THE PREPARATION OF SUBGRADES

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The word "subgrade" is used in this discussion to mean the *prepared surface* of the soil-substructure for receiving the base, pavement or wearing-surface. The word "soil-substructure" is used in referring to that part of the road structure underlying the subbase, base, pavement, or wearing-surface.

A rational approach to efficient design can be found in the answers to: What are the limiting values of stability of the soil-substructure at hand under different moisture conditions? What are the limiting values of stability of the substructure if deformations must be limited to certain maxima? What conditions of moisture content must be maintained constant or confined within narrow ranges of fluctuation to insure high stability at all times? What conditions must be maintained to insure constancy of volume? What methods of subgrade treatment will maintain the desired conditions in the soil-substructure? How much will these treatments cost? And, finally: What type and thickness of pavement or base is adequate if the subgrade is treated or prepared in such a way that the physical state of the soil-substructure will remain substantially unchanged with a known stability?

Volume changes of subgrade soil are responsible for setting up conditions under which rigid-type pavements are subjected to high stresses not always considered in the design of the slab. Water percolating through joints and cracks in concrete pavements causes certain cohesive soils to swell and raise the slabs at these points. Similar swelling occurs under the logitudinal edges of the pavement.

Vertical movements of slab ends at transverse joints have been found to be as much as two inches on some pavements in Nebraska. Upward movement of slab edges has been found in some cases, to reduce the crown of the pavement by one-half to three-fourths inch. Under such conditions uniform subgrade support obviously does not exist. It is conceivable that swell of the subgrade under a transverse joint might lift the slab clear of subgrade support for a span of 10 ft. In such a case the tensile stress in the bottom of a 7-in. slab would be 130 lb. per sq. in. from the dead weight of the slab itself. This added to stresses induced by wheel loads and temperature differentials makes a total which would result in rupture of the slab after a few repetitions. A similar condition of overstress occurs in a longitudinal direction when the edges of the slab are lifted and subgrade support is removed or reduced under interior portions of it.

The swelling of soil depends largely upon its capillary properties and therefore, one of the first attempts at maintaining constancy of volume was to add sufficient water to satisfy the capillary capacity of the subgrade.

This method of treatment has been used on several projects in Nebraska. On one section of an experimental project constructed in 1936 the subgrade was untreated, on another the top six inches was brought up to the optimum moisture content for compaction and on a third section the same treatment was extended to a depth of 12 in. Water was incorporated with the soil by thorough mixing with disc and blade machines and the moistened material was rolled back into place in six-inch lifts. Wheel rollers were used for compacting. Table 1 gives the results of compaction tests and tests

of samples taken from the finished subgrade.

Since its completion, distortion of the pavement at transverse joints has occurred on all three sections. However, on the moisture-treated sections it is less than half as severe as on the untreated section. There is no appreciable difference between the present condition of the pavement laid on the six-inch treatment and that laid on the twelve-inch treatment. Although the moisture treatment was not so effective on these experimental sections as might be expected, some rigid pavements laid during the last two years in Nebraska with similar subgrade treatment do not show any appreciable distortion to date.

The theory of this type of treatment assumes that changes in climatic conditions will not result in removal of the moisture from the subgrade. However, observations in Texas show that under certain conditions the moisture is lost to the extent of making the treatment worthless. It appears, therefore, that some means of maintaining the desired moisture content at all times in this type of subgrade preparation is essential for best results. Consideration might be given to the use of calcium chloride or other similar materials for this purpose.

TABLE 1

Soil Type	Density at Optimum Moistures, lb. per cu.ft.	Subgrade Density, lb. per cu.ft.	Optimum Moisture, per cent	Subgrade Moisture, per cent
Untreated Section				
Yellow Silty Clay.....	99.7	93.3	21.0	15.4
Black Silty Clay......	99.7	97.1	20.0	14.4
Yellow Silty Clay Loam	103.5	95.2	20.0	18.2
6-Inch Treatment				
Yellow Silty Clay. ...	101.0	99.7	20.5	20.8
Yellow Silty Clay Loam	102.9	100.3	20.2	20.8
12-Inch Treatment				
0 to 6 Inches:				
Yellow Silty Clay.	101.0	97.8	20.5	21.8
Black Silty Clay.....	97.8	96.5	21.5	22.8
6 to 12 Inches:				
Yellow Silty Clay	101.0	96.5	20.5	21.8
Black Silty Clay.....	97.8	97.8	21.5	22.2

TABLE 2

TESTS OF NATURAL SUBGRADE SOIL

Project No.	Sand, %	Silt, %	Clay, %	Liquid Limit	Plasticity Index	Density at Optimum Moisture, lb. per cu.ft.	Optimum Moisture, %
56	12	52	36	42	17	98.4	21.3
56	12	35	53	53	23	89.5	28.5
208	22	52	26	53	24	94.0	26.5
208	45	28	27	33	13	112.4	16.5
208	29	36	35	35	15	108.0	18.0
208	11	56	33	35	13	108.0	18.5
208	11	46	43	49	25	99.7	23.0

TABLE 3

TESTS OF TREATED SUBGRADE

Project No.	Depth of Treatment, Inches	Density at Optimum Moisture, lb. per cu.ft.	Subgrade Density, lb. per cu.ft.	Optimum Moisture, %	Subgrade Moisture, %
56	2	129.5	124.5	9.1	9.9
56	3	131.4	131.4	9.0	7.9
56	4	130.2	125.1	8.6	8.0
208	2	127.6	127.0	9.6	10.0
208	1½	121.9	124.5	9.3	8.7
208	2	121.9	121.3	10.6	10.1

Another method of preventing the permeation of water into the soil-substructure is to densify the subgrade sufficiently to make it relatively impervious. This can be accomplished by mixing granular material with the subgrade soil in the proper proportion. This mixture is then wetted to facilitate compaction and compacted as thoroughly as possible. The proportions of clay and granular materials should be such that after drying and subsequent rewetting the clay in the

mixture will swell just enough to close the voids and thus stop further wetting or percolation.

