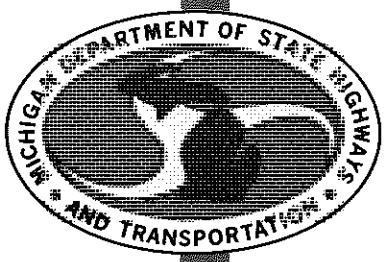
EVALUATION OF 22A GRADATION OPEN HEARTH SLAG AS A BASE AND SUBBASE CONSTRUCTION MATERIAL

Final Report



TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

EVALUATION OF 22A GRADATION OPEN HEARTH SLAG AS A BASE AND SUBBASE CONSTRUCTION MATERIAL

Final Report

J. H. DeFoe

Research Laboratory Section
Testing and Research Division
Research Project 68 E-43
Research Report No. R-1147

Michigan Transportation Commission
Hannes Meyers, Jr., Chairman; Carl V. Pellonpaa,
Vice-Chairman; Weston E. Vivian, Rodger D. Young,
Lawrence C. Patrick, Jr., William C. Marshall
John P. Woodford, Director
Lansing, May 1980

This project was initiated in October 1968 by the Research Laboratory for the purpose of determining the feasibility of continuing the use of steel slags (open hearth and basic oxygen furnace slags) meeting Departmental grading specifications for 22A as base and subbase aggregates. The project was initiated after extensive heaving had been observed in slag-base medians constructed on the Fisher Freeway, I 75 in Detroit.

The purpose of this final report is to summarize the findings of Research Project 68 E-43, Feasibility of Open Hearth Slag for Bases, along with results of other investigations concerning the use of steel furnace slags beginning with the Department's earliest studies conducted in 1959.

Research conducted specifically in connection with this project has been reported in Research Reports R-739, R-769 (unpublished), R-817, and R-884.

1) Research Report No. R-739, "Evaluation of Open Hearth Slag as a Highway Base Material," May 1970 (1). This report described the nature and extent of the heaving problem as initially observed. The production of slag and results of mineralogical analyses are presented. Laboratory results of volume change and frost susceptibility tests are given. The effects of acid treatment were also measured and discussed in this report.

2) Research Report No. R-769, "Further Evaluation of Open Hearth Slag as a Highway Base Material," July 1971 (2). This is an unpublished Departmental report which describes testing of slag beams placed in the field to simulate service conditions in order to evaluate effectiveness of acid treatment. The report also reviews problems encountered by other users of steel slags.

3) Research Report No. R-817, "Field Evaluation of Acid-Treated Open Hearth Slag Base Course," June 1972 (3). Full-scale test sections were constructed at the Dearborn St traffic island to compare the performance of acid-treated steel slag with a conventional aggregate base. This report describes the test sections and presents elevation changes after an exposure of one winter.

4) Research Report No. R-884, "Feasibility of Open Hearth Slag for Bases," September 1973 (4). A memorandum report summarizing project findings including the condition of the Dearborn St test sections after two years of service.

Results of laboratory tests and field evaluations presented in these four reports can be summarized as follows:

1) Open hearth (steel) slag is subject to volume change due to chemical action and is more susceptible to frost heaving than natural aggregate.

2) Acid treatment of the slag, proposed as a corrective measure by the producer, does not alleviate volume change caused by chemical action and increases susceptibility to frost action.

3) Heaving along the median of I 75 was more extensive than initially observed.

4) Mineralogical composition is varied and includes several unstable compounds which could cause volumetric expansion.

5) Expansion of slag material continues after three months of environmental exposure.

In addition to the previously described studies, in connection with Research Project 68 E-43, Department engineers and other investigators have reported concern with steel slag as long ago as 1954. A 1954 report by the National Slag Association (5) describes heaving problems when open hearth slag was used for parking lots, city streets, and airport runways.

Departmental concern about the structural integrity of steel furnace slag was expressed in Departmental correspondence beginning in 1959 (Refs. 6 through 11). Significant statements from each of these references are summarized as follows:

Reference No. 6 (September 10, 1959) - 1) Open hearth slag has exhibited both satisfactory and unsatisfactory service; 2) the material is chemically unstable and often undergoes detrimental volume change; 3) volume change is more evident in slags which have been aged only three to five years; whereas, slags aged from 20 to 25 years are more stable; and, 4) open hearth slag not recommended for use as pavement subbase, base course, or for backfill around culverts and abutments.

Reference No. 8 (May 11, 1960) - Two potentially troublesome characteristics are pointed out: 1) cementing action of the slag due to its high basicity, and 2) the presence of active chemical compounds which could result in appreciable volume changes. Free lime inclusions could cause upheavals or bulges in bituminous pavements as described in Kerkhoff (6). Finally, this memorandum states:

> "We do not believe, therefore, that this material should be used until an unbiased record of satisfactory performance in a variety of applications has been established."

