IMPROVEMENT OF SUBGRADES[1]

By Henry C Porter

Engineer of Research, Texas State Highway Department

SYNOPSIS

Because there is greater knowledge of processed surfacing materials than of the natural materials underlying a road, engineers have attempted to design highway pavements strong enough to overcome subgrade defects It is now known that this procedure is impractical, and that no matter how stable the superstructure may be, service qualities will depend largely upon the soil structure beneath Much has yet to be learned about soil mechanics, but many phenomena which are known are still disregarded in subgrade construction Many a pavement failure may be attributed to the placing of granular materials on clays in such fashion that gravity water is impounded Another natural law neglected is in the bulking of damp sand when disturbed and manipulated

The stabilizing of soils by treatment and admixture of other materials is resulting in a great deal of good The methods all have their places and should be used where practical At present, however, it appears that as a whole they are more practical for the roadway superstructure—subbases, bases, pavements and wearing-surfaces—than for underlying soils, especially in high embankments

In the construction of roadways, the engineer must deal with two classes of materials—processed materials, such as cements, asphalts, steels, etc , and natural materials, such as rock, gravel, sand, silt, and clays—both in their natural positions and when disturbed

Until lately, the available information for natural materials has been, in comparison with processed materials, very slight Consequently, design has been rarely thought of as applicable to them Here, an infinite number of variables must be dealt with, the limits of many of which have been known only vaguely, so that mathematical formulas have been unsatisfyingly indefinite Because of this uncertainty, engineers have endeavored to design pavements of processed materials, sufficiently efficient to overcome the defects in the underlying roadway structure composed of natural materials This procedure is now known to be impractical No matter how stable the superstructure is made, its subsequent service will depend to a large extent on the stability of the underlying soil structure—whether it be natural or artificially made

Even though there is a great deal to be learned relative to soil mechanics, there are a great many *known* phenomena that are not yet being generally applied

It is common knowledge that fluctuations of moisture content in soils cause most of the failures Engineers have generally thought that movements in highway soil-substructures were caused by capillary moisture, and that very little could be done in a practical way to prevent it No doubt, in some instances this is a fact, but experiments indicate that in many cases it is permeation of gravity water impounded on clay soils, in addition to their capillary moisture, that causes the trouble

[1] The word "subgrade" as generally used is somewhat indefinite It may refer to a prepared *surface,* or it may refer to a *layer or stratum next under the uppermost principal one,* with no limit as to depth Therefore, in the following discussion, the word "soil-substructure" is used in referring to the man-made part of the roadway structure underlying the subbase, base, pavement or wearing-surface, as the case may be, and the word "subgrade" is used to mean the *prepared surface* of the soil-substructure, for receiving the superstructure, or any part thereof

It can be said with reasonable certainty that in the past more failures have been caused by one single construction detail than all others combined The construction detail responsible for so many so-called "pavement failures" is the placing of granular materials on clays, when flanked by the clays, in such a manner that gravity water is impounded in the comparatively large voids of the granular material The gravity water eventually permeates the underlying clay soil and causes it to become unstable This statement applies not only to the base and subbase materials, but to all the materials in the man-made soil structure

Other known laws of nature that have been applied in the design and construction of the superstructure have been disregarded in the construction of the substructure The bulking of damp sand when disturbed and manipulated is an example In one instance the neglect of this phenomenon in the construction of an embankment in 1926 cost approximately $2500 00 in 1937, for rebuilding and repairing 1200 lineal feet of concrete pavement laid on the unstable soil-substructure in 1930

Another illustration of the subsequent ill effects of bulked sand was illustrated on a project built in 1935 The plans called for a 12-in depth (loose measurement) sand blanket to be placed entirely across the crown of the clay soil-substructure, with concrete pavement to be laid on the sand To permit the contractor to use the original clay shoulders of the roadway for hauling materials, and for operation of the concrete mixer, a 20-ft wide trench was first cut in the top of the clay soil-substructure Sand was placed in the trench to the required 12-in depth, wetted, and the 20-ft width pavement laid on the sand The pavement was cured by ponding water on it After the 10-day curing period, when the clay shoulder soil was cut away to the bottom of the sand under the pavement in order to extend the sand blanket to intersection with the roadway side slopes, air pockets were found between the bottom of the edge of pavement and top of the underlying sand As stated, the sand was wetted after being placed in the trench, but was probably disturbed afterward, during fine grading and shaping operations, and consequently bulked again After the pavement was laid, curing water probably reached the bulked sand, causing it to settle and recede from the bottom of the pavement

At the beginning of the study of irregularities or warping which developed in certain pavement surfaces, it appeared that these conditions occurred after long periods of slow rains and were caused by excessive expansion of clay substructure soil at the places where it was wetted most—such as leaky expansion joints and cracks On page 256, Volume 2 of "Proceedings of the International Conference," held at Harvard University in 1936, data on the subsequent effects of loss of moisture and volume of a soil-substructure are shown During the dry summer following the completion of the project in Navarro County, Texas, moisture and volume were lost to such an extent that the pavement receded in elevation as much as 0 2 ft along the center line and 0 4 ft along the edges Soil moisture content samples taken at different seasons in 1934, 1935 and 1936, showed as much as 14 per cent variation at 12-ft below the ground surface

This phenomenon has been observed in other places in Texas During the unusually dry summer of 1937, investigation of a project near the Gulf Coast revealed the clay soil had receded as much as 0 4 ft below the bottom of the pavement Some of the slabs failed to carry traffic loads, cracked and dropped to the receded soil Most of the cracking was approximately half way between the edge and centerline of the slabs Where one slab receded and the adjoining one did not, uneven joints of as much as 3 in were found

Where highly expansive clay soil must be used for the roadway soil-substructure and the wet and dry seasons of year are extreme, provisions must be made for protecting that soil from being overly wetted during rainy seasons and from undue loss of moisture during droughts This has been accomplished, in some places, by building the shoulders of pervious granular materials to slightly below the bottom of pavement or to the bottom of granular material under the pavement In all cases, the granular shoulder material should extend to intersection with the roadway side slopes This method applies to all types of pavement construction

Some very interesting and conclusive data relative to the accumulation of free water in entrenched sand under pavement are recorded on Test Section No 37, pages 194-198, Part II of the "Compilation of Data on the Guadalupe County Research Project," which experiments were made by the Texas State Highway Department in conjunction with the Bureau of Public Roads On the adjoining Test Section No 36, where the design is the same in every respect, except that the sand blanket extends to intersections with the roadway side slopes, no appreciable free water has ever been found in the sand during the three years of intensive observations