A Cement-Treated Base for Rigid Pavement

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The new Jackson (Mississippi) Municipal Airport is the first jet-age municipal airport to use a cement-treated base under rigid pavement. Because of its geological setting in an area of few natural deposits of satisfactory base materials, the existence of a good sandy soil on the site, and the need to pay special attention to the highly expansive clay on the site, the use of the cement treatment was found desirable. Results of laboratory tests of various mixes of the natural materials with cement are presented and discussed in describing the selection of the design mix. Methods of working the borrow pit and constructing the cement-treated base are discussed in detail.

• THE COMING of the jet age in air transportation found the airport runways of the City of Jackson, Miss. too short a length. A thorough study was made to determine whether it was feasible to expand the existing field or whether an alternate site should be developed. The study showed that the existing facilities could be expanded only at considerable expense, and even then they would not be entirely satisfactory. A group of possible new sites were studied minutely with respect to proximity to passenger origin, availability of land, approach clearances, topographic features, finances required, and many other details.

One site rated higher than the others with regard to most of the criteria considered and was chosen. This site was located in an adjoining county just across the Pearl River Valley from Jackson.

The selected site lies at the eastern edge of the alluvial valley of the Pearl River in the adjoining low, rounded hills. The alluvium in this area is predominantly silt. The surface covering of most of the hill section is a thin layer of lean clay; however, remnants of sandy river terraces are found on the tops of a few of the highest hills on the site. These surface layers are underlain by a thick, very expansive montmorillonitic, marine deposit known as Yazoo Clay.

PAVEMENT DESIGN CONSIDERATIONS

Borings showed that Yazoo Clay would be exposed in most of the cut sections, and laboratory tests and past experiences indicated this to be the most critical material from the design standpoint on the site. Results of the tests showed the following ranges of values: liquid limit, 70 to over 100; plasticity index, 40 to 70; volume change from LL, 80 to over 200 percent; and swell (compacted samples soaked 4 days), 10 to 20 percent. These values indicate this to be a treacherous material with which to deal. The soil is stable in its natural state, but swells considerably on being rewet after having dried. No instances of changed conditions have been observed where about 7 ft of lean clay overburden exists.

These factors were studied and satisfactory means of keeping the Yazoo Clay at its in situ condition during construction and subsequent years of use were considered. It was estimated that very little temperature change, if any, would occur more than 3 ft below the light-colored surface of a concrete pavement; therefore, little or no moisture change would occur because of temperature variation. This was considered to be the only type of protection against moisture change in the completed structure necessary as no ground water was encountered on the site. Thus, a thickness of select subgrade, subbase, base course, and pavement of 3.5 ft was believed to provide adequate thermal insulation for the Yazoo Clay. Cut sections had to be undercut 19 in. below subgrade elevation to provide the 3.5-ft thickness. To keep the exposed Yazoo Clay from drying during construction, it was specified that the lean clay backfill should be placed immediately, or the Yazoo Clay sprinkled sufficiently to prevent drying until the backfill could be placed. The subgrade was overlaid with 12 in. of subbase and base and 11 in. of pavement, as shown in Figure 1.

All fills under areas to be paved were constructed of the lean clay; the Yazoo Clay was deposited only in median areas where it was very unlikely that any pavement would ever be constructed.

A deposit of fine, clean sand containing thin clay and silt lenses was located near one end of the runway, and offered a source of base course material. Visual examination and laboratory classification tests indicated that it was a material of adequate stability, but, on further consideration, it was thought highly improbable that sufficient mixing could be effected to produce a uniform base on which to perform paving operations. Small pockets of clean sand would tend to ravel under paving equipment. Also, the material was fine enough to be easily transported by pumping action under moving aircraft if water entered the base. In its natural state, the sand was considered unsuitable for base course immediately beneath rigid pavement.

A study of the costs involved showed that because of haul distances, it would be cheaper to mix the sand with a moderate amount of cement to produce a satisfactory base than to import another material. Also it was believed that the cemented layer would provide additional protection and insulation over the Yazoo Clay. These facts were the basis for the decision to make a design study of cement stabilization in the top 6 in.