Reference No. 9 (May 31, 1960) - In this memorandum the potential for corrosion and damage to contacting masonry is acknowledged in addition to volume change and great variation in chemical composition.

The other references in this series of Departmental memoranda (Refs. 7, 10, 11) recognize and express these same concerns.

In Reference No. 12 a wide range of information on open hearth slag was compiled. Constituents of steel slag subject to expansion in hydration were listed and included calcium, magnesium and manganese oxides (CaO, MgO, and MnO, respectively). Performance experiences to that date (1968) were summarized.

Mansfield Ohio Airport - Small eruptions of bituminous surfacing occurred where open hearth slag was used as base. Surface course bituminous mixtures made with open hearth slag showed no problems.

Schaefer Rd - The bituminous surfacing mixture contained open hearth slag and showed no problems in service; however, laboratory samples of the same mix developed whitish powder on the surface indicating hydration of some compound.

Fisher Freeway Median - This severe heaving problem, which resulted in the initiation of this research project (68 E-43), is documented by photographs.

Parking Lot on Plymouth Rd - Blisters and surface heaving are shown by photographs.

Regarding drainability, the report states ". . . graded Ottawa sand can be substantially reduced in drainability by the leach solution from open hearth slag."

In addition to the Departmental measurements and correspondence about open hearth (steel furnace) slag, other agencies report severe problems with its use as a construction material. The City of Detroit reported in 1967 (13) a case of pavement damage due to the frost susceptible nature of open hearth slag. Laboratory tests resulted in volume changes ranging from 6.7 to 16.2 percent. Changes in gradation specifications were recommended.

Another problem with open hearth slag became apparent from a study of certain underdrains at the Detroit Metropolitan Airport (14). Perforated

