PROGRESS REPORT

31 March 1965

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Research Agency:	Iowa State University
Principal investigator:	James M. Hoover
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PROGRESS REPORT

FACTORS INFLUENCING STABILITY OF GRANULAR BASE COURSE MIXES

31 March 1965

Proj. HR-99 of the Iowa Highway Research Board

Proj. 516-S of the Iowa Engineering Experiment

Station, Iowa State University, Ames, Iowa

IEES Project 516-S
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SYNOPSIS REPORT OF PROGRESS ON IHRB PROJECT HR-99

"FACTORS INFLUENCING STABILITY OF GRANULAR BASE COURSE MIXES."

Problem 1. Determination of a suitable and realistic laboratory method of compaction. The purpose of this study was to obtain a laboratory compaction method producing a uniform, controllable density while minimizing degradation and segregation of compacted crushed stone samples.

A brief summary of results obtained with the Bedford, Taylor County, Iowa crushed stone were presented in the last progress report. Degradation and segregation studies during standard Proctor and vibratory compaction on two additional crushed stone samples have now been completed; one is a hard limestone from near Gilmore City, Iowa, while the other is a hard dolomite from near Garner, Iowa. The results are now being tabulated and will probably be reported in the next progress report.

Problem 2. Effect of gradation and mineralogy of the fines on shearing strength. The purpose of this study is to investigate the relation of cohesion and friction to the variation of the quantity of fines and the dominant minerals identified in the fines in each of the three representative Iowa crushed stones.

As mentioned in the 30 November 1964 Progress Report, two significant variables consistently reappeared in the theoretical study of this problem area. (1) Volume changes of the compacted crushed stone material may occur several times and in several ways during shear strength testing, (2) Particle surface adsorption of water and/or various ions carried by water may create additional friction and/or cohesion characteristics. In contrast the same adsorption characteristics may destroy the strength of a rolled stone base.

Consolidated-undrained triaxial shear tests with total volume change and pore pressure measurements are being conducted on 4 inch diameter by 8 inch high Bedford stone samples. Presently, each sample is produced using the whole crushed stone (i.e., no variation from original Iowa Highway Commission specified gradation) compacted by the vibratory procedure to standard Proctor optimum moisture content and density. Volume change of each sample during testing is measured by observing the change of volume of the cell fluid using a device designed and constructed in the IEES. This device is capable of measurements to an accuracy of less than 0.01 cubic inch. After each sample is near 100% consolidated, the axial load is applied at a constant rate of 0.0099 in/min. During shear, constant volume of pore fluid is maintained, thus allowing pore pressures to be measured and related to load and sample volume data. Each sample is loaded until a constant volume is reached; each test therefore requires a minimum of about 4 hours testing time and 15 hours calculation time per specimen. The latter is now being computer programmed and will require about 2 minutes for computation of data and graphing of results (as stated by the programmers).

Though a considerable number of samples has been tested in the past three months, results available for analysis at the time of this report are yet rather limited. The following is a very general summary of completed results to date on the Bedford stone, run at lateral pressures from 10 to 40 psi:

1. Total stress analysis indicates the Mohr envelopes of failure have a cohesion value (c) of 18.5 psi and friction angle (ϕ) of 36°.

2. Volume contraction during axial compression increased in proportion to stress to a mximum of 1.0% at about 2.3% strain

and at maximum principal stress.

3. Pore pressures during shear increased in proportion to stress, to a maximum of about one psi at about 2.3% strain, which point coincides with the maximum principal stress and maximum volume contraction.

4. Approximately tripling the strain returns the specimen to near its original volume while decreasing the maximum principal stress by less than 10%.

5. Further load application results in further, and eventual constant, volume change, at a maximum expansion of about 2.0% being achieved at about 20% strain. Maximum principal stress at this point of strain is reduced about one-fourth and continues reduction even though volume change remains constant with additional testing.

6. From the point of zero volume change in 4 above until constant volume expansion is reached, the stress-strain relationship is somewhat erratic; i.e., indicating points of slippage failure with each additional 2-4% strain. Similar changes, though not as pronounced, occur simultaneously in volume expansion; i.e., the volume increases very slightly at each obvious point of stress reduction.

7. Pore pressure changes appear to consistently follow the volume change as might be anticipated, reaching maximum positive gage pressure at or near maximum volume contraction and principal stress, then reducing quickly to zero prior to sample expansion to original volume. With continued volume expansion, pore pressure becomes negative; i.e., reduces to less than zero gage pressure.

No suction pore pressures had originally been anticipated with the crushed stone materials as it was assumed that they were free draining. The advent of obvious suction pressures created considerable concern as equipment was not available in this laboratory for measurement of such pressure. As a result, a compound pore pressure device has been borrowed, and is being used for the first time during writing of this report. Results with the sample under test at this moment have shown a positive pressure of about 1.0 psi, changing to over 4.0 psi negative pressure (still decreasing). The significance of this suction pressure in relation to stability of granular base mixes is obviously not to be determined at this stage of the project but does conjure some interesting hypotheses in the writers mind--maybe in the readers mind also?

In addition to the above noted results, molded samples have been run at lateral pressures up to 80 psi. Analyses are also being made on the basis of effective stresses, maximum principal stress ratios, and octahedral stresses. It now appears that the latter analysis may lead to a testing procedure in which the envelope of failure parameters, c and ø, can be determined on the basis of one tested specimen.

Chemical and mineralogical tests have been completed on all three crushed stone samples. A representative sample of each stone was ground to pass the No. 100 U. S. Standard mesh sieve. Part of each sample was used for X-ray mineralogical identification and the remaining portion was used for quantitative measurement of pH, cation exchange capacity (c.e.c.) and hydrochloric acid soluble and non-soluble minerals. A summary of the results are presented in Tables 1, 2, and 3. These results will be used to determine the relationship of mineralogy of the stones to their stability characteristics at a later date.

