and with various compaction methods and degrees of moisture control were also constructed. It is believed that some curing protection should be provided.

E. J. Sampson and H. G. Henderson, also of Oklahoma, reported on a laboratory investigation of the effects of various dispersing agents on the mechanical analysis of soil-cement mixtures. Sodium carbonate, sodium oxalate and sodium silicate were found to be effective in this order. The data also yielded interesting information on the effects of curing soil-cement mixes.

Some cost data are given from South Carolina, North Carolina and Ohio.

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GENERAL PROCEDURE, SOUTH CAROLINA PRACTICE

BY W. H. MILLS, JR.

In South Carolina stabilization is not considered if suitable sand-clays or top-soils are available economically. These materials can usually be hauled six to eight miles before their price in place exceeds that of stabilization.

When no suitable soil can be found within economical haul distance, preliminary samples are obtained for determination of the methods of stabilization and a recommendation for quantities on which bids will be received. If time is available, a complete set of laboratory data is obtained on these preliminary samples before any recommendation is made, if not, a recommendation is based on previous experience in soils having similar gradings and other characteristics. The laboratory tests include mechanical analysis, determination of liquid limit, plasticity index and shrinkage limit and determination of optimum moisture content for compaction on a mixture of soil with the quantity of cement which is estimated will be necessary for stabilization. Artificial weathering tests on specimens of soil-cement mixes containing various percentages of cement are always made. The percentages of cement are varied, depending on the type of soil, but usually the tests are made with 5, 7, and 9 per cent by weight. An estimate is made of the quantity of each type of soil to be encountered in the final grade and the quantity of stabilizer is determined for the average of the project with maximum and minimum limits to care for variations in the soil. Data from these tests are also used in setting quantities for construction by matching similar soils.

During grading operations, soils which require excessively high quantities of stabilizer are eliminated, if economically possible, by placing them in the bottoms of fills or wasting. Generally the soils as found within the limits of the cut sections are used throughout the project but in a few instances select materials from borrow pits are stabilized more economically. For instance, one location on a certain project would have required at least 12 per cent cement for stabilization but by using selected material from a

nearby pit the quantity of cement was reduced to 6 per cent.

After grading operations are completed, check samples from the finished grade must be tested to determine soil changes. The quantities selected for construction work are, of course, based on actual tests of each soil type and most of this information is obtained from the tests on the preliminary samples. However, check tests following the same procedure as mentioned for the preliminary samples are always made on samples obtained after grading operations are complete. The quantity of cement selected for construction is determined from the results of the artificial weathering tests by a comparison of the different specimens in regard to their condition and losses. Usually the quantity selected gives a loss of less than 5 per cent at the end of 20 cycles, but tests are continued to 50 cycles.

MIXING METHODS

Two methods of mixing have been used successfully—the mixed-in-place or road mix method and the traveling mixing plant.

Mixed-in-Place Method: In the road mix method the soil is first pulverized as completely as practicable for the full width and depth. Cement is applied either from bags spaced at specified intervals on the roadway and emptied by hand or by mechanically operated sand spreaders which are attached to dump trucks. A disc harrow set so as to penetrate about half the depth of the pulverized soil should be run over the soil immediately after cement is spread in order to partially cut the dry cement into the soil. This aids materially in reducing losses of cement during the early part of the dry mixing period.

In our work mixing has always been done by heavy road machines supplemented by disc harrows, although special equipments such as orchard cultivators, disc plows, etc., have been used in a few cases to supplement the road machines. Dry mixing is continued until the soil-cement mixture is uniform in color and in order to accomplish this the soil is moved by the blade from the subgrade for the entire width of the road. Cement has been applied to soil containing almost the optimum moisture without resulting in trouble during the mixing period, but mixing is easier if the soil is dry and, of course, the subgrade must be stable.

After dry mixing is completed, samples of the mix are obtained at intervals not greater than 250 ft. and moisture contents are determined by drying. From these data the approximate quantity of water which must be added can be calculated. An adequate allowance of water must be made for evaporation during mixing or delays will occur in adjusting the moisture during the compaction period. The material is spread to the approximate cross-section before the application of water in order to avoid ponding and wet streaks. Water should be applied from a pressure distributor for the entire width in order to obtain uniform distribution and between loads the mix should be disced in order to avoid ponding. Mixing is continued by the use of heavy road machines and disc harrows until the moisture is uniform, and as a check the moisture content is again determined at intervals not greater than 250 ft.

Machine Mixing: The Barber-Green traveling plant increases the rate of construction considerably over the road mix method but figures of relative costs are not available.

The preparation of the soil for this machine consists of scarifying, partially pulverizing, and windrowing at least one day's run ahead. The moisture content of the soil in the windrow is determined and the quantity of water necessary to increase the moisture content to the optimum with an adequate amount for

evaporation is calculated. On the first project cement was applied from a hopper on a platform of the machine so that it went in with the soil at the front of the pugmill. Water was applied from a spray located at intervals above the pug-mill. However, on the last project cement was spread on the windrowed soil ahead of the mixing machine from bags spaced at the correct intervals. This procedure appeared more satisfactory because of the additional mixing action obtained with the loading device and in the hopper and also because it eliminated crowding of trucks and other equipment around the machine. The application of water was also changed to near the end of the pug-mill to increase the length of the dry mixing period.