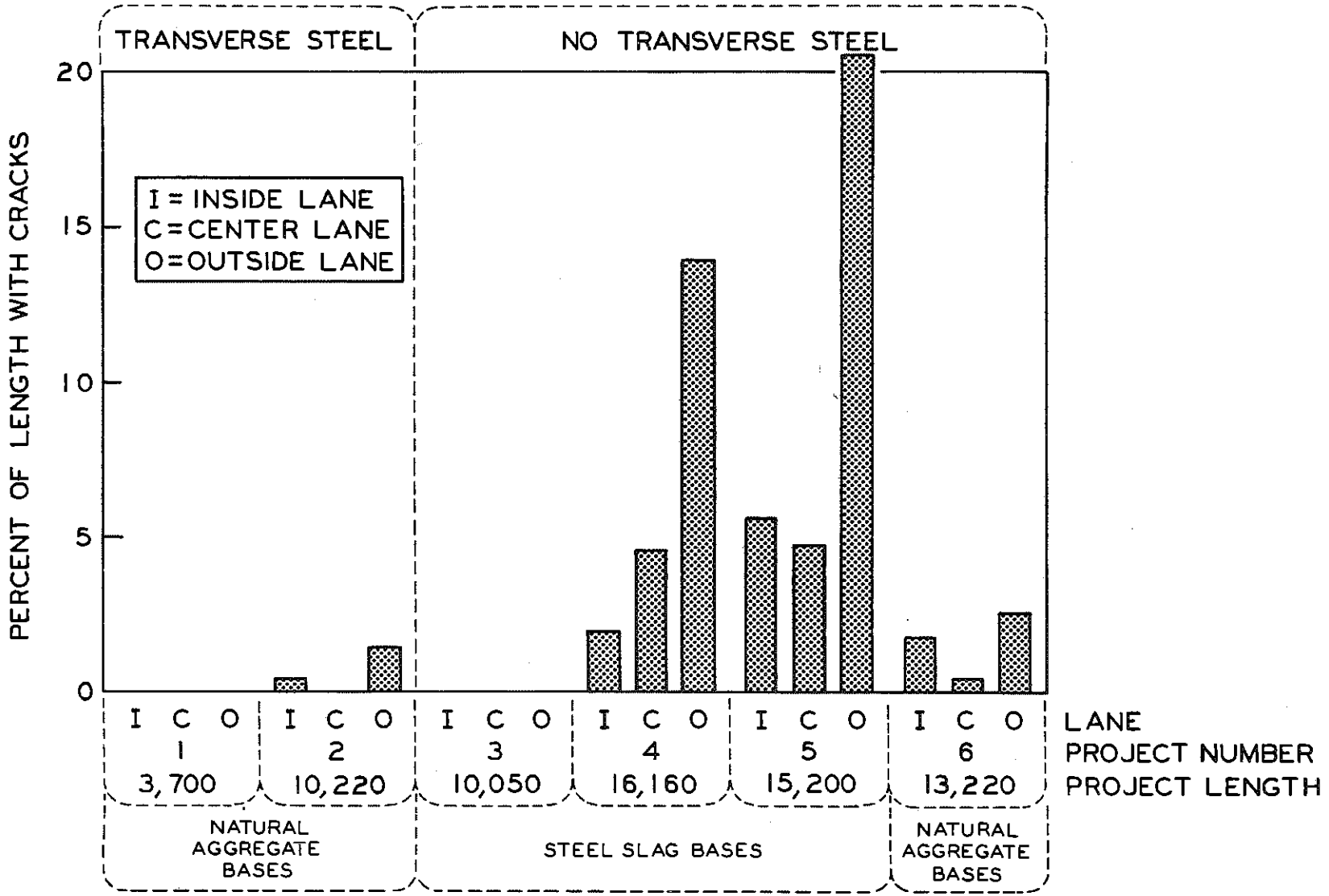


Figure 1. Percent of lane with longitudinal cracks on Projects 1 through 6 as of March 1979 (from Ref. (18)).

metal edge drains and appurtenant catch basins were found to contain deposits of carbonate scale after only one year of service, despite the fact that natural aggregate filter material was used. Drainability tests performed by the Department's Testing Laboratory (12) confirmed that water flowing through the slag base course had clogged the underlying layers of filter material. Detailed laboratory analyses conducted by independent laboratories for the Wayne County Road Commission indicated the same cause. As a result, Wayne County recommended a full-scale field evaluation to study this problem and check the producer's suggested methods of correction by treating the slag with carbon dioxide.

Concrete floor slabs, placed over steel furnace slag backfill, heaved from 1 to 3 in. (approximately 9 percent) with slag ranging in thickness from less than 1 ft to 3 ft (15).

The use of approved open hearth slag has been permitted since 1957 by the Pennsylvania DOT for certain subbase, surfacing, and stabilized shoulders. Specifications (16) require that the slag be seasoned in a controlled stockpile for a minimum of six months, with provision for keeping the material in a damp condition. Research studies (17) showed expansion to continue after 17 months of seasoning, with the finer portions (passing the 3/4-in. sieve) being more expansive than the larger fractions. Recommendations resulting from these studies include: 12-month stockpiling prior to use with a definite arrangement for watering; periodic inspection of the piles; and wasting the upper 2 to 3 ft of slag in each pile. Pennsylvania research recommendations also caution against a possible lack of adhesion of slag to asphalt if open hearth slag is used in bituminous concrete. Experimental construction projects, using open hearth slag aggregate in bituminous concrete, aggregate-cement bases, and shoulder construction, are being evaluated in Pennsylvania.

The most recent Departmental study which involved steel furnace slag concerned problems on I 275 in Wayne County (18). The steel slag base course exhibited frost heave values ranging from 1.06 to 4.07 mm per day. Frost heave values of from 1 to 2 mm per day are classified as low and values from 2 to 4 mm per day are considered moderate. In addition, the slag base material was shown to be impervious rather than to be free draining as a base should be. Of the six construction projects in this study, three with steel slag bases showed a significant amount of longitudinal cracking; whereas, the projects with natural aggregate bases had much less longitudinal cracking (Fig. 1). A photographic history of problems encountered in Michigan with steel furnace slag is presented in Figures 2 through 10.

