Highway Design and Construction Problems Associated With the Loessial Soils Of West Tennessee

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•TENNESSEE'S Loess Belt lies in the western part of the state and is a portion of the Lower Mississippi Valley loess region. It extends from the Mississippi River eastward, encompassing an area of approximately 3500 sq mi. Thicknesses up to 90 ft occur along the Chickasaw Bluffs that border the Mississippi just north of Memphis. The loess thins to a feather edge along a line that approximately parallels the Mississippi some 30 mi to the east (Fig. 1).

The typical loess of West Tennessee classifies as an A-4(8) with approximately 95 to 100 percent of the material passing a No. 200 sieve. Occasionally, a sample will classify as an A-6 or even as an A-7 with low group indices. The liquid limit is generally around 30 to 35, with PI's ranging from 4 to about 10. The average density, using the standard Proctor method (AASHO T 99-57, Method A), is about 105 pcf at an optimum moisture content of 15 percent. The California Bearing Ratio, based on ASTM designation D 1883-61 T, for this material generally ranges between 15 and 25. The modulus of subgrade reaction in several fill sections along Interstate 40 in Fayette County, under very optimum conditions, ranged between 300 and 450 psi. Direct shear tests conducted on undisturbed samples taken from Project I-40-1(68)3 in Shelby County showed friction angles from 27 to 32 deg. Based on the physical data, one might not ordinarily consider this soil as presenting any great problems, especially if he were not familiar with loess and only had these data to work with. However, those familiar

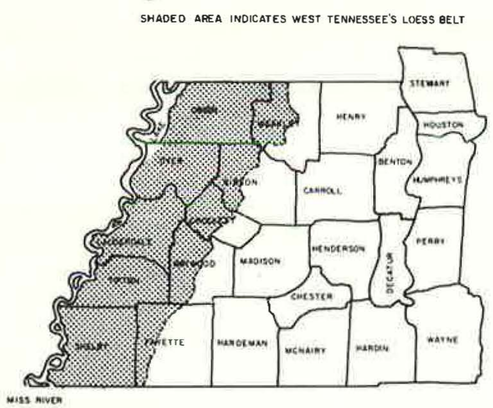

Figure 1. West Tennessee's Loess Belt.

TABLE I

PROPERTIES OF SAMPLES TESTED

County	Obion	Lauderdale	Dyer	Dyer	Dyer	Dyer	Dyer
Route No.	S.R 3	S.R 3	SR 3	SR 3	SR 3	S.R 3	SR2[illegible]
Sample No.	2	1	2	9	10	11	5
Station No.		676+50					
Depth	1½'-2'	1½'-2'	2-2½	1½-2'	1½-2'	1½-2'	1½-2'
Location	WBL	EBL	WBL	EBL	WBL	WBL	EBL
Gradation — Total Percent Passing							
No. 4	100			100	100		100
No. 10	99	100		97	97		99
No. 40	97	99	100	92	95	100	97
No. 100	95	98	99	90	92	98	96
No. 200	94	97	98	89	91	97	95
% Silt	72	79	82	65	61	77	73
% Clay	22	18	16	24	30	20	22
Atterberg Limits, Density, etc.							
Liquid Limit	29	29	31	33	45	32	34
Plastic Limit	24	25	25	20	25	26	23
Plasticity Index	5	4	6	13	20	6	11
AASHO Type	A-4	A-4	A-4	A-6	A-7-6	A-4	A-6
Group Index	8	8	8	9	13	8	8
Proctor Density	109	108	105	109	100	102	104
Optimum Moisture	12	14	15	14	19	16	16
In-Place Moisture	26	29	25	22	24	24	25

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TABLE 2
BEARING VS MOISTURE

Test No.	% Moisture at Compaction	Additional Moisture	*% of Standard C.B.R.
1	17 % (Optimum)	Soaked-96 hours	13.5
2	20%	Unsoaked	10.0
3	23%	Unsoaked	2.5
4	25%	Unsoaked	1.0
5	25%	Soaked-96 hours	.16