At first the mix was discharged from the machine into a large windrow and spread by hand to the correct cross-section, but this procedure was altered on the last few projects and motor patrols were used for spreading. In order to perform this work economically it was necessary to accumulate a windrow 300 to 500 ft. long and at times this procedure would leave mixed and wet material in the windrow for as much as 3 to 4 hours. Tests have shown that this does not effect the mix adversely and the resistance to artificial weathering of specimens made at different intervals after mixing does not change appreciably unless the mix is allowed to remain uncompacted for periods greater than six hours.

The mixture obtained with the Barber-Green machine has not always been satisfactory in heavy clay soils. Due to the plasticity of the clay, balls containing a high percentage of moisture and in some instances an excess quantity of cement are frequently discharged from the pug-mill. On most of our projects it has been necessary to supplement the mixing of the Barber-Green with disc harrows and road machines. After the final mixing is completed the material is spread and disced so as to loosen it to the bottom. The moisture content is again determined and adjusted if necessary before compaction begins.

COMPACTION

The Proctor Principle of soil compaction using the sheepsfoot roller in the field was used on the Johnsonville Project constructed in 1935 and has been used on all projects since. It has been observed that the compacting force should be varied with different types of soil in order to secure maximum density. In sandy soils sheepsfoot rollers exerting high unit pressures will not work to the surface but will dig into the mix and keep it loose. In heavy clay soils rollers having low unit pressures will not give satisfactory densities at moisture contents within workable ranges.

The mixture should be shaped to the approximate cross-section all during the compaction period so that uniform compaction can be obtained from the bottom up. Also, it is necessary that the equipment be shifted throughout the width of the road to avoid uneven compaction which may result in streaks much softer and less dense than properly compacted material. More difficulty is always experienced in compacting the edges with present equipment.

The finishing of the surface presents difficulties which have not altogether been overcome. In clay soil it is our practice to continue with the sheepsfoot roller until the feet are running on the surface and penetrating approximately $\frac{1}{8}$ in. The excess material is removed by blading down to the depth of these penetrations. In sandy soils the roller is removed after it has worked to within approximately one inch of the top; the loose material is spread to the correct cross-section and compacted with pneumatic-tired rollers or loaded trucks. It is often necessary to add moisture to the

top inch of the mix during the compacting period due to excess evaporation but such additions must be carefully mixed to avoid scaling. After all blading is completed the surface is again rolled with pneumatic-tired rollers.

Compaction of the mix is one of the essential operations and great care should be exercised during this part of the work. The compaction of the top one-half inch of soil-cement mixtures appears to be one of the weak points in the present construction methods and there have been evidences of softness and scaling for this depth in a few places.

No curing has been specified on any projects constructed to date. So far it has not been demonstrated that this expense is justified. A tar prime is usually applied to the base within 48 hours after construction and in some cases it has been applied the day of construction as soon as the surface dries. A bituminous wearing surface consisting of a single treatment of asphalt and stone or a mixed-in-place treatment with 50 lb. of aggregate and cut-back asphalt is applied before traffic is allowed on the base. The single treatment does not appear to be adequate for ordinary traffic needs.

SAMPLING, SOIL CLASSIFICATION AND CEMENT REQUIREMENT—NORTH CAROLINA

By L. D. Hicks

Four soil-cement base projects were built in North Carolina from 1937 to 1939 comprising totals of 7 miles and 80,984 sq. yd. These bases are considered satisfactory.

A considerable range in soils was covered and the methods of sampling, soil classification and determination of amounts of cement to use are particularly interesting.

SAMPLING PROCEDURE

In order to determine the proper amount of portland cement to use, durability tests must be made of soil-cement mixtures in which varying amounts of cement are used with the particular soil. Since the necessary amounts vary with the kind of soil, it is imperative that the samples truly represent the material to be encountered.

The Bureau of Chemistry and Soils places soils having the same character of profile, the same range in color, structure, consistency, the same sequence of horizons and degree of horizontal development, the same general conditions of relief and drainage and usually a common or similar origin and mode of formation in groups called series. This is the unit of soil classification. Soils from the same horizons of the same series, the A horizon excepted, are very similar. If a sample is taken from the B horizon of a certain series in one locality it will have similar characteristics to another sample taken from the same horizon of the same series in a different locality. It is logical then to conclude that samples taken from all of the horizons of each of the several soil series to be encountered on a project will represent all of the soils on that project. By this same token, it is reasonable to conclude that samples from the same horizons of the same series and taken from different parts of the country will have similar characteristics. The A horizon or topsoil is generally ignored, as soil from this horizon is usually only a few inches thick and rarely occurs alone in the subgrade after the grading work is done. In fact, such a condition should be avoided during grading operations as this horizon generally contains a high percentage of organic matter, which in sandy soils prevents them from reacting with a normal amount of cement.