Experiences With Expansive Clay in Jackson (Miss.) Area

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The very expansive, slickensided Yazoo clay in the Jackson, Miss., area has presented many problems to engineers. Upheavals of roads and streets of as much as one foot are common. Structures on hillsides in which conventional foundations were used have moved downhill several feet. Many slides have occurred in excavation slopes where the Yazoo clay was exposed.

Laboratory investigations and observations have indicated certain characteristics that can be taken into account in design and construction to eliminate, or at least minimize, undesirable performance of the expansive clay.

● JACKSON, MISS., lies in a physiographic belt known as the Jackson Plateau, which is a subdivision of the Gulf Coastal Plains Province. This belt runs in a generally east-west direction across the State of Mississippi with its western end at the eastern edge of the Yazoo River basin and becomes indistinguishable near the Alabama line on the east. The predominant soil of this belt is a fat, very expansive, stiff marine clay called the Yazoo clay because of its outcropping along the Yazoo River basin.

GEOLOGIC HISTORY OF AREA

The Yazoo clay was deposited in glacial times, probably in the rather shallow waters of the Gulf of Mexico that covered most of Mississippi during several periods. The deposit is generally thick—about 400 ft around Jackson. In later periods the Yazoo clay was covered with a loessial-type material that ranges in depth today from 0 to 10 or 12 ft. The loessial-type material is generally classified as a lean clay.

CHARACTERISTICS OF YAZOO CLAY

The top 10 to 15 ft of the Yazoo clay became highly weathered while exposed during its earlier history and this changed the color from the normal dark blue to a yellowish green. The many shrinkage cracks that developed in the weathered part closed during subsequent periods when the overburden was placed, but they remain in evidence today as joints or slickensides. The unweathered part is not jointed. Atterberg limits and volume change tests on a hundred or so samples of Yazoo clay from the Jackson area showed liquid limit values ranging from 50 to 120, plasticity index values ranging from 30 to 80, and volume changes from the liquid limit ranging from 70 to 190 percent.

In connection with the paving design for the new Jackson Municipal Airport, laboratory-soaked CBR tests were performed on several specimens of typical Yazoo clay. Figure 1 shows the results of such a test on a typical sample with liquid limit of about 70 percent and volume change from liquid limit of about 100 percent. The graph at the bottom shows the moisture-density relationship, and the middle graph shows soaked CBR values versus molding moisture contents. It should be noted that the soaked CBR values are low (about 5) at low molding moisture contents but increase to a peak value (about 15) at a moisture content just above optimum. The upper plot of percent swell versus molding moisture content shows that the amount of swell is highest at low molding moisture contents and decreases rapidly as optimum is approached. At a molding moisture content of 8 1/2 percent, the height of the specimen increased 18 percent; while at optimum (15 percent) the swell was only 2 percent. Even less swell was experienced where the molding moisture content exceeded optimum. These characteristics and relationships have been found by a number of investigators (1) of clays and are considered typical of such soils.

The effects of drying on the amount of swell during subsequent wetting when specimens of the previously described sample were molded at 95 percent modified and optimum are illustrated by Figure 2. Specimens were allowed to dry in an air-conditioned room for 10 days, after which they were submerged for 8 days. The shrinkage in 10 days amounted to about 0.5 percent; and subsequent 8 days of soaking produced a swell of about 12 percent. A laboratory CBR test similar to the one shown in Figure 1 was performed on this material except that the compactive effort used was approximately 95 percent of modified AASHO effort. The specimen molded at about optimum moisture content showed a swell of about 2 percent when soaked for 4 days as compared to about 9 percent for the sample of (Figure 2) that had been allowed to dry for 10 days.

