PROGRESS REPORT

30 November 1964

Iowa, HPR-1(1), Item 42

Research project HR-99, Factors Influencing Stability
of Granular Base Course Mixes.

Research agency: Iowa State University.

Principal investigator: Professor James M. Hoover.

Date project started: November 1, 1963
Completion date: October 31, 1965

Budget (2 year total): $84,120.

Expended to November 1, 1964: $41,518.34

PROGRESS REPORT

FACTORS INFLUENCING STABILITY OF GRANULAR BASE COURSE MIXES

30 November 1964

Proj. HR-99 of the Iowa Highway Research Board
Proj. 516-S of the Iowa Engineering Experiment
Station, Iowa State University, Ames, Iowa

IEES Proj. 516-S
Nov. 30, 1964

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. Four lab compaction procedures were tried on a weathered, moderately hard limestone of the Pennsylvania System (which outcrops half the state of Iowa) obtained from near Bedford, Taylor County, Iowa. The procedures tested were (1) standard Proctor compaction, (2) static compaction, (3) vibratory compaction, and (4) drop hammer compaction, i.e., molding the whole sample by pounding on each end. Complete mechanical analyses were run on each sample portion representing one point of a moisture-density curve, for analysis of degradation during each of the compaction procedures. Since the Proctor method is the only standardized procedure, it served as the guide for maximum density and moisture content in each of the other procedures.

To date, the results indicate densities equivalent to standard Proctor can be produced by any of the other compaction methods used. However, optimum moisture contents may vary from 0.3% above to 1.0% below standard optimum.

The influence of compaction on degradation and segregation of the sample as obtained from the quarry is extremely variable (Table 1). For example, the static method reduced the gravel fraction by 10% on a total weight basis, while increasing the sand, silt and clay fractions by 3.5, 4.4, and 2.1% respectively. Segregation of particles was obvious in almost all of the

Table 1. Synopsis results of laboratory method of compaction study.

Compaction Procedure & Conditions	Dry Density, pcf	Moisture Content, % dry soil wt.	Variation of Particle Sizes, % of total dry sample Gravel	Sand	Silt	Clay	Visual Segregation
Control Samples (no compaction)	-	-	73.2	12.9	8.4	5.5	-
Standard Proctor	127.4	10.9	66.2	15.7	12.3	6.8	none
Static 0.1 in/min loading to 1 ton total load 5 min. holding time at 1 ton total load	128.1	9.8	63.2	16.4	12.8	7.6	slight at center
Vibratory 35 lb weight 2 min vibration 3600 cycles/min frequency 0.330 mm amplitude	126.9	11.0	73.3	12.2	9.2	5.3	none
Drop Hammer 15 blows each end	126.0	10.9	65.7	14.2	12.8	7.3	slight at ends

static compaction samples. To the opposite extreme, the vibratory method produced no degradation and no visual segregation when the following criteria was used: (1) 35 lb. weight on top of the sample inside a 4.0 inch diameter by 4.5 inch high mold, (2) 2 minutes of vibration time per specimen; (3) 3600 cycles/minute frequency; and (4) 0.330 mm amplitude. The standard Proctor and drop hammer methods produced degradation and segregation intermediate between the static and vibratory procedures.

Two additional crushed stones are being studied for degradation and segregation during standard Proctor and vibratory compaction only. One stone is a hard limestone from near Gilmore City, Iowa, while the other is a hard dolomite from near Garner, Iowa. A complete report summarizing all phases of the compaction study will be prepared as soon as the above phase is completed.

A rolled stone base or subbase course must meet 2 major criteria. First, it must have the supporting capacity to withstand repetitive design loadings. Second, the support capacity must not be reduced due to entry or movement of moisture. In many situations, it must be either free draining or waterproof, for prevention of reduction of supporting capacity by entry of water from the surface, edges, or subgrade; the latter by capillarity. The first criterion is normally not too difficult to meet with empirical design practices. The second is little understood, often overlooked, and sometimes judiciously disregarded. An overabundance of silt-size particles can make a soil or crushed stone particularly susceptible to moisture movement. Tests conducted on a recent rolled stone base problem west of Des Moines indicate high moisture content and high quantities of silt and clay particles, some of which may have come from the subgrade through moisture movement. Thus, if a crushed limestone is held to specifications of particle size distribution for maximum benefit to shear strength and binding qualities, yet be moisture resistant, the field compaction procedure must cause little or no degradation and segregation. Much research is still needed to iron out this problem; in particular, field compaction and service studies.

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 several representative Iowa crushed stones.

To date, this portion of the project has undergone intensive theoretical study and literature review of the following variables:

1. Size, shape and form of packing of granular and fine particles within a compacted crushed stone system.
2. Known frictional characteristics of pure minerals common in limestone.
3. Frictional and cohesive resistance and internal pore water pressure due to water lubrication and polishing of the particle surface.
4. Rate of sliding between particles during shearing tests.
5. Relation of stress to volume change of combinations of granular and fine materials during shear.
6. Remolding effect, or reorientation of contact between particles, during compaction, consolidation and shear testing.

The result of this study has been to produce equations and parameters, (and of course lengthy discussions). However, two significant fragments necessary for the laboratory investigation phase of this study have become apparent and continually reappear in the developed theory:

1. Volume change of a compacted crushed stone material may occur several times and in several ways during shear strength testing. Each

time even a minor volume change occurs, a major change of strength may also occur.

2. Particle surface adsorption of water and/or various chemical ions carried by water can create additional friction and/or cohesion characteristics due to the mineralogy and gradation of the limestone. In contrast, the same adsorption characteristics can completely destroy the strength of a rolled stone base.

Equipment constructed by the I.E.E.S. shop is being used to measure volume change (during triaxial shear testing) to less than 0.01 cubic inch on Taylor County crushed stone samples with particle gradations ranging from all plus No. 10 sieve to all minus No. 200 sieve material. Taylor County crushed stone specimens are also being prepared containing minute quantities of calcium and sodium chloride to study the effect of modification of the clay minerals on frictional and cohesive characteristics.

If the concepts mentioned above can be proven in the laboratory, the major mechanism of rutting of granular base courses under flexible surfaces may be known. In addition, and most important, the physical cause for many of our rolled stone base problems in Iowa may also be known. The laboratory phase of this study is now under way, though it will be possibly a year or more before the theories and many variables can be completely tested and analyzed.

<u>Problem 3. Improvement of the shear strength of crushed stone materials with organic and inorganic chemical stabilization additives.</u> The purpose 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 poor quality. Knowledge gained in Problems 1 and 2 of the project are assisting in the investigation of this problem

area as they relate to stability mechanisms.

The use of a minute quantity of an organic chemical dissolved in the mix water for optimum moisture content and density has been investigated as a stabilizer of a poor quality limestone, in cooperation with project HR-97. The results of this study were reported in the last Progress Report and are included in a paper to be presented to the Annual Meeting of the Highway Research Board (copies are being furnished the Director of Research, Iowa State Highway Comm.). In general, the chemical known commercially as Arquad 2HT, is an effective additive for improving the shear strength of the crushed stone under adverse moisture conditions. Maximum benefits were achieved with about 0.02% of the chemical, by dry material weight, increasing the frictional resistance to shear by over 40% that obtained in untreated stone after saturation. The treatment also gave a greater permeability to the stone, indicating the chemical does not keep water out of the whole material but imparts its improvements through aggregating and waterproofing small particles into a larger, more stable, structural unit.

Stabilization studies using very small quantities of Portland Cement are under way. Cement contents of only 1%, by dry material weight, have thus far produced significant increases in shearing strength and stability.