CEMENT TREATMENT DESIGN

Examination of samples and boring logs from the sand deposit proposed for use as base material showed that the amount of silt and clay in the final base material could be controlled to a considerable extent by the manner in which the material was taken from the pit. It was proposed that the material be removed by a shovel or dragline cutting up a vertical face. In so doing, the number of silt and clay layers cut could be controlled, thereby controlling the amount of material passing the No. 200 sieve.

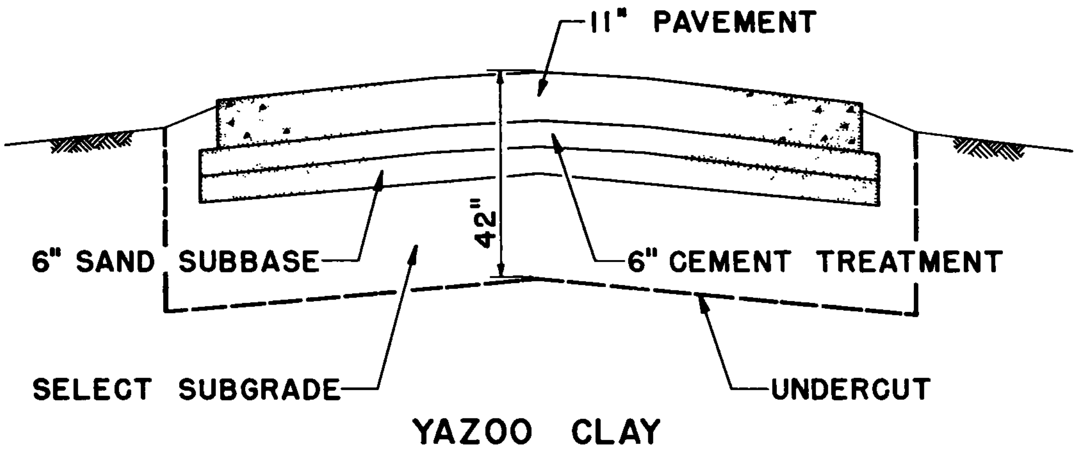

Figure 1. Typical cut section.

Laboratory moisture-density curves had been produced for untreated soil for four samples selected to cover the range of materials available in the borrow area in connection with subbase design. The characteristics of the four samples are given in Table 1. Because of time limitations it was necessary to compact specimens containing cement only at about the optimum moisture contents determined previously for the untreated soils. The specimens were compacted in a standard 4-in. diameter mold, using modified AASHO compactive effort, and were broken by compression at the end of 7 and 28 days of moist curing.

Plots of compressive strength vs percentage of cement are shown in Figure 2 for the individual samples. These data indicate that the compressive strength obtained varies with the amount of cement used and also with the sample tested.

TABLE 1

CHARACTERISTICS OF SAMPLES OF MATERIALS AVAILABLE IN BORROW AREA

Sample No.	Sample	Percent Passing			LL	PI	Max. Dens.	Opt. Moist.
		No. 40	No. 60	No. 200				
1	Clayey sand	100	99	27	30	4	118.0	12.6
2	Clayey sand	97	52	18	25	3	122.7	10.6
3	Sandy silt	99	90	53	29	7	123.6	11.6
4	Silty sand	98	83	13	NP	NP	116.7	11.2