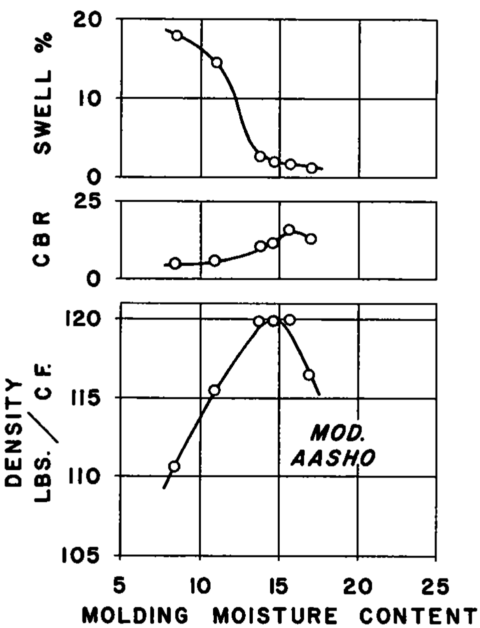

Figure 1. CBR test — Yazoo clay.

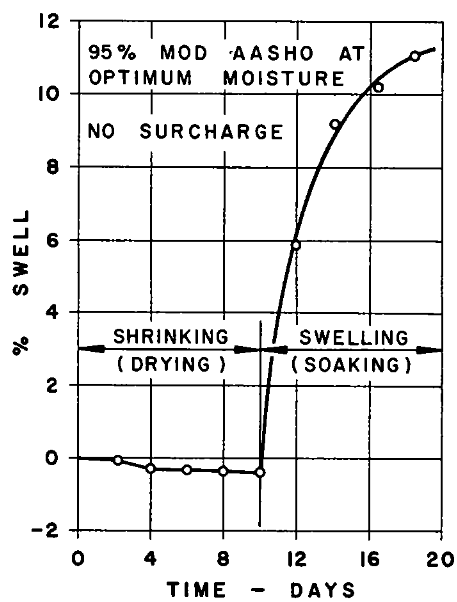

Figure 2. Effects of drying on amount of swell.

When air-dried Yazoo clay is subjected to wetting, it slakes quickly, whereas material at natural moisture content is affected very little by water. An air-dried lump about the size of a tennis ball was placed in a dish containing about 1/2 in. of water and at the same time a similar-sized specimen at natural moisture content was submerged. At the end of an hour the air-dried specimen was almost completely slaked while the other specimen showed only a barely noticeable amount of slaking.

Because of the structure of the soil it is very difficult to arrive at a shear strength for the highly fissured, weathered Yazoo clay; the shear strength of the unweathered material can be determined more satisfactorily. A study of values available from a number of projects around Jackson showed that shear strength values of the weathered portion range from about 0.4 to over 1 ton per sq ft, and those for the unweathered portion ranged upward from 1.75 tons per sq ft. Attempts to use various types of triaxial and direct shear tests on the weathered material have not proven satisfactory, and most engineers have used the unconfined compression test for design purposes. General practice in the area has been to use about the lower quartile of the range of unconfined compression tests, or even lower, for design shear strengths. This has proven so satisfactory that it raises a question as to whether these values are ultraconservative. However, until further investigation indicates conclusively that higher values can be used reasonably, it is believed that the more conservative approach should be used.

From the physical characteristics of the previously discussed clay it may be stated that detrimental swelling can be expected when Yazoo clay is allowed to dry below optimum and is then wetted. Slaking will occur when air-dried material is wetted.

DIFFICULTIES

Many cases of structure distress due to heaving or sliding of the Yazoo clay are to be found. These "distresses" vary from very slight movements to displacements of as much as 1 ft and are to be found in every type of structure: private homes, public buildings, utility lines, streets, highways. A few examples of the most evident to the casual passer-by will be discussed.

Before citing these examples it would be well to call attention to the change of moisture content within soil. When soil is exposed to the atmosphere, it goes through drying and wetting cycles according to the weather. When soil is covered with a highway or airport pavement there is a tendency for soils with moisture contents below optimum to become wetter while those with higher moisture contents may tend to dry slightly (2). These tendencies, however, may be changed if the soil is covered with a floor slab for a building to be artificially heated or cooled, thereby producing a different subgrade thermal regime.

