OFFICE MEMORANDUM

MICHIGAN
STATE HIGHWAY DEPARTMENT
JOHN C. MACKIE, COMMISSIONER

December 30, 1960

To: W. W. McLaughlin
Testing and Research Engineer

From: E. A. Finney

Subject: Investigation of Thorite Filling and Patching Compound for Sealing Core Holes in Box Type Prestressed Beams. Research Project 60 B-53. Report No. 354.

As requested in your memorandum of October 25, 1960, we have tested the subject material and are submitting the following report by M. G. Brown.

For comparative purposes laboratory tests were run on Thorite and an Embeco mortar mix proportioned as specified in Article 5.01.15 of the Michigan State Highway Department 1960 Standard Specifications.

Accelerated Freezing and Thawing Tests

Four air-entrained concrete beams, 3 by 4 by 16 in., were cored with a 1-in. diamond bit. Four equally spaced holes in each beam were filled alternately with the two materials to the full depth of the 3-in. dimension. The Embeco mixture had a consistency of 100 flow, and the Thorite had approximately the same consistency when proportioned according to the manufacturer's directions. The extremely short setting time of the Thorite precluded flow measurement.

After curing under polyethylene in laboratory air for seven days, two beams were subjected to freezing and thawing in water and the other two to freezing and thawing in a 2-percent rock salt solution at the rate of 6 cycles a day. Figs. 1 and 2 show the condition of the plugged beams after 96 and 66 cycles of freezing and thawing in water and in brine, respectively. The tests were discontinued at 130 and 100 cycles. These pictures show that the Thorite plugs held up almost as well as the Embeco in this test. Both showed some breakdown on the plug tops and bottons.

Incidentally, the influence of air entrainment on the durability of concrete is again graphically illustrated in the pictures of beams frozen and thawed in brine (Fig. 2). The beam containing no intentionally entrained air failed earlier than the Thorite plug and much earlier than the Embeco.

Flexural and Compressive Strength

Strength tests were made on 1- by 1- by 12-in. mortar beams moist cured for 1, 3, 7, and 14 days. Two beams for each material at each age were broken by third-point loading. Three breaks were made on each beam and the resulting four pieces were tested in compression as modified cubes.

Results are shown in Tables 1 and 2. One-day strengths of the two materials are comparable, but at later ages the Embeco mortar was considerably stronger than the Thorite.

TABLE 1
FLEXURAL STRENGTH

Material	Flexural Strength, psi*			
	1 day	3 days	7 days	14 days
Thorite	364	486	497	555
Embeco	293	776	953	1110

* Average of six breaks

TABLE 2
COMPRESSIVE STRENGTH

Material	Compressive Strength, psi*			
	1 day	3 days	7 days	14 days
Thorite	738	1225	1525	1816
Embeco	937	3212	4837	5100

* Average of eight tests, modified cubes

Shrinkage

Volume change upon setting and hardening was measured by the dilatometer method, in which a flexible membrane was used to enclose the fresh mortar and changes in volume were indicated by a pycnometer arrangement. This method gives the total shrinkage from the original volume of fresh mortar.

Average values for four specimens of each material are given in Table 3. Linear shrinkage would be about one-third of the cubical contraction shown in the table. Early shrinkage was less for the Thorite specimens than the Embeco, but at seven days both materials had contracted about the same amount. At 14 days, shrinkage of the Thorite was slightly greater.

TABLE 3
SHRINKAGE

Material	Shrinkage, percent of original volume*				
	1 day	2 days	3 days	7 days	14 days
Thorite	2.06	2.46	2.87	3.36	3.46
Embeco	2.19	2.81	3.30	3.34	3.24

* Average of four tests each material.

Composition

The dry Thorite mix, as received, was sieved and found to have the following particle size distribution:

Sieve No.	Percent Retained
100	50.0
200	1.2
270	4.5
Passing 270	44.3

All the material retained on the No. 100 sieve was a fine quartz sand. The finer 50 percent of the Thorite sample appeared to be mainly portland cement. Chemical analysis of the minus-100 fraction by the Research Laboratory Division is given in Table 4 (Column 4) which also shows typical analysis of portland cement (Column 1) and aluminate cement (Column 2). The Thorite analysis corresponds quite closely to the composition of the 60:40 mixture of portland and aluminate cements computed from the data in Columns 1 and 2 and tabulated in Column 3. According to Bauer, mixtures of this type are known to have a very fast or "flash" set, a property which is characteristic of the Thorite material. At ordinary laboratory temperatures, Thorite mixtures become unplaceable within about 5 min afger adding water and considerable heat is evolved in the setting process. To check this deduction of composition a sample of aluminate cement is being obtained and will be combined with Type 1 portland cement in an attempt to synthesize a product having the properties of Thorite.

