TESTING FOR DELETERIOUS MATERIALS IN CONCRETE AGGREGATES

By F C Lang, *Engineer of Tests and Inspection, Minnesota Highway Department*

SYNOPSIS

The harmful effects of deleterious substances in aggregates were tested by means of concrete beams in which the coarse aggregate was composed entirely of particles of the materials under suspicion The beams were tested in flexure and subjected to freezing and thawing Breakage under freezing and thawing and low structural strength indicated the materials which had bad effects This appears to be a better method of testing than freezing and thawing of the aggregates alone

Specifications for concrete aggregates have always contained some statement about deleterious materials The earlier ones simply stated that they should not be used and then left their identification entirely to the engineer or inspectors on the job In later specifications some substances have been named and the maximum allowable percentages have been given Aside, however, from naming a few of the best known deleterious substances, the latest standard specifications are still vague as to what constitutes such materials The probable reason for this indefiniteness is that there is no standard test method for measuring the harmfulness of any particular substance which may be under suspicion In this paper the solution of one particular problem is described It is believed that the same or similar methods could be used for measuring the harmfulness of any deleterious material

The particular problem in Minnesota was whether or not particles containing iron oxide were similar to shale in their action in concrete pavements A contractor was about to open a new gravel pit in which there were such particles and he had to know what percentage would be permitted

The Minnesota Highway Specifications stated that—"The maximum permissable quantity of shale or other materials having similar characteristics shall not exceed 0 4 per cent by weight for that portion retained on the $\frac{3}{4}$-in screen and for the entire sample 0 7 per cent by weight "

It was decided to make strength and freezing and thawing tests on 2 by 2 by 10-in concrete beams, in which the coarse aggregates were to be entirely composed of the deleterious materials and all other conditions were to be the same Only one type of particle containing iron oxide was used as coarse aggregate The size of the specimens made this possible The concrete was proportioned 1 2 655 3 571 by absolute volume with 5 56 gallons of water per sack of cement The maximum size of the coarse aggregate was $\frac{3}{4}$ in The concrete was vibrated in the forms, then given 24-hr wet burlap cure followed by a 48-hr steam cure after which they were immersed in water for 24 hr High early strength portland cement was used Four beams were made for each aggregate Two of these were placed in the moist curing room, the other two were alternately frozen and thawed Prior to freezing the beams were placed in metal trays The water in the tray was 0 2 in deep after the beams were in the tray They were then placed in the freezing chamber where the temperature was $-10°$F for $3\frac{1}{2}$ hr after which they were immediately immersed in the thawing tank for $1\frac{1}{2}$ hr The water in the thawing tank was kept between 75° and 80°F by thermostatic control. After each cycle the beams were given a quarter turn.

Figure 1 is view of a pavement built a few years before with some particles containing iron oxide in the coarse aggregate which shows the popping that is characteristic of shale. The dark surface around the hole is an iron oxide stain. At the time this pavement was built the specifications limited the amount of shale but contained nothing about other materials having similar characteristics. This indicated that the action of some particles containing iron oxide in concrete was similar to that of shale. In the new pit, however, there were a number of different kinds of

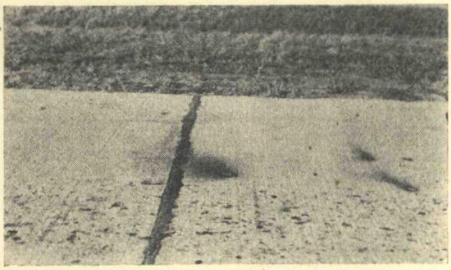

Figure 1. Effects of Certain Types of Iron Oxide Particles in Concrete Pavement.

such particles and a decision had to be made as to the percentages of each that would be permitted in the coarse aggregate. Figure 2 shows some of the different kinds of particles containing iron oxide found in this pit. These are described as follows:

Types 1B, 1B1—"chocolate bars and niggertoes"—ferrous material around a core of distinctly different composition and color. The composition of the core varies from a hard granular material to a fine grained material such as clay. The texture of the shell is very fine and usually shows a laminated structure. In some instances the core and shell are found separately in a gravel pit. The separated core is shown in Type 1A. The shell is shown in Type 2B. Because of the discoloration from the core the shell, type 2B, appears in the photograph about the same as types 1B or 1B1, which contain the core.

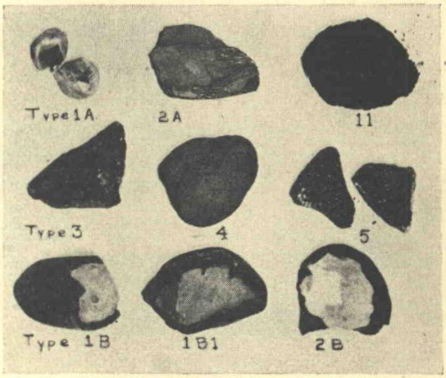

Figure 2. Types of Iron Oxide Particles

Types 2A and 3 are particles composed throughout of a formation similar to the shell material shown in type 2B.