This type of treatment has been used under several rigid-type pavements in Nebraska. Tables 2 and 3 give the test data on two of these projects. Cheap, locally-available sand was used as the admixture on both projects. No distortion of the pavement has been observed where this type of subgrade treatment has been used.

The quantity of sand added to the natural soil was sufficient to reduce the plasticity index in all cases to between six and ten. No differences are apparent as yet in the performance of different depths of treatment.

Theoretical analysis shows that increasing the bearing capacity of a subgrade has small effect in reducing the stresses in a rigid type pavement unless the subgrade is altered in such a way that it furnishes not only vertical reactions in supporting the pavement, but also acts as a continuous body. From this it is concluded that it is hardly worthwhile to spend much money in increasing the bearing capacity of the subgrade unless in doing so the character of the whole soil-substructure is changed so that it will act somewhat as a continuous body. It may be possible that the construction of semi-rigid stabilized soil base courses under rigid type pavements may permit some reduction in the stresses, and, therefore, the thickness of the pavement. Considerable research is necessary to determine what might be done in this direction.

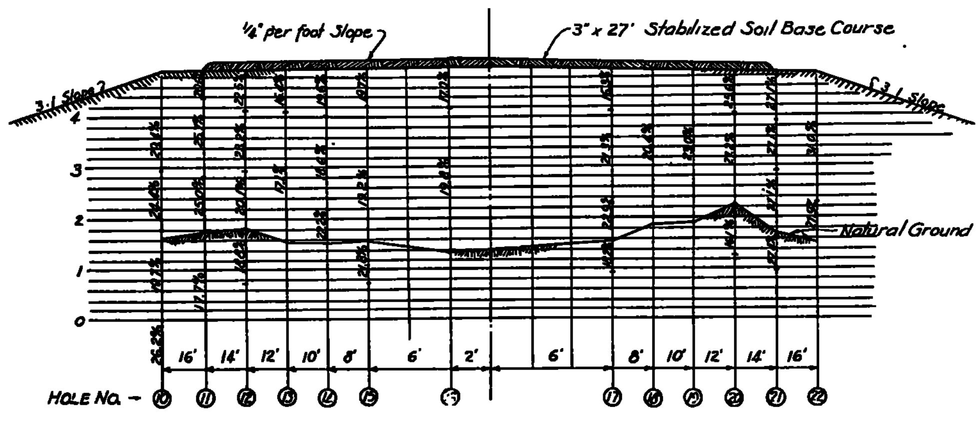

Figure 1. Distribution of Moisture in Embankment. Condition on March 15, 1938

In contrast to the requirements for subgrades to support rigid type pavements, flexible pavements require soil-substructures which have high bearing capacity. Most soils have a sufficient bearing capacity to support the loads transmitted to them through relatively thin flexible pavements if their moisture contents are kept below certain critical values. It is necessary, therefore, in treating subgrades for flexible pavements to prevent the permeation of gravitational water and the rise of moisture by capillarity. Capillary moisture can be kept from the subgrade by providing proper drainage features in the design of the road.

The shoulders are the most vulnerable part of the roadbed as far as absorption of surface water is concerned. Water percolates through them and back under the edges of the pavement causing frequent edge failures. Figure 1 shows a typical condition of moisture distribution throughout the cross-section of a highway

embankment in the spring of the year after snow, which has been piled on the shoulders during the winter, has melted.

In order to overcome this difficulty, the shoulders on several projects constructed in Nebraska this season have been treated by densifying the top three or four inches enough to make them relatively impervious. This is done by mixing granular material with the soil in the outer five feet of each shoulder and wetting and thoroughly compacting the resulting mixture. The soils on the projects treated in this manner were all silty clays of the A-4 classification. The treatment has not been tried on any heavy clay subgrades.

Although these shoulder treatments have not gone through enough cycles of climatic changes to determine definitely their effectiveness in preventing the entrance of surface water into the subgrade, it appears that the desired results will be accomplished. A more effective treatment would no doubt be obtained if a material such as emulsified asphalt, tar or cement were mixed with the soil-aggregate mixtures in the proper proportion.

Another method of keeping a subgrade in a condition of high supporting power consists of 8 in. of sand 18 in. below the finished grade. This type of construction was employed on a portion of one project in Nebraska this year. The embankment was constructed across a lake and the embankment material was obtained from the lake bottom. It contained 60 per cent sand, 20 per cent silt and 20 per cent clay. Its liquid limit was 38 and its plasticity index was 4. It was saturated with water when placed in the embankment. The soil is a very poor subgrade material when wet, but entirely satisfactory if kept dry. The cut-off layer of sand placed in the embankment not only prevented moisture from reaching the top 18 in. of the soil-substructure but also permitted moisture in the upper part of the embankment material to escape more rapidly than otherwise would have been the case. In a relatively short time after placing it, this material dried sufficiently to develop enough bearing capacity to permit construction of the surface course.