TABLE 4
MATERIAL ANALYSIS

	Portland Cement, Type 1*	Aluminate Cement*	60% P.C. 40% Al.	Thorite, -100 sieve
Loss on ignition	1.3	0.0	0.8	0.6
Insoluble matter	0.2	4.8	2.0	0.0
Sulfuric anhydride (SO_3)	1.8	0.1	1.1	1.0
Silca (SiO_2)	21.3	5.3	14.9	15.4
Alumina (Al_2O_3)	6.0	39.8	19.5	21.0
Ferric oxide (Fe_2O_3)	2.7	14.6	7.4	7.4
Lime (CaO)	63.2	33.5	51.3	54.1
Magnesia (MgO)	2.9	1.3	2.2	0.7

* Bogue, R. H., The Chemistry of Portland Cement. New York; Reinhold Publishing Co., 1947.

Setting Time

At the suggestion of R. S. Fultin, the setting times of Thorite and Embeco in the cold were compared when 1-in. holes in test beams were filled with the two materials outdoors in the winter. Air temperature was 7 F and material temperatures 5F after standing outside overnight. Cold water was poured through the holes prior to grouting and an ice film formed immediately in the holes and on the beam. The Embeco mix froze solid in about 5 min but the Thorite stayed plastic for about 10 min. The Thorite seemed to generate enough heat to keep it from freezing until it had set. The beam was left outdoors for cold curing for three days and then placed in water for freezing and thawing in the laboratory. Outdoor temperatures rose to about 35 F on the second and third days.

After 72 cycles of freezing and thawing, plugs of both materials were weak and crumbly but were still retained in the holes. The Thorite plugs were slightly loose, probably from having set at a somewhat warmer internal temperature than the surrounding concrete.

Concluding Remarks

While the Thorite compound is not as strong or durable as the Embeco mortar, it has other advantages which recommend it for the intended use. Fast setting time and the accompanying liberation of considerable heat are extremely valuable aids when grouting small holes in concrete box beams in cold weather. It is also advantageous in warmer weather, since it speeds up the operation of closing the hole in the pavement course above the beam.

The results of the cold weather tests indicate that plugs of either material should not be placed when the temperature of air or concrete is below 32 F.