Type 4—Ochre—red to rust color. These particles are very light, chalk easily and are highly absorptive.

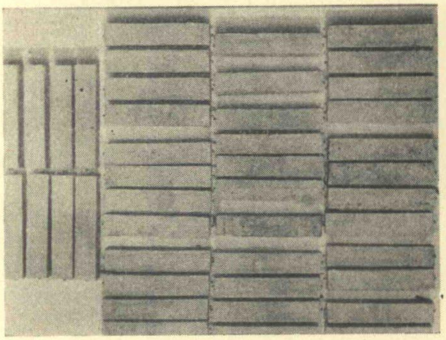

Figure 3. Beams Before Being Tested

Type 5—Iron cemented particles—these pieces are heavy, hard and of granular texture and not very absorptive.

Type 11—This particle is black, has open structure, and has the general appearance of charcoal.

Figure 3 shows the beams before the freezing and thawing tests were made.

The metal plugs in each end were for measuring the linear expansion. A full set consisted of four beams. Two were placed in the moist curing room and tested in flexure at the end of 28 days, the other two were subjected to the freezing and thawing cycles.

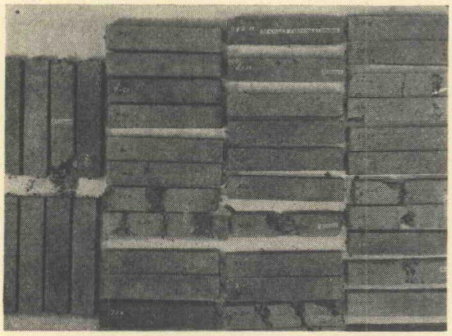

Figure 4. Beams After Freezing and Thawing.

while in some they are apparently undamaged. In addition to the sets in which particles containing iron oxide were used as coarse aggregate, there was one set containing shale and two in which aggregates of established quality were used. The beams were considered as failed when they broke into two or more pieces.

The first failure occurred at 11 cycles for the shale aggregate. There was considerable variation in the number of cycles at which failure occurred when the different types of particles containing iron oxide were used as coarse aggregate. The first failure was at 14 cycles and one set of beams was intact at the end of 35 cycles. After looking at these beams the producer and other interested parties raised no question about the harmfulness of certain particles containing iron oxide in concrete aggregates.

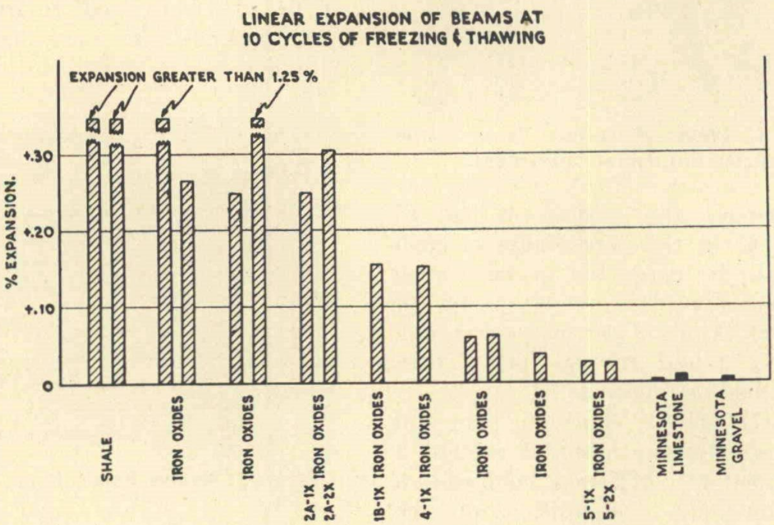

Figure 5

The same beams arranged in the same order after several cycles of freezing and thawing are shown in figure 4. The beams that have been frozen and thawed are badly broken in many sets

Figure 5 shows the linear expansion of the concrete beams after 10 cycles of freezing and thawing. The expansion of the beams containing standard coarse aggregates is shown at the right and at the left the expansion is shown when shale was used It is apparent that between these two extremes there is a considerable variation in the expansion of the beams containing different types of iron oxide particles The two at the left showing the most expansion were type 2B (shells of "niggertoes") and type 3 (the solid particle of material similar to the shells)

The aggregate freezing and thawing test (A S T M C-137-38T) was made on shale and the various types of par-

Beams containing shale as aggregate failed at 11 cycles while in the freezing and thawing test on the aggregate shale showed very little more loss in fineness modulus than the aggregate in the beams which survived 35 cycles

Figure 7 shows the modulus of rupture of the beams at 28 days and the number of freezing and thawing cycles at failure There is no correlation and none is to be expected The figure is shown to illustrate the fact that non-expansive particles may be deleterious on account

