R-375

COMPARISON OF STONE DUST AND NATURAL SOIL PARTICLES AS USED FOR THE FINES FRACTION OF AGGREGATE BASE COURSE MIXTURES

First Progress Report

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Synopsis

This is a progress report presenting the results of a literature search and preliminary laboratory study made to determine whether the "fines" portion of graded aggregate mixtures may be increased beyond present specification limits when this portion consists of limestone dust rather than natural gravel fines, and also to compare relative performance of these two minus-200 materials.

The work indicates that limestone (non-plastic) fines should be allowed in aggregate mixtures in amounts no greater than are permitted for normal gravel fines. Due to their frost susceptibility, greater quantities of limestone fines could be at least as detrimental as corresponding amounts of natural gravel fines.

Work on this project is continuing with special studies to determine the effects of freezing on the different limestone mixtures and their possible improvement by the use of chloride salts.

COMPARISON OF STONE DUST AND NATURAL SOIL PARTICLES AS USED FOR THE FINES FRACTION OF AGGREGATE BASE COURSE MIXTURES

Present MSHD specifications require that the minus 200 portion of a suitable base course aggregate shall not exceed 7 percent, a value determined after considerable study and field observation. Adherence to this limitation has resulted in satisfactory performance of pavements even when subjected to the combined forces of traffic, frost action, and other detrimental conditions.

There is a belief, however, that should the minus 200 portion of an aggregate consist of relatively inert limestone dust, rather than natural gravel "fines," higher quantities of such materials could be tolerated without detrimental effects. Roads constructed of limestone containing as much as 12 percent fines have reportedly given satisfactory performance over a period of years.

Research Project 61 E-23, "Comparison of Stone Dust and Natural Soil Particles as used for the Fines Fraction of Aggregate Base Course Mixtures," was initiated by the Research Laboratory Division in August 1961, at the request of R. L. Greenman, Assistant Testing and Research Engineer. The purpose of this project is comparing the characteristics of stone dust fines with natural gravel fines where each is used as the minus 200 portion of its corresponding graded base course aggregate, and determining whether limestone dust can be tolerated in higher quantities than present specifications allow.

Prior to beginning this study an inspection was made of limestone base bituminous roads used within the plant area of the Dow Chemical Company at Midland. High percentages of limestone fines had reportedly been used in the construction of these base courses. Although the roads were in acceptable condition after about 14 years of service there were several indications that distress had been encountered. Furthermore, construction and maintenance records were meager so that a comprehensive history of the roads was not available. It is possible that these roads remained as open surface structures for some time after construction, during which period they most likely were treated liberally with various chloride salts.

Laboratory Tests

Four commercially available limestones have been used in the laboratory portion of this study, designated by their source as Presque Isle, Wallace, Drummond, and Inland. In addition, a laboratory limestone sample of unknown origin was used in certain tests. A typical 22A gravel was used for comparative study along with special fines of ground quartz and gravel, Brookston clay, Ontonagon clay, and Kaolinite.

Laboratory determination of the qualitative effects of modifying granular materials is very difficult and the results may not be entirely applicable to field conditions, where variations in compaction, gradation, and weather effects are critical. One of the more important of these factors is frost action. Laboratory equipment now available for this study does not permit a realistic determination or measurement of frost heave phenomena but work in this area is planned for a later date. However, because frost activity is a function of several soil properties and characteristics, a reasonable prediction of the reaction of the various mixtures to frost action can be made from data obtained to date. Tests performed have included moisture absorption, compressive strength, capillary rise, moisture holding ability, porosity, and such classification determinations as Atterberg limits, specific gravity, hydrometer analysis, Proctor density, and void ratio.

Classification Tests

All of the limestone fines tested were found to be non-plastic and highly water absorptive. The Inland and Presque Isle samples were soft and easily broken by abrasion. The Drummond and Wallace samples were much harder. Maximum Proctor densities varied with the limestone and with the percentage of fines (Fig. 1). The maximum density of the softer limestone was approximately 132 pcf at an optimum moisture content of 7.8 percent. Densities for the harder samples were approximately 141.5 pcf at 6.6 percent moisture content. These values were obtained where the fines fraction was 5 percent. When the fines contents were increased to 12 percent, maximum densities were increased by about 4 pcf.