Roads and streets show some of the most striking examples of troubles that stem from the presence of Yazoo clay. Examination of the profiles of pavement surfaces shows that most of the "wavy" condition is caused by upheavals above the as-built grade. Cracks in the pavement and the curbs are wider at the top than at the bottom as a result of this upward movement. Figure 3 shows the high point of such a movement with a differential displacement in the curbing of about 3 in. The lower side of the curbing was estimated to be about 1 in. above as-built grade. There is no readily

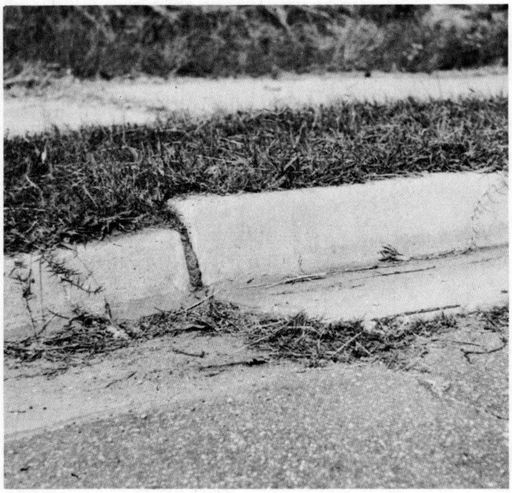

Figure 3.

Figure 4.

apparent explanation for the difference in amount of heave of the two sides of the joint. Probably it is due to difference in resistance to heave. Many of these areas of heave can be identified as places where the pavement was cut, the subgrade trenched for utility connections, and the trench walls allowed to dry; or where dry backfill was placed around structures.

No "drunken forests" have been observed but a "tipsy sidewalk" was seen in front of one home in Jackson (Figure 4). Indications are that the utility lines to the house are located in a trench along the right-hand side of the walk and that heave occurred over the trench. Figure 5 shows one case at a bridge abutment where the upheaval amounted to 5 in.

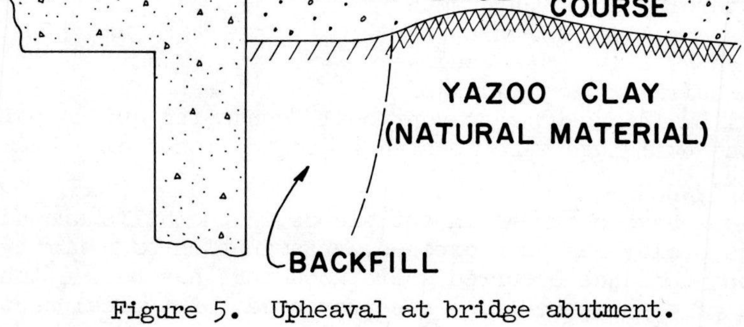

Figure 5. Upheaval at bridge abutment.

The natural ground, Yazoo clay, was excavated to give working room and the space backfilled with non-heaving material. It is noted that the heave has occurred over the interface between the natural ground and the backfill. The face of the natural ground would have had ample opportunity to dry considerably while the bridge was being constructed and before the backfill was placed. Little effort is made during the course of normal construction to prevent cut faces or fill material from losing moisture, and therefore, little imagination is required to envision a detrimental amount of drying taking place in cut faces, trench walls, road foundations, and stockpiles of fill or backfill material.

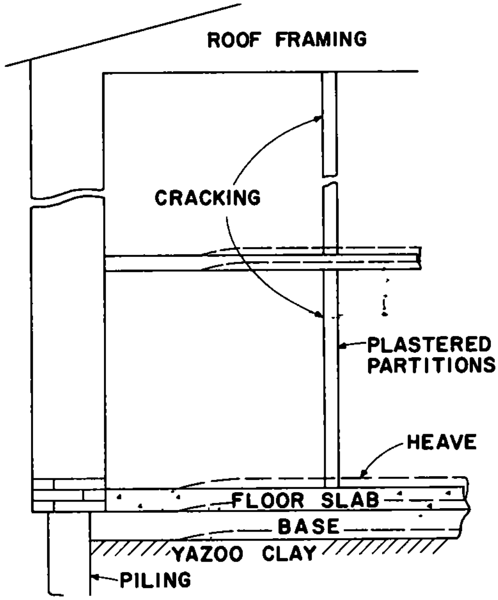

Figure 6. Upheaval in 4-storied building.