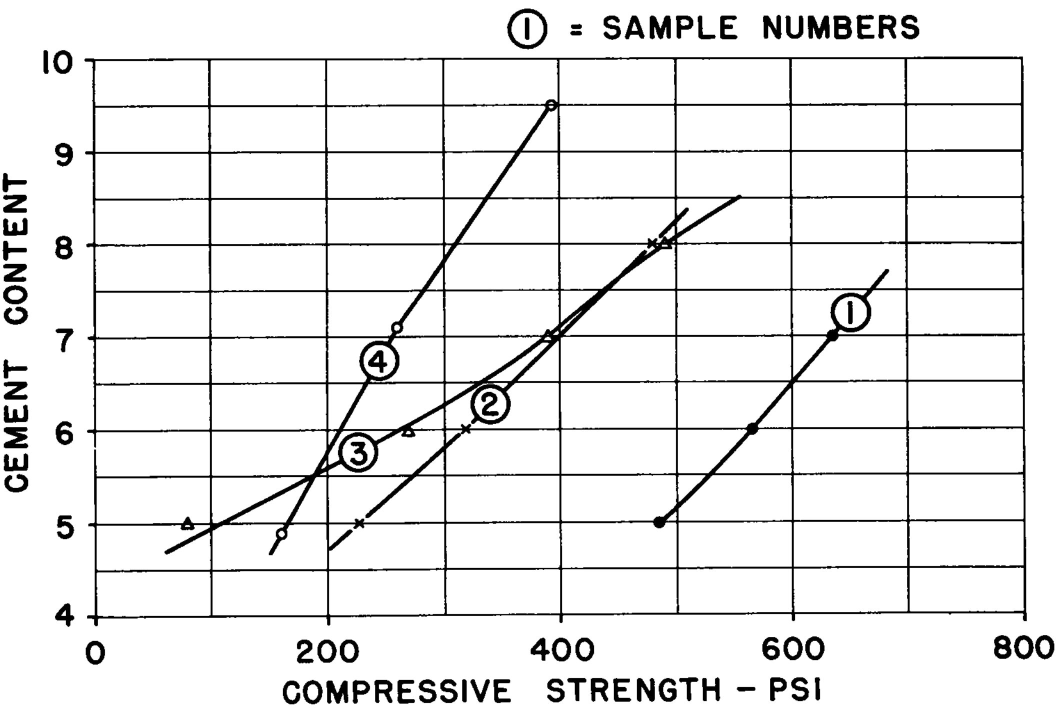

Figure 2. Compressive strength vs cement content.

The cause of variation in strength with sample tested was analyzed by plotting the percentage of material passing the No. 200 sieve against the compressive strength at 6 percent cement (Fig. 3). This curve indicates that maximum strength for cement used is obtained with about 28 percent passing the No. 200 sieve.

At this point it was necessary to decide on the minimum acceptable compressive strength. Based on long experience the Portland Cement Association recommends a minimum of 300 psi at 7 days for use with flexible pavements. It was felt that this figure could be reduced slightly for rigid pavements inasmuch as the design considerations do not envision such strength. Examination of laboratory specimens indicated that those breaking at 200 psi or more were well-cemented. This material so treated would be unlikely to pump, and would provide a stable working surface for paving operations. However, to add a little conservatism to the requirements, a minimum strength of 250 psi at 7 days was selected.

To arrive at the most economical and practical soil-cement mix which would provide the selected minimum compressive strength a plot of cement content vs percentage of material passing the No. 200 sieve was made from Figure 2 for a compressive strength of 250 psi and is shown in Figure 4.

Examination of this plot shows that the cement required to produce minimum strength varies inversely with the percentage passing the No. 200 sieve. This observation is based on samples 1, 2, and 4. Sample 3 was not considered in the analysis because the quantity of this material was limited and could only be used for mixing with the sand in cases of deficiency in material passing the No. 200 sieve. A study of the boring logs for the pit indicated that a material with 20 to 30 percent passing the No. 200 sieve would be produced in most cases by pit operation and that little mixing of additional fines would be required. Figure 4 shows that such a material would require about 4 to 5 percent cement to obtain the desired strength.

The laboratory investigations just described were all performed on well-pulverized and blended samples. It was realized, however, that field conditions would probably be different, and it was specified that the contractor should build a test section at the