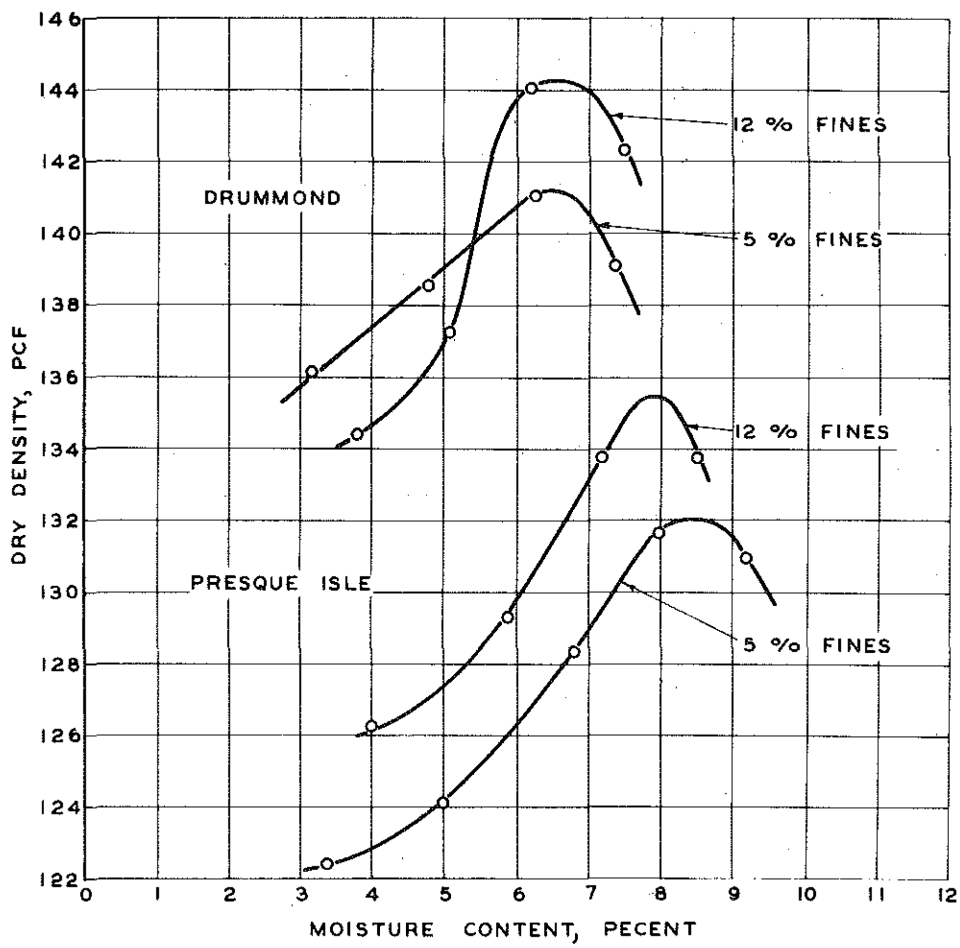

Figure 1. Compaction characteristics
of different limestone mixtures (Proctor test).

Plasticity of the gravel fines studied varied from non-plastic (for ground quartz and silica) to a plasticity index of 32 for Ontonagon clay fines.