*A.S.T.M. Designation D1883-16T

TABLE 3
RESULTS OF COMPRESSIVE STRENGTH TESTS

% Cement	Time and Curing Conditions			
	7 Days Moisture Room	14 Days Moisture Room	5 Days Moist. Room 2 Days Immersion	5 Days Moist. Room 9 Days Immersion
5	250 psi	310 psi	147 psi	127 psi
7	342 psi	462 psi	238 psi	391 psi
9	394 psi	537 psi	382 psi	457 psi

with this particular material are keenly aware of the problems that can result if proper design and construction procedures are not followed.

Not until after the beginning of the Interstate program in 1956 did Tennessee become particularly concerned about the design and construction of the roadways in the Loess Belt. Even then, many engineers failed to recognize that here was a unique material that required special consideration in design as well as construction. Recently, however, due mainly to failures, considerable work, which should eventually lead to more appropriate designs, has been done by the Division of Materials and Tests. Subgrade failures associated with flexible pavements along several of the major primary routes have been the main concern in recent years.

Due to its gradation and high silt content, loess has a very "high capillarity." Thus moisture accumulation in the subgrade is the primary factor affecting the stability of roadways constructed in the Loess Belt. Normally, a great deal of this capillary water would be loss by evaporation, but because of the impervious cap or seal formed by the base and pavement, upward moving moisture is trapped. This moisture movement is further accelerated by the vibratory action of passing vehicles. Once the moisture accumulation begins to approach the plastic limit content, further vibratory action tends to knead and compress the subgrade soil to the point of failure. A recent investigation of rutting-type pavement failures along State Route 3 (US 51) in Dyer, Lauderdale, and Obion Counties, and State Route 20 in Dyer County revealed moisture contents near or at the plastic limit in the subgrade soils directly beneath the pavement (Table 1). These high moisture contents occurred in cut sections as well as fill sections.

Table 2 illustrates the loss of bearing when moisture is increased above optimum. The sample used in this case was an A-4(8) with a liquid limit of 34 and a PI of 9. Each sample was compacted to the maximum density possible with the moisture content shown. This is not a valid test with regard to ASTM specifications; however, it does illustrate the importance of close moisture control in compaction, and it was used for illustration in a recent departmental compaction seminar.

Based on the findings along the primary roadways just mentioned, as well as on laboratory investigations, the Division of Materials and Tests will make certain recommendations to the Design Division regarding base and pavement types and thicknesses, and subgrade treatment. If flexible pavements are used, subgrade treatment with 6 or 7 percent (by weight) portland cement, as well as a portland cement stabilized base, will be recommended. This is in addition to the normal flexible pavement thicknesses used in this area, which, for this type roadway, generally total 7 in. The decision to use a cement-treated subgrade stems largely from recent lab tests conducted using varying percentages of portland cement. Table 3 gives the results of compressive strength tests conducted on samples of loess containing 5, 7, and 9 percent portland cement by weight at various time-intervals and under various curing conditions. The soil used in this case was an A-4(8) with a liquid limit of 39 and a PI of 9. The clay content in the soil was 24 percent. This is somewhat higher than the clay percentage usually found in the loess of Dyer County.

If rigid pavements are desired, a soil-cement base is recommended. Rigid pavements generally are much more satisfactory than flexible pavements where the design is based on comparable load requirements. Of the some 40 mi of Interstate highways constructed within the Loess Belt, all have had rigid pavements with either a soil-cement base or a cement-treated dense granular base. Much of this mileage has been open for 2 years or more, and there have been no base and/or pavement failures of any consequence.

A number of years ago sand-gravel layers or "blankets" were recommended as "capillary breaks" to prevent moisture from accumulating beneath the pavement along a section of State Route 3 in Lauderdale and Dyer Counties. Due to the improper placement of this material, however, the results were unsatisfactory. With the proper design, there would appear to be no reason for the failure of this method, if the proper construction methods were utilized. This type of drainage should be especially effective in relatively low, flat-lying areas that require shallow fills.