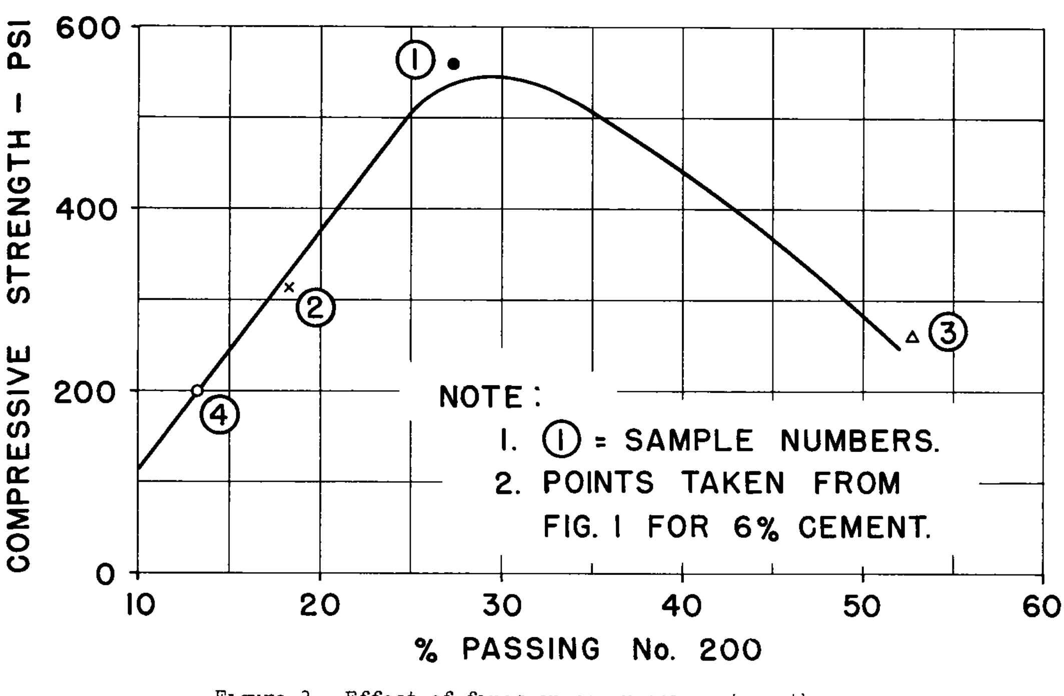

Figure 3. Effect of fines on compressive strength.

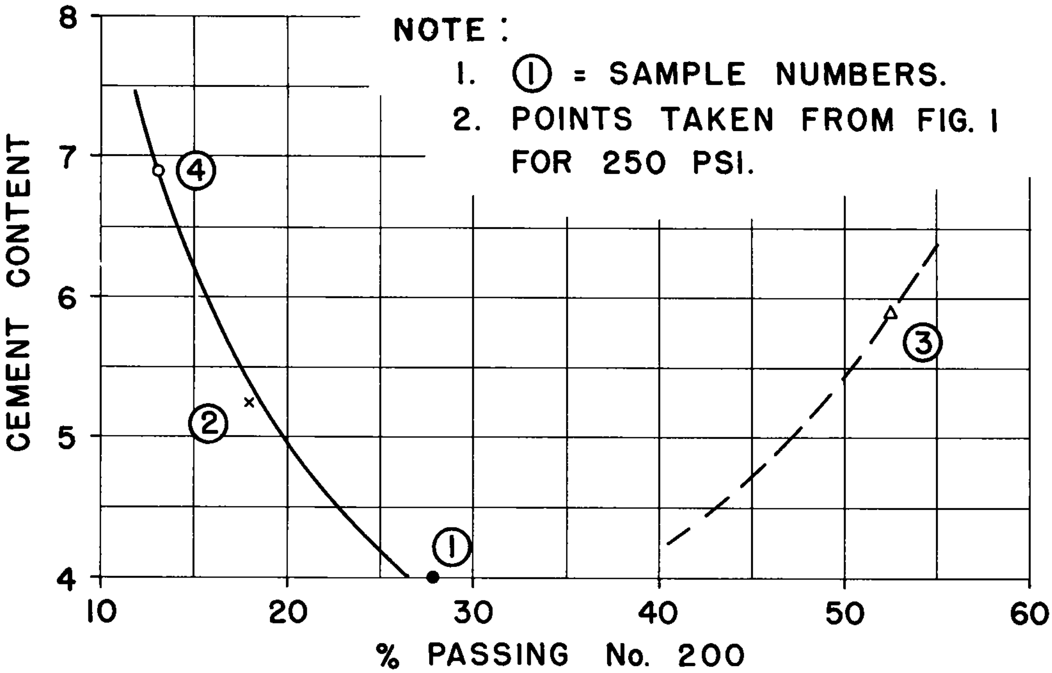

Figure 4. Cement required for 250 psi.

beginning in which operating procedures would be established. Construction of the test section showed that the pulverization requirements of 100 percent passing the 1-in. sieve and 75 percent passing the No. 4 sieve could be met consistently, but that the field behavior of this material differed considerably from the well-pulverized laboratory material.