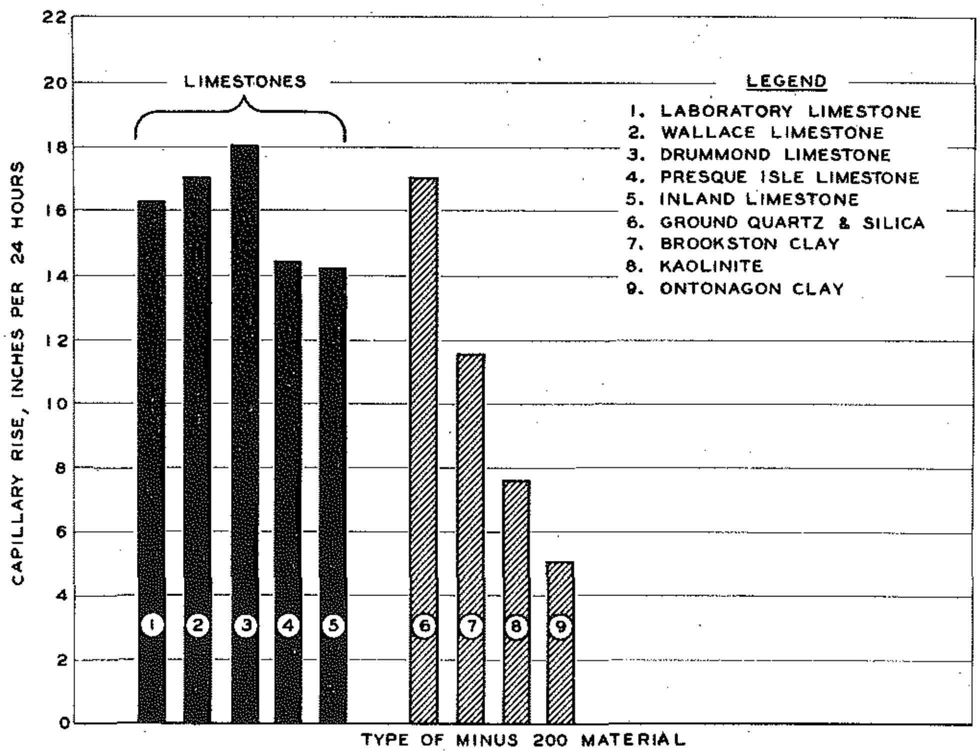

Figure 2. Capillary rise of different minus 200 materials.

Capillary Rise Test

In this test the capillary rise and water holding properties of the fine portion of the materials were determined, using the minus-200 fraction (Fig. 2). The limestone fines were compared with different natural soil fines and with Kaolinite. This test showed that, in general, limestone fines had greater capillary and moisture holding properties. Drummond, Wallace, Inland, and Presque Isle stone dust were highest in capillary rise, in the order named, and all showed higher values than did Brookston or Ontonagon on Kaolinite clays. This test indicated that limestone fines should be limited at least as much as are gravel fines in aggregate mixtures.

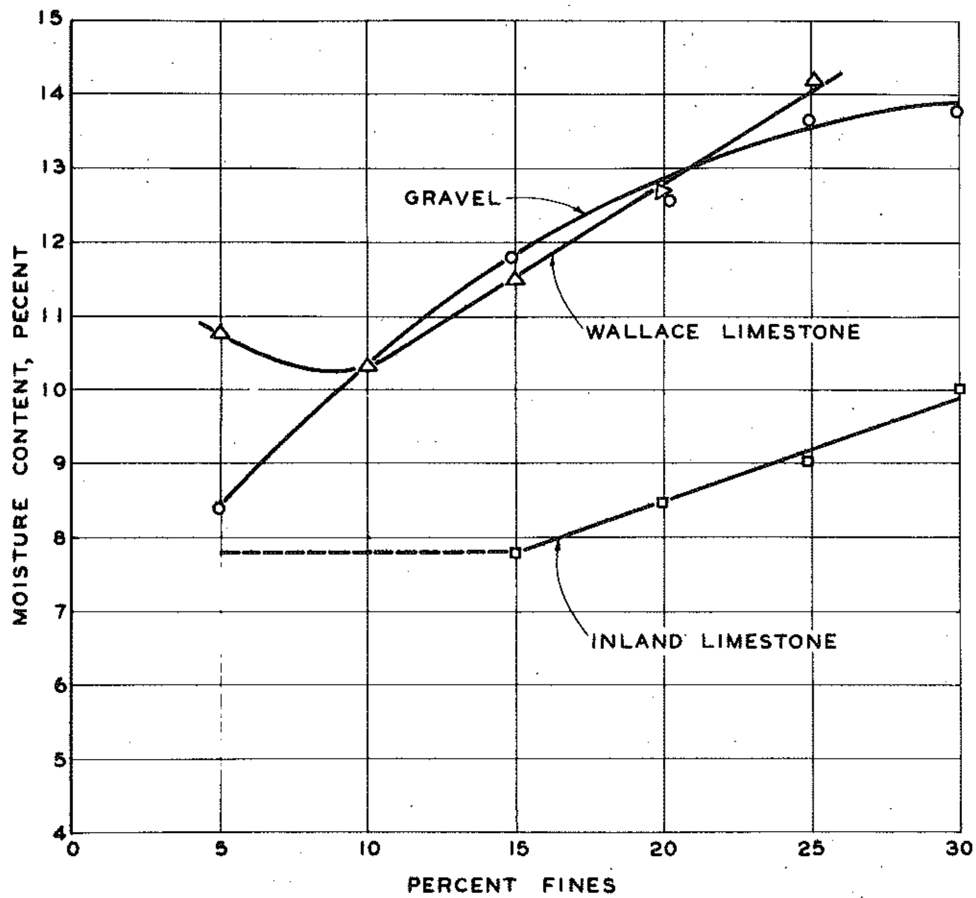

Figure 3. Effect of minus 200 material on 24-hr capillary moisture absorption (samples molded by static loading to less than maximum density).