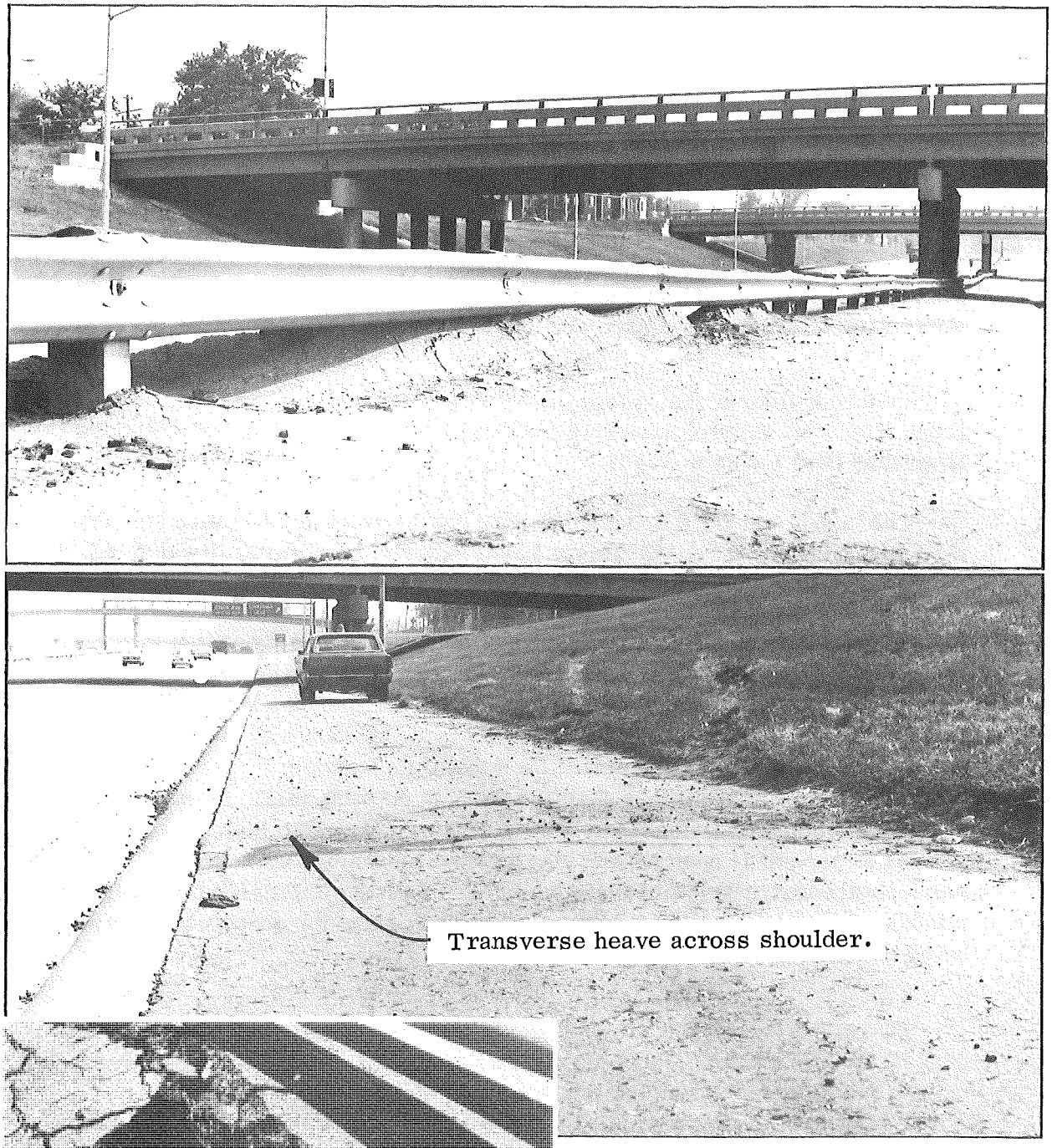


Figure 2. Heaving of bituminous surfacing placed over base of steel furnace slag, Fisher Freeway, I 75, Wayne County.

Figure 3. Bituminous surface, Dearborn St traffic island, constructed over base of steel furnace slag (1968).

Figure 4. Shopping mall parking lot, 14 Mile and I 75, with open hearth slag base (constructed 1967 and 1968).