Aside from appropriate base and pavement thicknesses and proper drainage, rigid controls must be exercised in the construction of loess embankments. The emplacement of loess in fills at or very near optimum moisture content (within 2 percent) is essential if maximum stability is to be achieved. Permeability and CBR tests have proven that loess, when compacted to its maximum density at optimum moisture content, is essentially impervious. Tennessee's present specifications require earth fills to be compacted to 95 percent of the maximum density (AASHO T 99-57, Method A). The need for attaining the specified density becomes even more essential where the plasticity index is less than 5. The absolute necessity for close field control in the construction of loess embankments cannot be overemphasized.

Side slopes for fills are presently constructed on a 2:1 ratio. Due to the highly erosive nature of loess this has produced some problems, especially on relatively steep gradients. It would seem that 3:1 slopes would be more desirable, as they would facilitate seeding, fertilization, and general maintenance. Where gradients are steep, curbs and flumes might be used to prevent large quantities of water from flowing over the fill slopes. The type of vegetation on these slopes is also important. Grasses that tend to "clump," such as fescue, are not as desirable as the "creeping" grasses, such as Bermuda. Sodding of slopes has been done on several urban projects in recent months. Sodding, of course, is the most desirable erosion preventative; however, it is a rather expensive method and generally cannot be justified, especially in rural areas.

In the last 2 years, the Tennessee Department of Highways has adopted a backslope design of 3:1 for loessial soils in rural areas. This particular slope was arrived at essentially as a compromise, resulting from a controversy as to whether near-vertical or conventional soil slopes were more desirable. In urban areas, backslopes of 2:1 with sodding are utilized. As in other states where highways are constructed through loess deposits, backslope erosion is a rather significant problem (Fig. 2). It is generally

Figure 2. An example of the highly erosive nature of loess. These slopes had originally been constructed on a 2:1 slope ratio and had gone unattended for approximately 18 months.

Figure 3. An example of a relatively stable vertical cut in loess. This particular cut is in a gravel pit in Tipton County. It is approximately 25 ft in depth.

believed by some in the department that since loess does possess the rather unusual characteristic of standing on very steep slopes, this inherent characteristic should be taken advantage of in many cases by constructing slopes with near-vertical faces (Figs. 3, 4). This belief is shared only by those persons in the department that are trained or experienced in soil engineering. Design and Construction personnel have maintained that conventional slopes ($1\frac{1}{2}$:1 to $2\frac{1}{2}$:1) are much more desirable, not only from an aesthetic viewpoint but for maximum stability as well. It is recognized that there is merit in both concepts; therefore, this paper will not attempt to delve into the details involved in either school of thought.

Whatever the slope design chosen, surface drainage must be controlled at all times. Surface water in sizeable quantities must never be allowed to pour over the face of the cut, not even after the establishment of vegetation. The method devised for controlling this depends to a large degree on the configuration of the terrain behind the top of the slope. In some cases this may be handled by the construction of a shallow flat-bottomed ditch 10 to 15 ft behind the top of the slope. This ditch should be paved, sodded or seeded, depending on the gradient. The natural vegetation should be disturbed as little as possible, especially between the ditch and the top of the cut. Benches are generally recommended for cuts exceeding 25 ft and at 20-ft intervals thereafter. These benches should be constructed with a minimum 20-ft width, and in such a manner that surface water is diverted to the rear. Very heavy seeding or sodding at the slope-bench contact is suggested.

Figure 4. An example of "columnar slabbing" in loess in a gravel pit in Lauderdale County.

Side ditches should also be flat-bottomed and, depending on the gradient, should be paved, sodded or seeded.

In past years, Tennessee's design and construction methods and policies have not been in accord with the rather unique engineering characteristics of loess. In more recent years, efforts have been made to formulate designs and develop construction methods that are more compatible with these characteristics. Still more work needs to be done, however, in the development of more definitive policies regarding the location, design, construction, and maintenance of all roadways that traverse the Loess Belt.