OFFICE OF TESTING AND RESEARCH

E. A. Finney, Director
Research Laboratory Division

EAF:js

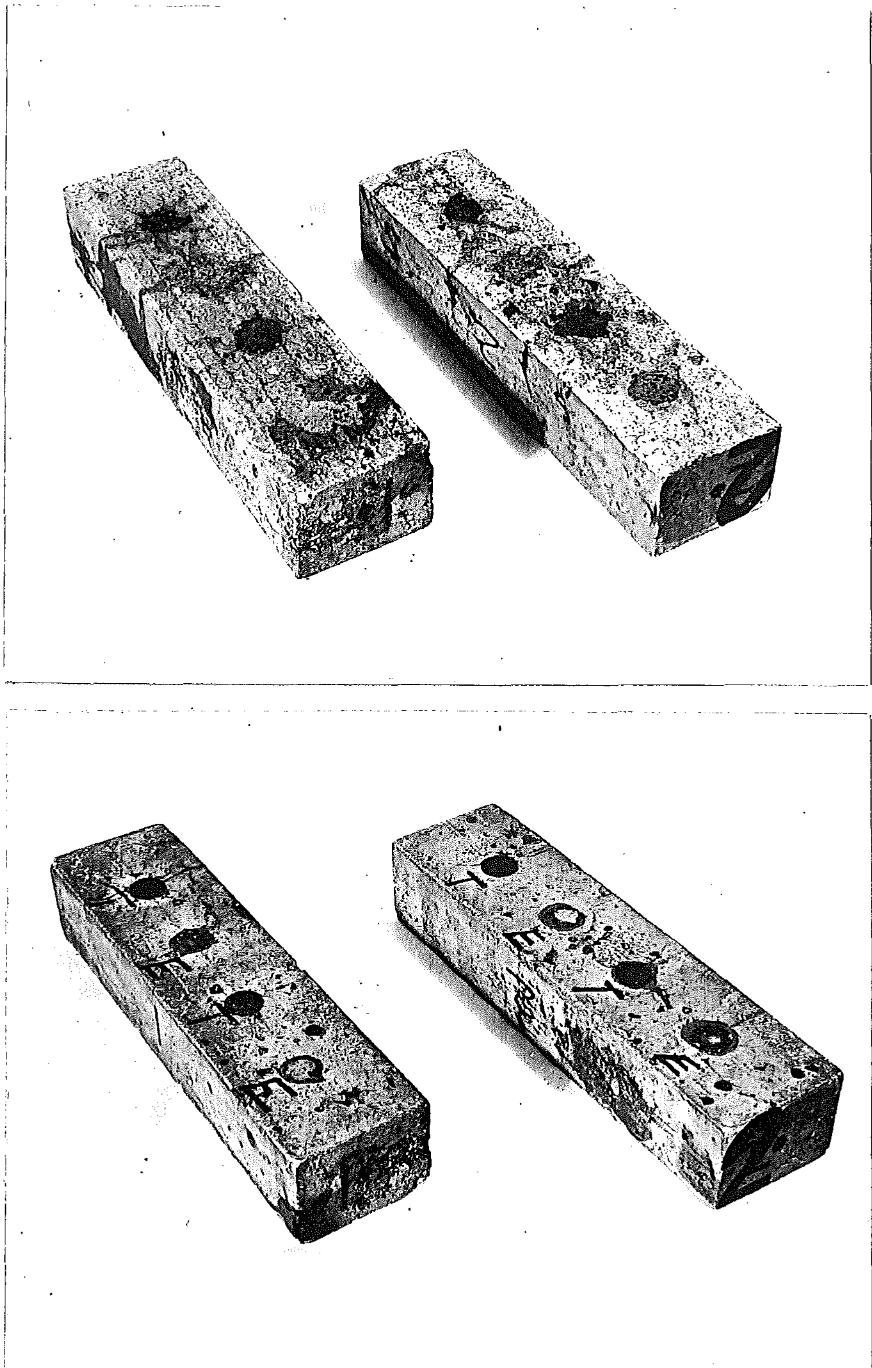

Figure 1. Top (above) and bottom surfaces (below) of air-entrained concrete beams, each with two Thorite (T) and two Embeco plugs (E) of 1-in. diameter plugs, after 96 cycles of rapid freeze-thaw in water.

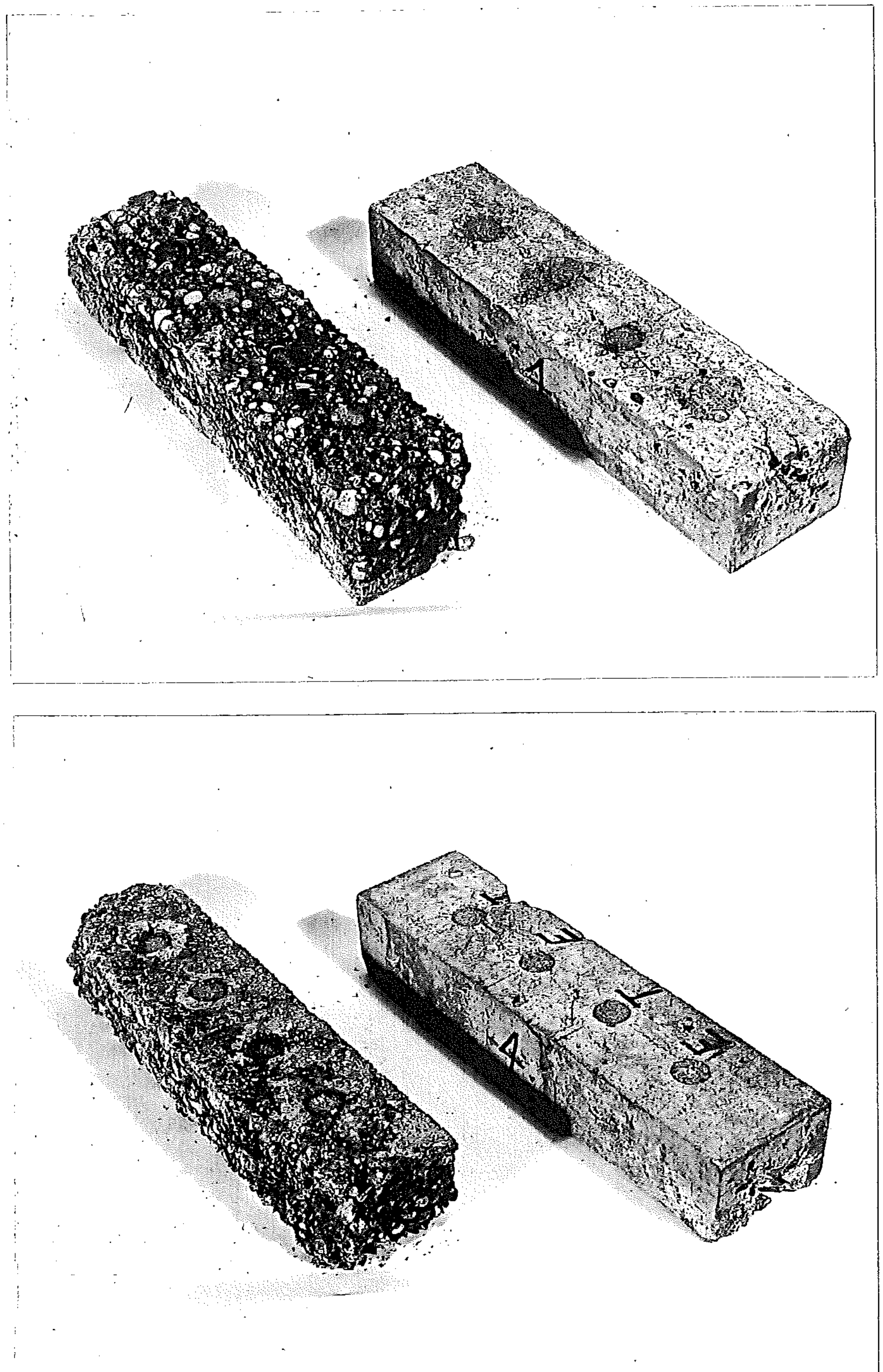

Figure 2. Top (above) and bottom surfaces (below) of similar beams after 66 cycles of rapid freeze-thaw in a 2-percent sodium chloride solution. Left beam was not air-entrained concrete.