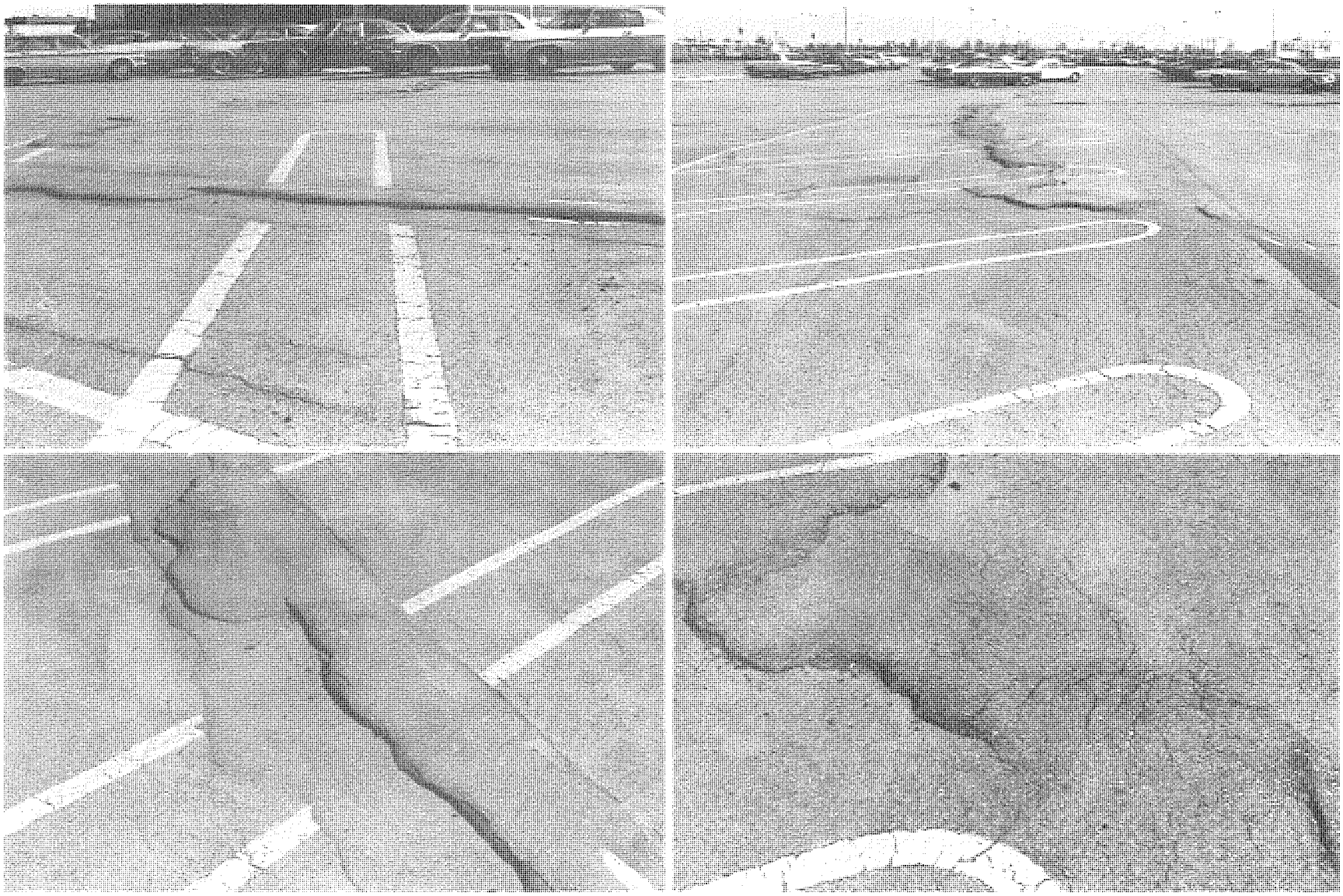
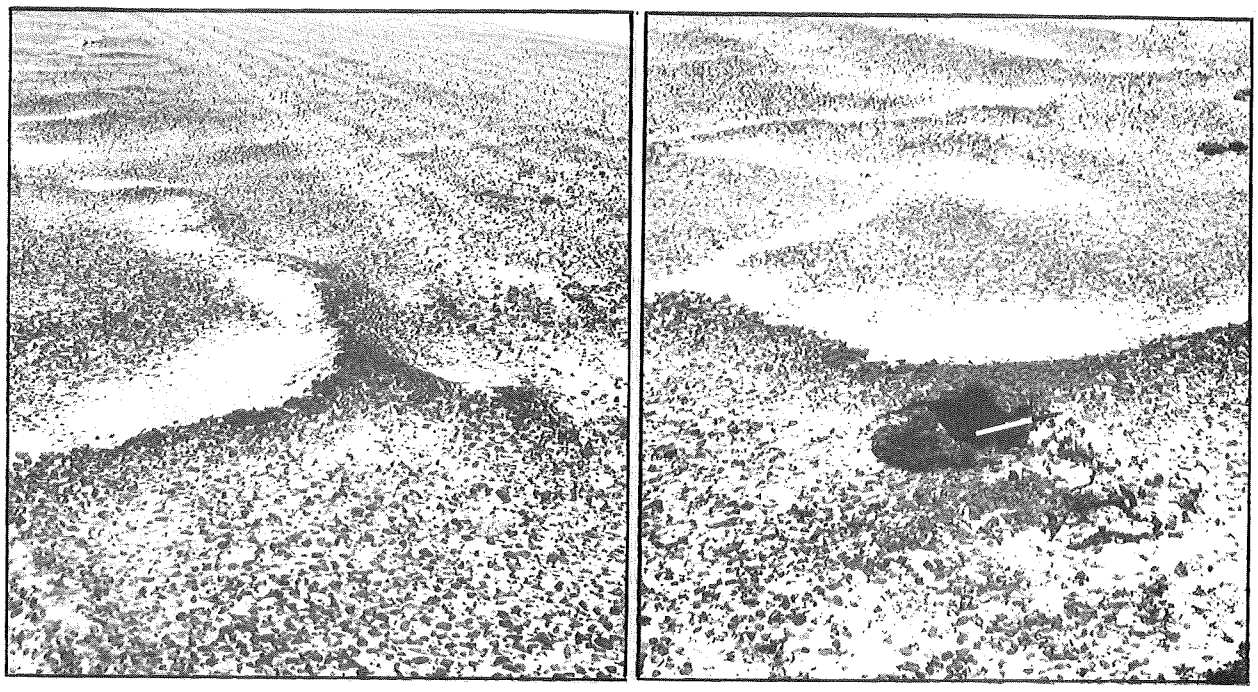