One of the first problems encountered during construction was that of obtaining sufficient blending of material on the fill to produce a reasonably uniform soil. This was shown to be necessary by the discovery of a number of small spots (less than 100 sq ft) lacking sufficient fines and other small spots having excessive fines. The low amount of cement (5 percent) did not provide sufficient cement to produce minimum strength requirements in these areas. Moisture requirements for each of these spots differed considerably from that needed in most of the base, and it was found almost impossible to produce satisfactory moisture conditions in the whole area at one time.

Before beginning construction of the untreated subbase, laboratory moisture-density relationships had been determined on a typical sample meeting the specification requirements. It was observed that the action of the hammer on the small lifts in the laboratory mold produced further pulverization that was not duplicated in the field by the action of vibratory, pneumatic, and sheepsfoot rollers. A study of the effects of pulverization on density is shown in Figure 5. Curve 1 represents a completely pulverized sample. The sample represented by curve 2 received a moderate amount of pulverization in the field during excavation, and limited additional pulverization in the laboratory. Curves 3, 4, and 5 represent samples with limited field and laboratory pulverization.

Sheepsfoot, pneumatic, and vibratory rollers were tried in various weights and in various combinations, and the moisture content of the material was varied considerably during early stages of subbase construction. Almost regardless of equipment, the density obtained compared favorably with that of curves 3, 4, and 5 of Figure 5. The clay layers in the pit were generally in a very firm condition and at a moisture content of about optimum or a little less. When compaction could be completed without

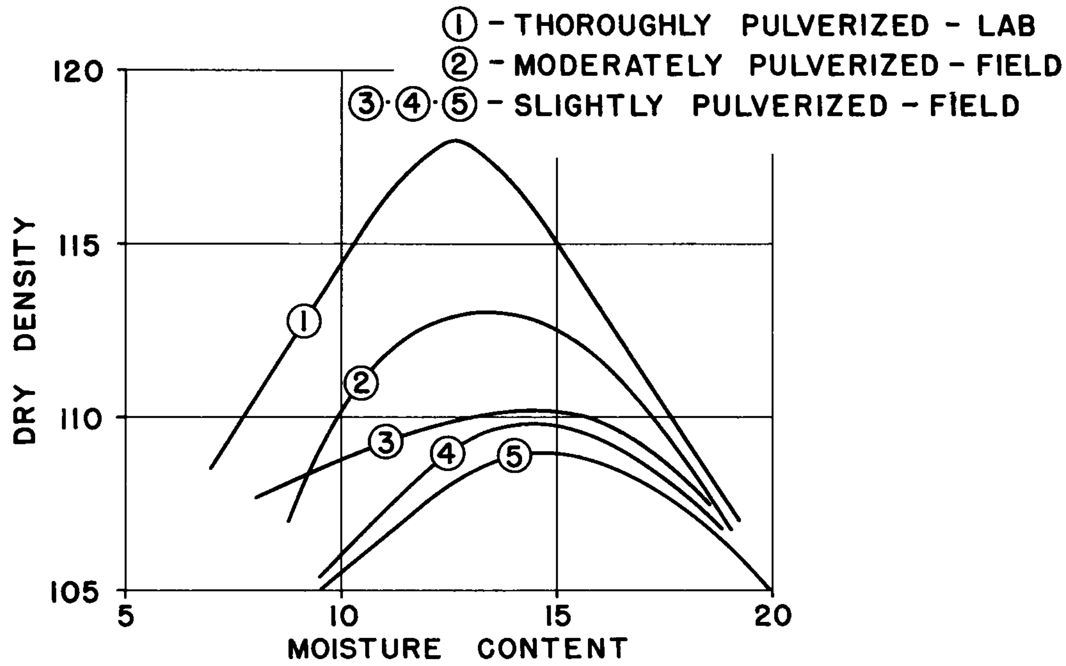

Figure 5. Moisture-density curves, subbase material.