Moisture Absorption

Cylindrical samples of the different limestones and gravel containing 5 to 30 percent fines were molded at near optimal conditions, air dried to constant weight or moist cured for several days, and placed on a wet capillary pad in a moist cabinet. Moisture intake increased slightly with increasing fines content in all cases (Fig. 3). Absorption was rapid and the samples softened readily upon contact with water.

Modified CBR Tests

Samples containing different percentages of fines were molded and left in the molds during curing and testing. The bearing strength of the samples was tested by penetration of a circular plunger in a manner similar to the CBR test. Loads obtained at different penetrations were

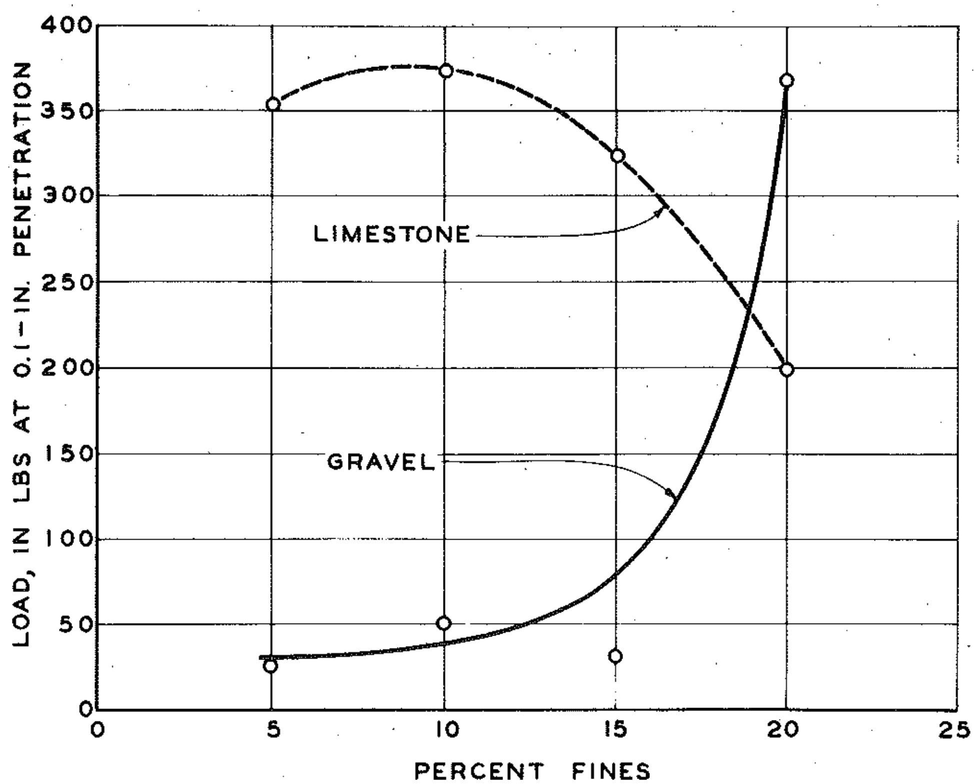

Figure 4. Effect of fines content on sample strength (as obtained by penetration of a 1.25-in. plunger).

erratic, but in general natural gravels increased in load bearing capacity as the percentage of fines increased (Fig. 4). This was not true for limestones. Such samples reached an optimum strength of about 10 percent fines after which further increase in fines reduced the strength.

LITERATURE REVIEW

A review of existing literature pertaining to the use of fines in base course materials indicates that frost action is a function of the fines content regardless of whether these are natural soils or limestone dust. In certain cases particular caution has been recommended when using porous non-plastic fines.

Data from various state highway departments concerning the frost action problem (1) indicate the following facts and recommendations:

Alabama: Materials most susceptible to frost action are those of high silt content either friable or plastic. Frost action is not related to P.I.

Arizona: Use non-plastic material with maximum of 8 percent passing No. 200 sieve.

Colorado: Use 5 to 10 percent non-plastic binder. Control the fines within narrow limits.

Florida and Georgia: Limerock more susceptible to frost damage than their other materials.

Idaho: Prefer limiting minus 200 material to 6 to 8 percent of non-plastic fines.

Maine: Generally, all soils with minus 200 material in excess of 10 percent are highly frost susceptible.

Nebraska: Limit minus 200 material to 8 to 10 percent, P.I. to 3 or 4.

New Hampshire: Limit minus 200 material to 5 percent.

New Jersey: Open crushed stone containing more than 12 percent passing No. 200 sieve most susceptible to frost action.