Figure 5. Shopping mall parking lot, 14 Mile and I 75, with open hearth slag base (constructed 1967 and 1968).



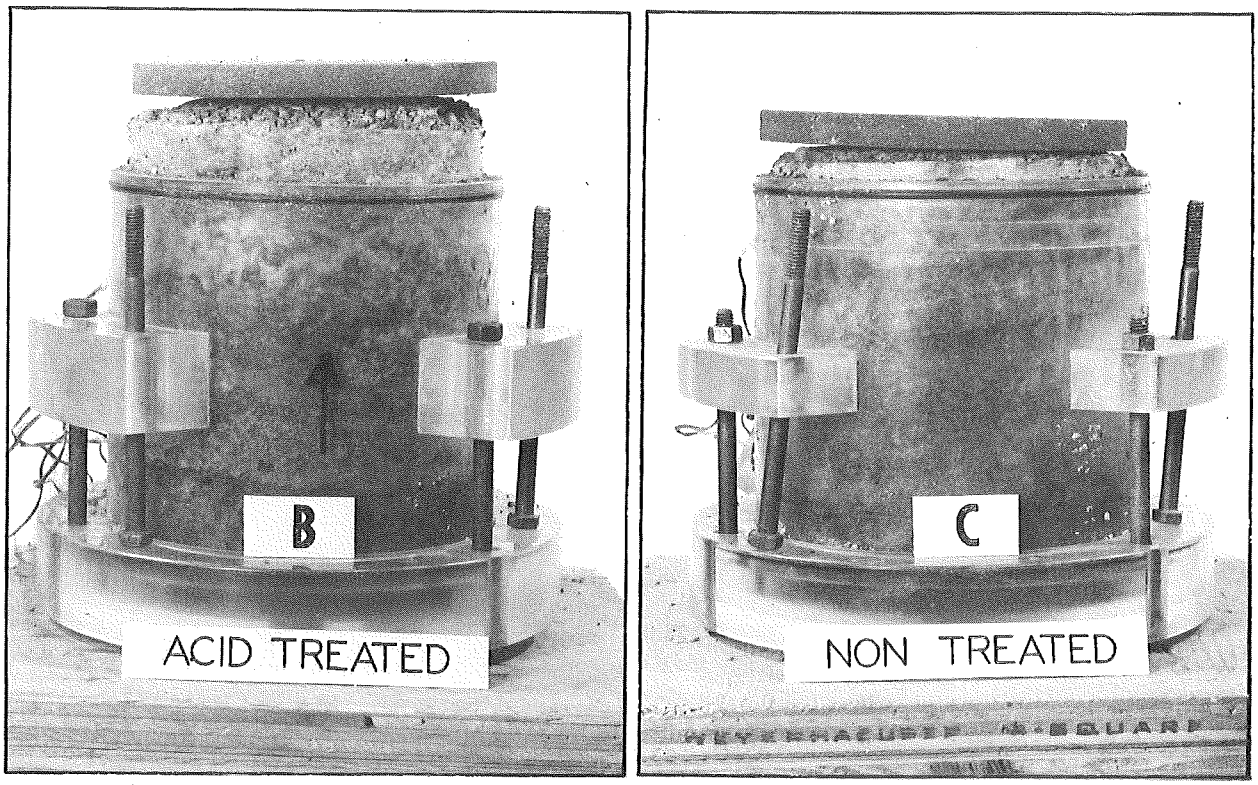


Figure 7. Laboratory frost susceptibility tests showing relative heaving of acid treated and non-treated steel furnace slag.

