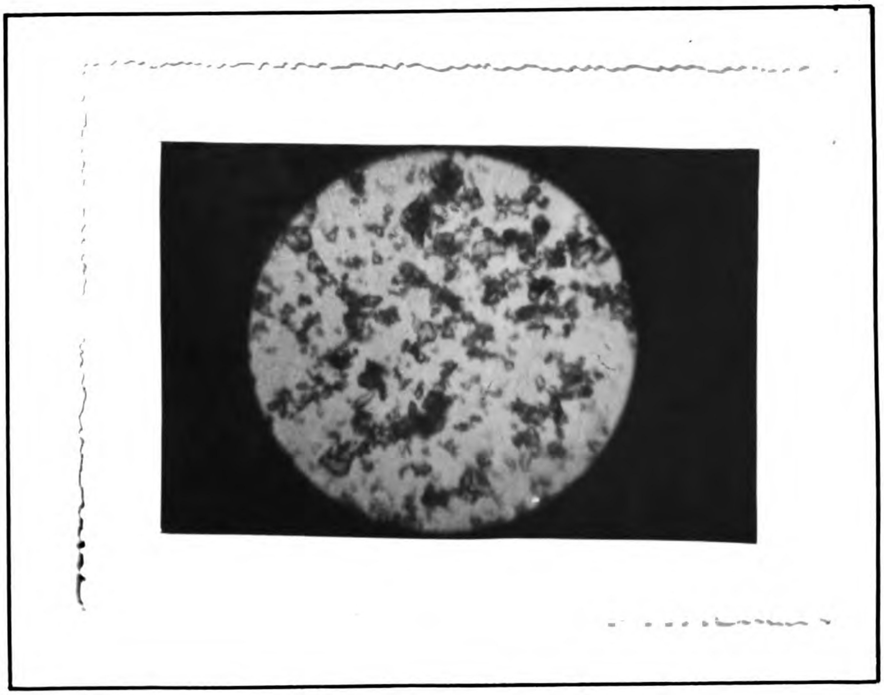


This 100 diameter photograph of the pozzolith speaks for itself. Over the broader field, there are no clusters;-the pozzolith mixes thoroughly with the cement particles and complete dispersion is observed.

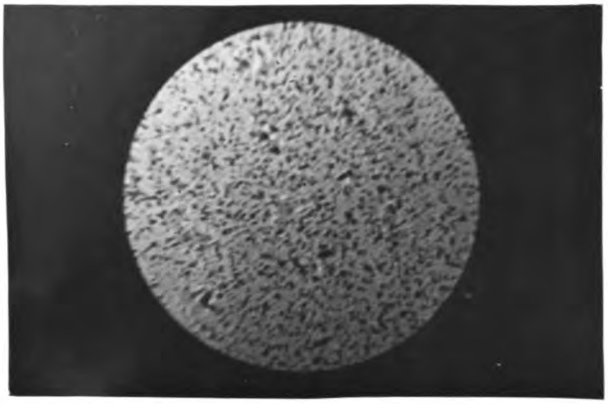


This photo-micrograph of 100 diameters is the cement mortar containing 15% pozzolith. As shown, there is practically no grouping of the mix in large clusters, but the opposite, namely, the extremely even distribution of the particles and on careful examination, the great density of the mix. It is apparent that this admixture, administered in the proper quantities, is the most desirable of the group of admixtures under observation.