Texas: Freeze damage increased by any condition causing subgrade to be highly permeable.

Washington: Worst frost susceptible materials are those containing small to moderate amounts of silty binder, generally non-plastic or feebly plastic.

Wisconsin: Any type material having more than 10 percent minus 200 material is most frost susceptible.

Haley and Kaplar (2) found in their laboratory studies that the percent of frost heave increased markedly as the percent fines were increased from 2 to 25 percent for all of eight different soil and aggregate types tested.

Croney (3), of the British Road Research Laboratory, reported that chalk was a particularly frost susceptible material. Otherwise chalk, being in effect a soft limestone, provides a very stable subgrade.

DISCUSSION

Although increasing the allowable quantity of non-plastic fines might affect a soil-aggregate in several ways, the most important effect concerns the susceptibility of the resultant mixture to frost action. Basically, there are three requirements for frost action in graded aggregate or soil, 1) freezing temperature in the mass, 2) availability of water, and 3) soil material capable of moving large amounts of water, in a short time, by means of capillary action. Ice crystals formed in certain areas of the soil attract water from surrounding soil in all directions. As an ice crystal grows, more water is attracted. The addition of soil fines, above a specified minimum quantity, allows much easier transmission of water throughout the mass, especially if such fines have a pore size conducive to capillary action. Natural soil fines that are plastic and even those containing peat (2) have caused a reduction in the rate of frost heave when present in sufficient quantity to block capillary pores and reduce permeability. Limestone fines, on the other hand, do not offer pore-blocking characteristics, but cause an increase in capillary absorption and water retention as more fines are added. No significant increase in structural strength has been found when adding limestone fines that might tend to offset the increased frost susceptibility. In fact, 10 percent minus 200 material appears to be about the optimum for compressive strength or penetration resistance for limestone mixtures. In the Research Laboratory Division's laboratory tests, loss of strength with increase in fines was less pronounced when the harder limestones (Drummond or Wallace) were used.

A field example of the effect of added non-plastic fines can be found in the Department's research project involving Poz-O-Pac shoulders near Midland. On one portion of this job lime and flyash were added to a well graded 20B gravel mix raising the minus 200 portion to 10 to 15 percent. The lime and flyash did not react completely during the first winter in several areas, leaving the flyash as a silt-size minus 200 fraction. Considerable frost damage was noticeable during the winter and early spring. Adjacent areas of graded aggregates containing about 5-percent fines were not affected by frost action.

The laboratory investigation of this problem is continuing. Frost action in soil is quite complex and can vary with many factors. It may be possible to improve the characteristics of limestone fines by the use of admixtures. Calcium chloride in the specified amount (6 lb per ton) was included with most of the studies made so far, but showed no appreciable effect on the samples during the relatively short period of the tests. Sodium chloride and lime have been observed to be effective in stabilizing certain soils. It may be that sodium chloride added to limestone fines would permit the use of more minus 200 material. This will be studied in future work.

CONCLUSIONS

An evaluation of the effect that variations in the fine portion of an aggregate might have on the performance of a whole sample represents a complex study if all of the many variables are to be considered. Predictions of performance based on laboratory tests are hazardous but such tests do permit the determination of certain characteristics of the mixture that should indicate probable field performance. Based on work completed to date and study of the literature, the following conclusions appear warranted:

1. Limestone fines permitted more capillary moisture movement than did plastic fines, and their presence in amounts above present restrictions should increase the susceptibility of the mix to frost action.

2. Moisture absorption and water holding properties were increased in limestones by an increase in the minus 200 fraction.

3. The use of higher percentages of fines offered no increase in the structural strength of limestone mixtures that might tend to compensate for the detrimental increase in frost susceptibility. Compressive strength and plunger penetration resistance decreased when the minus 200 fraction of the samples exceeded about 10 percent.

4. A literature survey indicated that the quantity of soil fines should be kept to a minimum. In this respect no distinction was made between plastic and non-plastic fines.

5. All of the limestones tested were non-plastic. Inland and Presque Isle samples were soft and easily broken down by abrasion forces. Drummond and Wallace samples were hard and very resistant to abrasion. All absorbed water rapidly.

6. Specifications should not be changed to allow higher quantities of limestone fines in soil-aggregate mixtures. Increasing the fines would increase water absorption properties and allow faster movement of water within the mixture by capillarity. This would eventually lead to increased frost damage.

7. Work on this project is continuing with emphasis to be placed on the effects of freezing and the use of chloride salts to improve the mixtures.

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