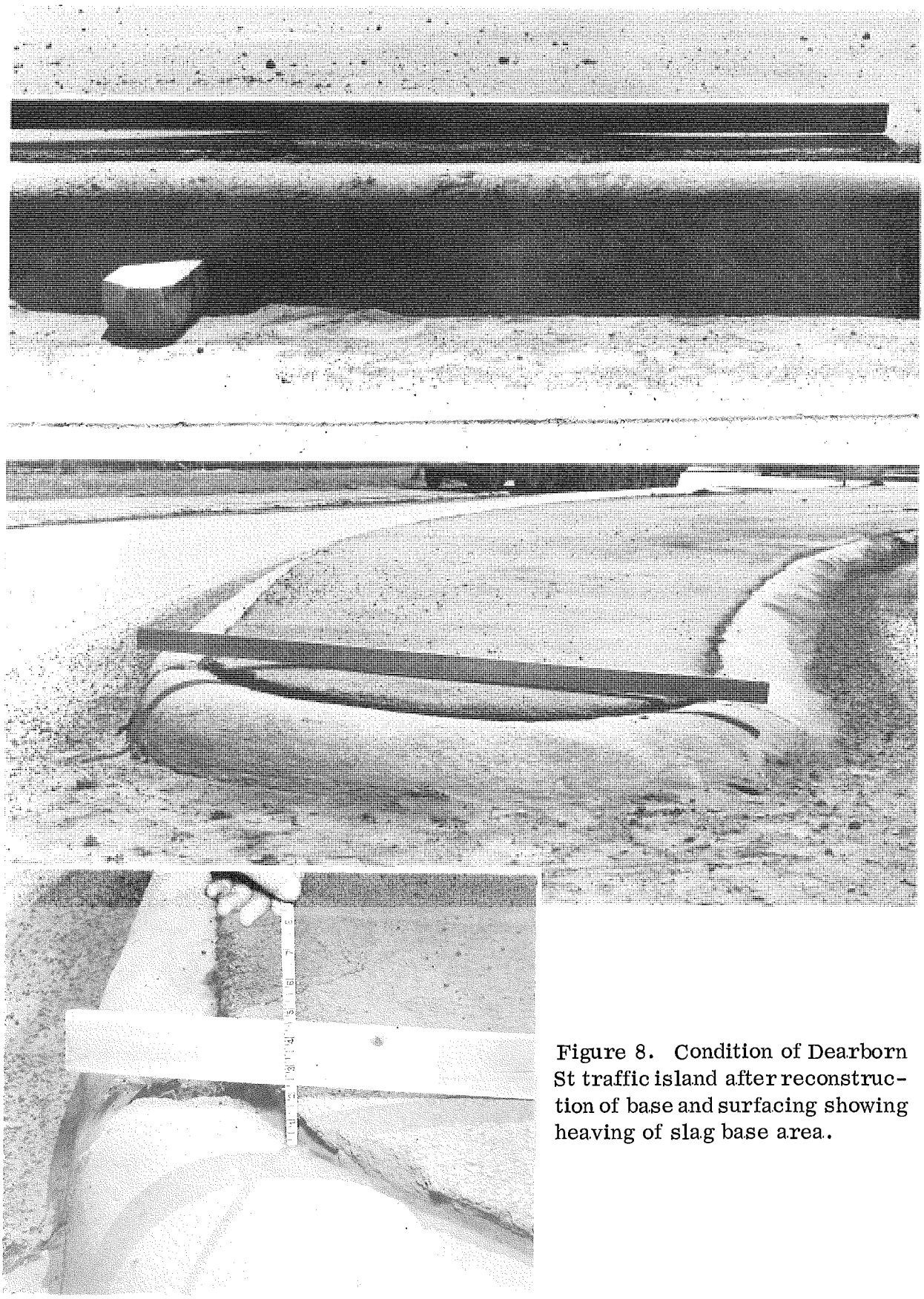


Figure 8. Condition of Dearborn St traffic island after reconstruction of base and surfacing showing heaving of slag base area.

Vertical slab displacement of approximately 2 in.

Core hole through pavement showing water retained in the slag base.