With respect to distresses in buildings, cases of differential vertical movement of as much as 1 ft in ordinary dwellings have been reported. One interesting case of a 4-story building is illustrated in Figure 6. The bearing walls were placed on piling and showed no movement. Partition walls on the lower floor were placed on a slab with a few inches of base course laid directly on Yazoo clay. Upheaval in the interior of the floor slabs forced partition walls upward causing much damage to interior walls, floors, and ceilings all the way to the top floor.

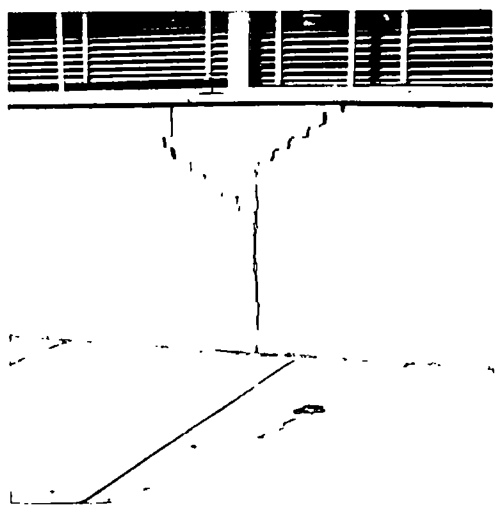

Figure 7.

Figure 7 shows a case where upheaval has cracked the exterior wall severely. The window sill has been displaced upward over an inch. The interior of this building presents a rather disturbing appearance with cracked walls and floor slabs uplifted as much as 2 in. The condition of this building is typical of several small buildings with conventional foundation and no piling. In every case the buildings were located where the Yazoo clay had little or no overburden.

Many slides have occurred in cut slopes in the hills around Jackson where the Yazoo clay has been exposed. Examination of a number of slides indicated that none has occurred where good turf has been established or where drying of the exposed face was prevented. A typical section of a

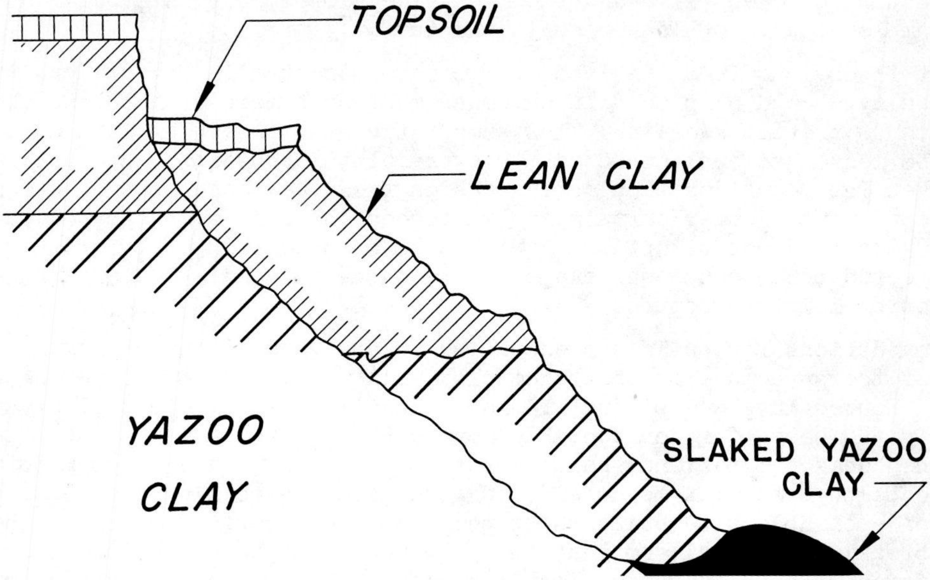

Figure 8. Section of a slide.

slide investigated in considerable detail is shown in Figure 8. This area was bare of vegetation, had been exposed for several weeks, and was observed to have developed large shrinkage cracks. Several rains occurred during the time the cut face was exposed. When the slide was repaired, the slaked material was found at the toe of the slope. The other material showed no evidences of slaking and became quite stable under a little traffic of earth-moving equipment. A typical slide along a roadway is shown in Figure 9. It has been necessary for maintenance forces to remove slaked material that has flowed out over the roadway here several times.