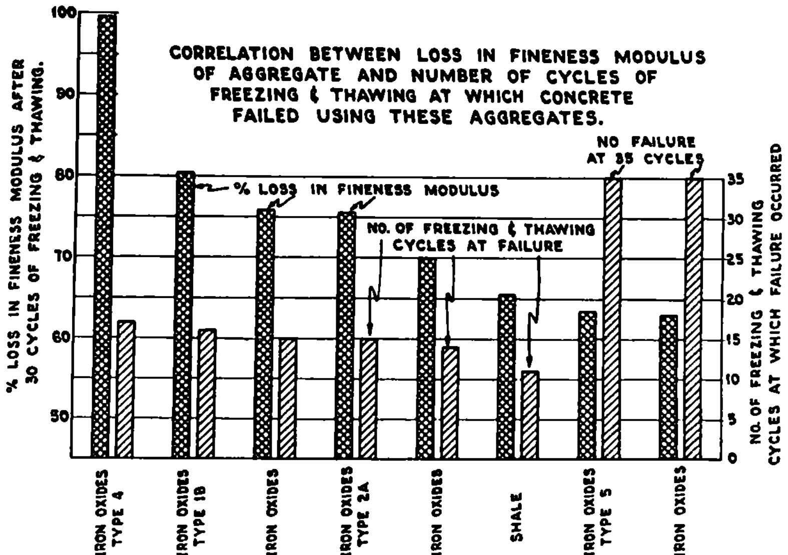

Figure 6

ticles containing iron oxide The column cross-hatched in two directions at the left of each pair in figure 6 shows the percentage of loss in fineness modulus of the aggregate after 30 cycles of freezing and thawing The other column cross-hatched in one direction shows the number of freezing and thawing cycles of the concrete beams at failure It is quite apparent that there is very little, if any, correlation between the loss in fineness modulus in the aggregate test and the resistance of the concrete to disintegration from freezing and thawing

of their low structural strength As an illustration the third type from the right would pass if the specifications required only 25 cycles of freezing and thawing of the concrete beams but would fail if a modulus of rupture of 700 were required

At the completion of the test the beams were examined and a decision was made as to which type of particles containing iron oxide did not comply with the specifications All particles containing iron oxide were considered to have the characteristics of shale when beams in which they were used as coarse aggregate failed at 20 cycles or less

After this decision was made it was necessary for the contractor to remove had been removed and the pebbles washed The belt was 48 in wide, 14 ft long and moved at a speed of 65 ft per min

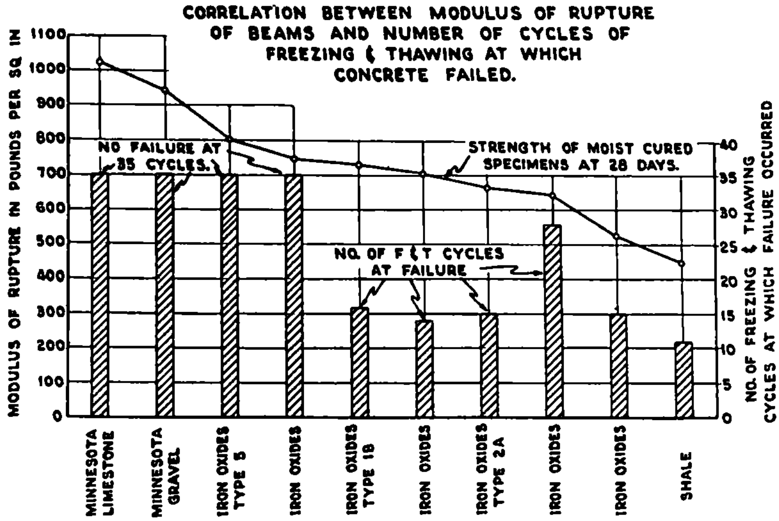

Figure 7

the excess objectionable material. This was done by hand-picking in two different places. Figure 8 shows one gang of pickers At this point the sand

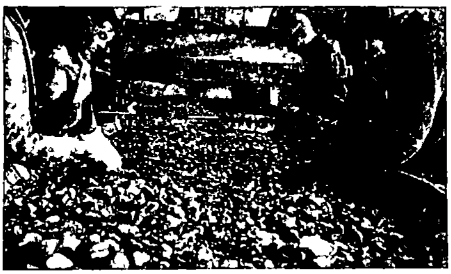

Figure 8. Hand Removal of Objectionable Particles at Gravel Pit.

After picking the gravel was placed in separate piles of about 40 tons for inspection Rejected material was run through the plant and passed by the pickers a second time

This paper illustrates a method of measuring directly the harmfulness of certain deleterious materials when used in concrete There appears to be no question but that this method of testing more closely approaches the conditions of service than freezing and thawing the aggregates separately It has the further advantage that the test is easier to make More thought should be given to this method of testing expansive and structurally weak materials in aggregates