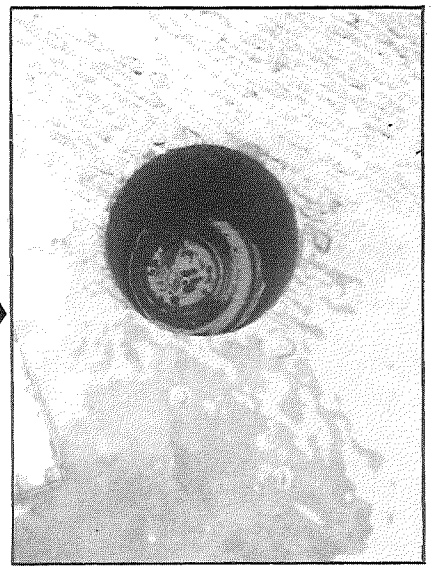
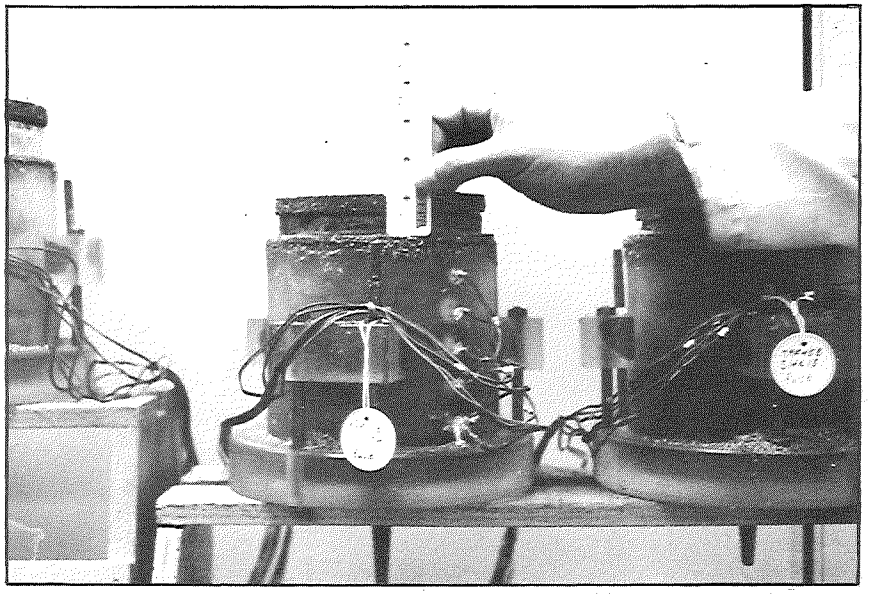


Figure 9. Heaving of concrete pavement slab constructed on a base of steel furnace slag, I 275 in Wayne County.



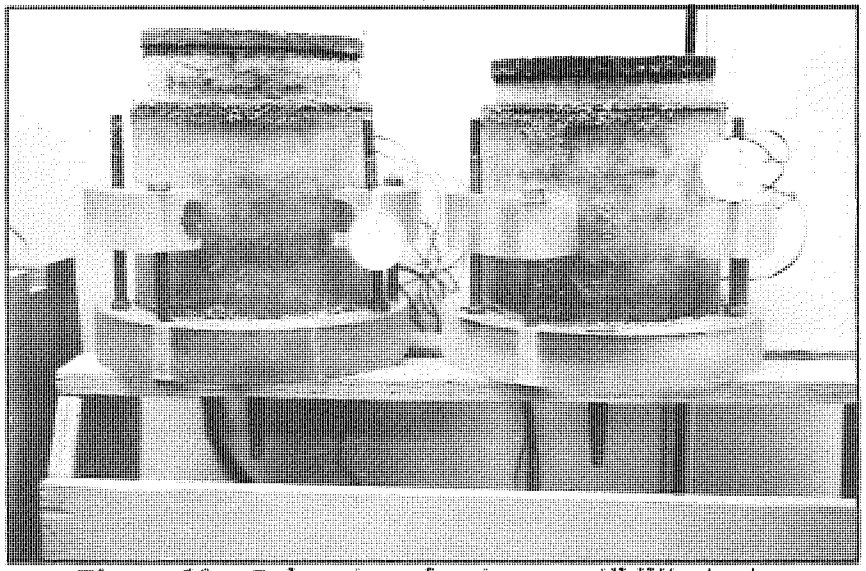


Figure 10. Laboratory frost susceptibility tests showing heaving of steel furnace slag taken from the base course of I 275, Wayne County (1979).

CONCLUSIONS

During the past 20 years the Department has conducted research and testing to determine the suitability of steel furnace slag (e.g., open hearth, basic oxygen, and electric furnace) for use in highway base and subbase construction. For this purpose, steel furnace slag meeting existing Department specifications for a 22A base and subbase gradation has not proven to be a satisfactory construction material for the following reasons:

1) The material is frost susceptible and exhibits differential heaving tendencies under a pavement surface.

2) Steel slag has poor drainability with a self-clogging tendency due to the formation of solid leachates.

3) The slag exhibits unpredictable volume changes (expansion) due to internal chemical constituents which can cause heaving of pavement surfaces.

4) Chemical composition of the slag is extremely variable and cannot be controlled by the manufacturing process.

RECOMMENDATIONS

Steel furnace slag, especially of the types and gradations evaluated, should not be used for highway base or subbase construction. Research is now being conducted to evaluate the performance of steel furnace slag from which the fine portion (passing the No. 4 sieve) has been removed. It is expected that this might reduce the frost heave potential and provide a more suitable pavement support, providing there is no excessive degradation of the slag during handling and compaction.

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