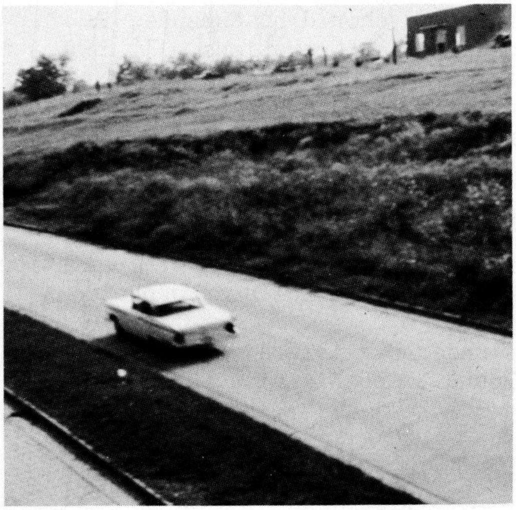

Figure 9.

DESIGN AND CONSTRUCTION

It is considered theoretically possible to construct an embankment of Yazoo clay for a roadway or street that would be entirely satisfactory for many years. However, it is considered improbable that such a structure could be maintained so that detrimental moisture change of the Yazoo clay could be entirely prevented. It is believed that any circumstances that removed vegetative cover from the slopes or changed the thermal regime produced by the pavement would cause volume change in the clay. Therefore, it is believed necessary to restrict the use of Yazoo clay as a fill material to the bottoms of deep fills and to cover side slopes of such embankments with ample amounts of leaner soils and turf.

It is obvious from the laboratory data presented in Figure 1 that Yazoo clay should be placed in an embankment at a moisture content above optimum to prevent swelling. The shear strength of such an embankment will be less than one compacted at lower moisture contents, and this must be taken into consideration during design from the standpoint of stability and settlement. Under certain circumstances the soil might dry out after being compacted wet of optimum, but little or no detrimental shrinkage may be expected because the shrinkage limit is only slightly less than the compaction moisture content.

Foundations for buildings should be so designed that vertical movement of the structure of the Yazoo clay will not be reflected in the structure. Poured-in-place piling are recommended with sufficient clearance under grade beams for considerable movement to take place without affecting the beams. Experience has shown that there is little or no moisture change below 8 ft. It is considered good practice to line the top 6 or 8 ft of each hole with builders' paper, plastic sheeting, or some other bond-breaking material, so that the pile would not be subjected to an upward force in case of heave along the piling. Sufficient length of piling is provided below the 8-ft depth to absorb the imposed load in skin friction and end bearing. Slab foundations should not be used even when as much as a foot of base course material is placed between the slab and the Yazoo clay.

Cut slopes should be completed, blanketed with topsoil, and grassed in as nearly a continuous operation as possible to prevent drying of the clay. Although no slides were observed on slopes definitely identified as flatter than 3 to 1, flattening slopes above should not be considered sufficient protection against sliding. The use of 4 to 1 or 5 to 1 slopes for cut sections, however, is recommended wherever possible as added precaution. Establishment of turf by the quickest method possible (preferably solid sodding) is considered highly essential.

The foregoing discussion indicates that a prime effort in both design and construction where Yazoo clay is involved should be expended in keeping the material from drying during construction operations. It is believed that adherence to these recommended design principles and construction procedures will do much to eliminate the troublesome effects of Yazoo clay. It is further believed that application can be made to expansive clays in other sections of the country.

REFERENCES

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2. REDUS, J. F., "Moisture Conditions under Flexible Airfield Pavements." Jour. Soil Mechanics and Foundations Division, ASCE, 83: 1159-61 (1957).