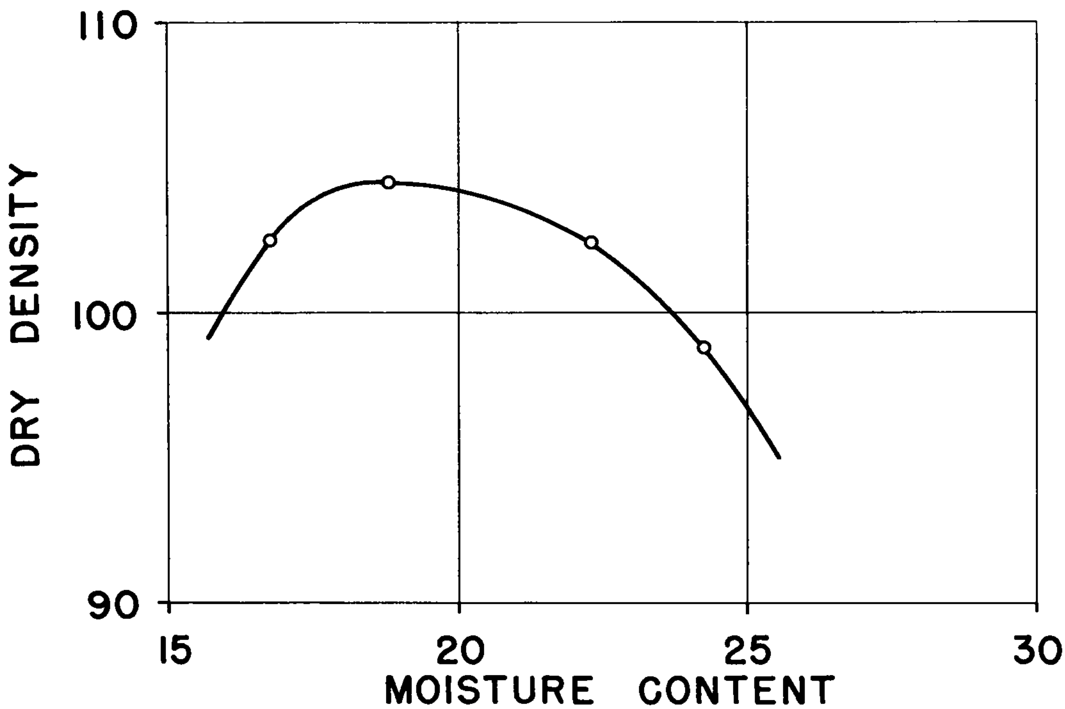

Figure 6. Moisture-density curve, cement treatment (5.5 percent cement).

the clay becoming wetter, the clay balls showed little deformation under the rollers. However, when the moisture content of the balls increased appreciably, they flattened considerably under the rollers and produced a spongy condition. It then became necessary to dry the clay sufficiently to bring about stable conditions before satisfactory compaction could be obtained.

Based on this finding, a laboratory curve for compaction control purposes was produced by adding 5.5 percent cement to a sample that had limited field and laboratory pulverization (Fig. 6). Test section construction indicated this to be about the maximum density obtainable in the field with reasonable construction effort. The compaction effort consisted of 4 to 6 coverages of a sheepsfoot roller producing a bearing of about 300 psi, two coverages of a vibratory roller, and 2 coverages of a light penumatic roller.

Cores taken from the test section showed that compressive strengths were generally a little below the 250 psi required, ranging from about 150 to 270 psi. From these tests it was apparent that additional pulverization or additional cement would be required to produce a base course with the desired compressive strength. It was decided that blending would be accomplished, the material pulverized more, and 6.5 percent cement added for another trial.

At this point in the history of this project (early November 1961) a rainy season began and lasted well into December. It appears that weather conditions will obviate further cement treatment work until the spring of 1962.

In conclusion, the design procedures required for the cement treatment for this project were of a routine nature based on thoroughly pulverized laboratory samples. After the relationships were established on ideal samples, however, it was necessary to perform laboratory tests on samples which were comparable to the mixes and blends produced in the field to provide control standards. The critical item in this problem has proved to be the degree of pulverization of the clay lumps, which must be taken into account during design testing to predict what can be obtained in the field with satisfaction.