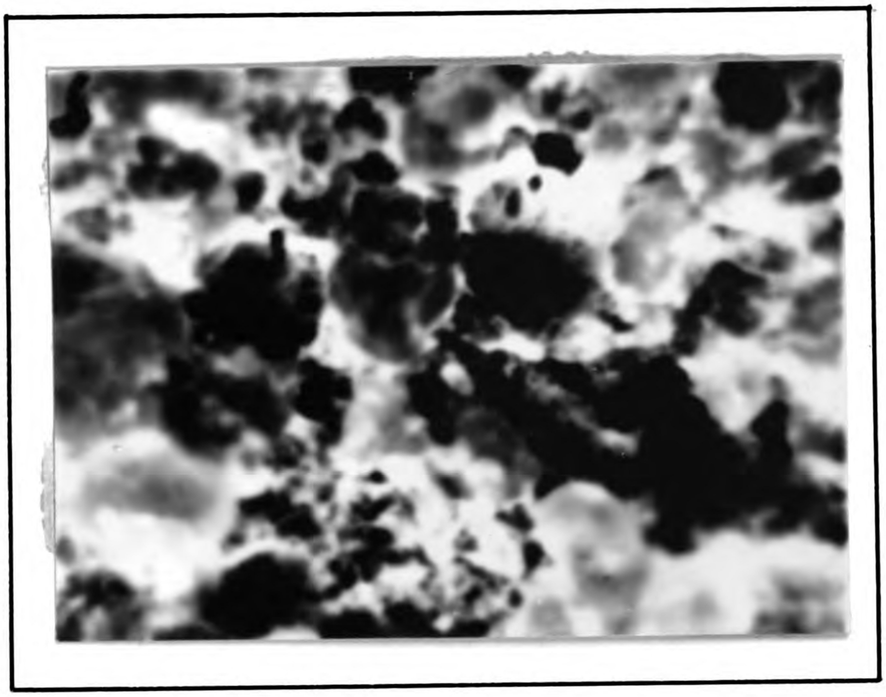
SUGAR



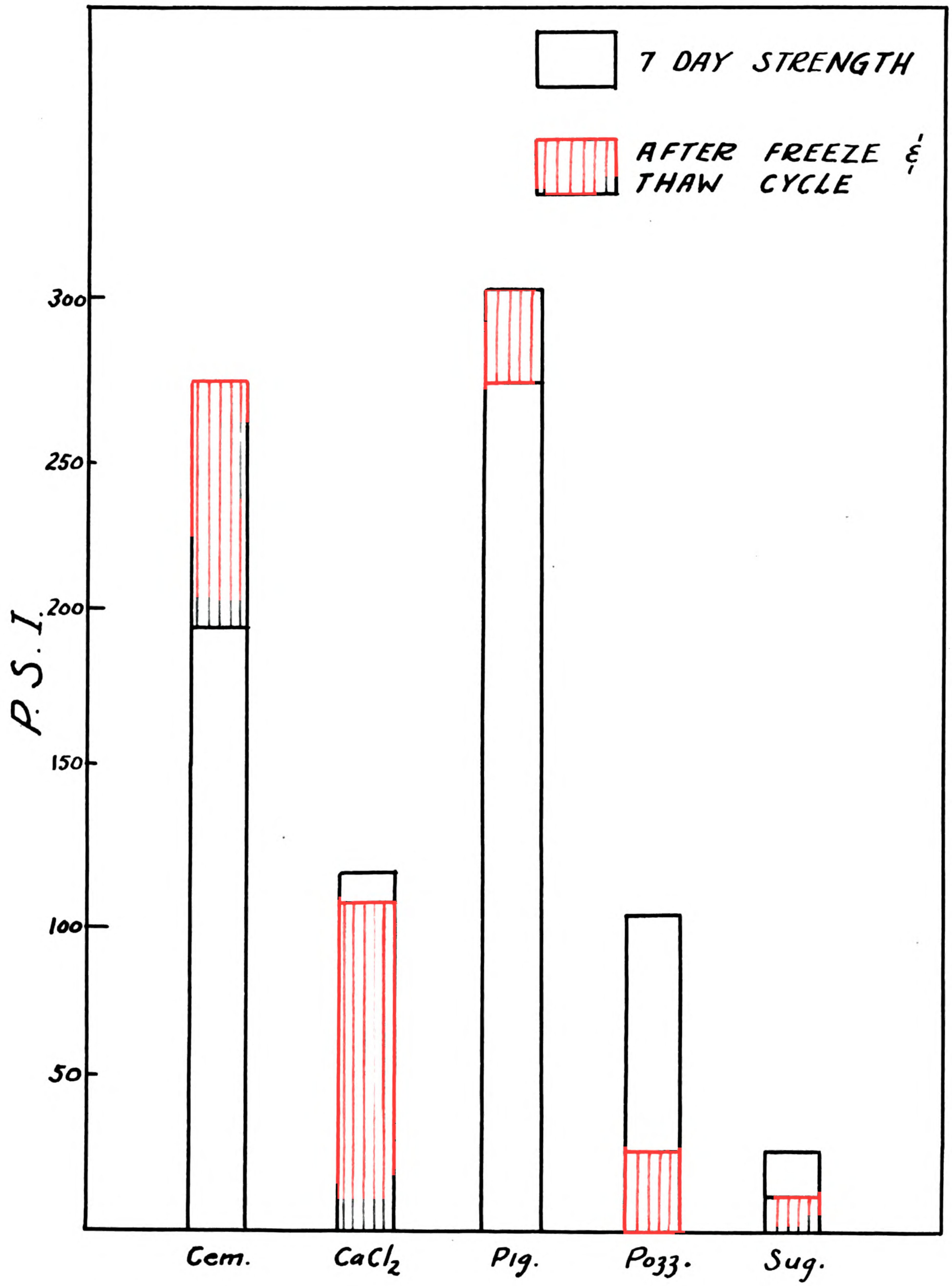
This is a 450 diameter photo-micrograph of a suspension of cement in water with 15% sugar added. Sugar does nothing toward dispersion but instead, a certain amount of sugar is absorbed on the outer surface of the chain-like clusters which not onlyprevents correct hydration, but when the concrete sets, the sugar dries out also and becomes crystalline, and with a crystalline structure at the inter-granular boundary of concrete particles it can readily be seen the reason for the decrease in the strength of a concrete by the use of sugar as an admixture, accidentally or other-wise.



This 100 diameter photo-micrograph of sugar in the mix does not show a great deal except cover a broader field and showing that while sugar will produce a very plastic mix, it does not do it by good dispersion, as the tendency is still toward clusters of the dement particles.



This 100 diameter magnification of the hardened cement mortar briquet contains sugar as an admixture. This is the poorest admixture that could be possible added, even though it produces a very plastic mix. The deep shadows indicate the place where a large clump has pulled out under the tension instead of failing on the face of a single plane. The poor dispersion and the large number of cracks (not too clear on this picture) are further reason for care being taken to exclude sugar being used as,and for,an admixture.



TENSILE STRENGTH OF MORTAR

Conclusions

The ambiguity of the bar graph is due to the fact that although the freezing and thawing cycle was going on, the briquets were also aging and gaining strength at the same time. The poor showing of the pozzolith was due to the fact that such a large percentage of this admixture was used to show up conclusively in the photo-micrographs. Ordinarily only about 2% or 3% is added, but in this case it was about 15%.

After the freezing and thawing cycle it was the sugar sample that definitely failed. This was due to the breaking up of the sugar crystals under the expanding and contracting,- leaving almost no binder between the sand particles. The other briquets when examined after being subjected to the freezing and thawing cycle showed no appreciable difference under the microscope so they went un-photographed.

In general, it has been shown that this method of analysis of concrete has proved satisfactory. It is common knowledge that calcium chloride will give concrete high early strength or that sugar in the mix will decrease the strength of a concrete, etc., etc., but this thesis has shown <u>why</u> admixtures effect concrete in this manner.

ROOM USE ONLY