<u>Problem 3. Improvement of the shear strength of crushed stone materials with organic and inorganic chemical stabilization additives.</u> The purpose

Table I. Mineral Constituents of the Whole Material by X-ray Diffraction

Stone Designation	Calcite	Dolomite	Quartz	Feldspars	Calcite/Dolomite Ratio*
Bedford	Predominant	Small Amount	Trace	Not Identifiable	25
Garner	Predominant	Second Predominant	Trace	Not Identifiable	1.16
Gilmore City	Predominant	None	Trace	Not Identifiable	∞

*Obtained from X-ray peak intensity.

Table 2. Non-HCl Acid Soluble Clay Mineral Constituents of the Whole Material by X-ray Diffraction

Stone Designation	Mont.	Vermiculite-Chlorite	Micaceous Material	Kaolinite	Quartz
Bedford	None	Not Identifiable	Predominant	Poorly Crystalline	Large Amount
Garner	None	Small Amount	Predominant	Second Predominant	Large Amount
Gilmore City	None	None	None	Predominant	Small Amount

Table 3. Quantitative Chemical Analysis of Whole Material.

Stone Designation	pH	CEC, (me/100.0g)	Non-HCl Soluble Clay Minerals, %	Non-clay Mineral, Non-Acid Soluble Material, %	HCl Soluble Calcareous Material, %
Bedford	9.40	10.88	10.92	Trace	89.08
Garner	9.25	10.60	5.70	1.03	93.27
Gilmore City	8.99	5.86	<1.66	Trace	>98.34

of this study is to investigate the effects of economically feasible stabilization additives on the shearing resistance and stability of compacted crushed stone materials, particularly stones of poorer quality.

The effective use of a minute quantity of an organic chemical dissolved in the mix water of compacted Bedford samples has previously been reported in detail.

Stabilization studies using 0, 1, 3, and 5% by dry weight of Type I Portland Cement, with the Bedford crushed stones, are under way. While a considerable number of samples have been tested by C-U triaxial tests with volume and pore pressure measurements, computations and graphical tabulations are not yet completed.

Two types of freeze-thaw tests: ASTM standard D 560-57, and the Iowa Freeze-Thaw Test*, have been completed on the Bedford stone stabilized with 1, 3, and 5% Type I Portland Cement, and are under way on the Garner stone. One change was made from the ASTM method in that the specimens were compacted by vibration (in accordance with data obtained from Problem area 1 to eliminate compactive degradation.) rather than by the Proctor method. Two changes were made in the reference cited Iowa method; i.e., (1) 4.0 inch diameter by 4.56 inch high specimens were (2) compacted by vibration. Following compaction all samples were cured for 7 days in a 100 R. H. atmosphere at a constant temperature of 70°F.

Summary results of the completed freeze-thaw tests are shown in Table 4 and 5 and represent the average of 3 specimens for each entry shown. As noted in Table 4 all specimen strengths are in direct re-

*George, K.P. and Davidson, D. T. Development of a Freeze-Thaw Test for the Design of Soil-Cement. Highway Research Record No. 36, 1963. Published by Highway Research Board, NAS-NRC.

lation to (1) cement content and (2) freeze-thaw durability. Measurement of sample height change during F-T showed averages of 0.3, 2.6 and 8.0% expansion with 5,3, and 1% cement contents respectively, after 10 cycles in the Iowa F-T test. Extrapolation of expansion results to 0% cement content indicate about 11% linear height expansion after 10 cycles. Extrapolation of strength results to 0% cement content indicate about 200 psi for the control specimens and 90 psi for the F-T specimens with an R_f of about 46 percent. An R_f of about 80 percent has previously been indicated as a satisfactory criterion to freeze-thaw resistance of cement-treated Iowa materials.

Portland Cement Association durability criteria indicates soil-cement freeze-thaw loss of not over 14% for this soil (A-1a) under the ASTM freeze-thaw test. In accordance with this criteria the 5% cement content passed very satisfactorily (Table 5). The 3 and 1% cement specimens indicated failure after 6 and 2 F-T cycles respectively.

No general conclusions will be hypothesized with the above results until the freeze-thaw testing of the remaining two stones, treated with cement, are completed.

Stabilization studies utilizing a very small percentage of sodium chloride with the Bedford stone and tested by C-U triaxial tests, previously mentioned, have been completed. Computations and graphical tabulations are under way. An identical study and testing procedure using a very small percentage of calcium chloride has been started. Results so far are not particularly encouraging.

This project was originally proposed for a three-year period. The project was approved for two years subject to renewal for a third year; the present rate of progress indicates that a third year still will be

Table 4. Summary Results of Iowa-Freeze Thaw Test on Cement-Treated Bedford Stone.

Sample Designation	Cement Content, % dry soil wt.	P_c,* psi	P_f,** psi	R_f,*** %
B-5	5	965	947	98
B-3	3	317	218	69
B-1	1	227	109	52

*Unconfined compressive strength of control specimens immersed in distilled water for duration of test period of the F-T specimens.

**Unconfined compressive strength of F-T specimens following 10 cycles of freezing and thawing.

***Index of resistance of freeze-thaw, i.e., P_f expressed as a percentage of P_c.

Table 5. Summary results of ASTM D 560-57 Freeze-Thaw Tests on Cement-Treated Bedford Stone.

Sample Designation	Cement Content, % dry soil wt.	Soil-Cement Loss, %
B-5	5	0.7 at 12 cycles
B-3	3	100 at 10 cycles
B-1	1	100 at 4 cycles

required in order to complete the testing and analysis, and a proposal for extension will be submitted this summer.