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"WORKING PLATFORM" REQUIREMENTS FOR PAVEMENT CONSTRUCTION

**A WHITE PAPER
Prepared for the
Technical Review Panel**

**PROJECT IHR-R30
UPGRADE SUBGRADE STABILITY MANUAL
Illinois Cooperative Highway and Transportation
Research Program**

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1. Introduction

Pavement foundations are designed primarily to withstand construction traffic loading and to act as a construction platform for the laying and compaction of subsequent layers. In addition, the foundation protects the subgrade, if adverse weather occurs during construction, and contributes (to some degree) to the structural strength of the completed pavement during its service life.

The foundation stresses are relatively high during construction, although the number of stress repetitions from construction traffic is relatively low and is not as channelized as normal service life traffic.

The capping layer is a transitional component that adapts the characteristics of the subgrade to the functions of a pavement foundation. Thus, the capping or in-situ stabilized soil layer is used to improve and protect weak subgrades by using relatively inexpensive material between the subgrade and the subbase.

In the United Kingdom (UK), pavement foundations are currently designed using established empirical relationships and a recipe specification, according to which specified materials are laid and compacted using specified methods. A new philosophy for a performance specification approach is currently being researched in the UK (1). The UK standard practice for the use of capping and the new performance specification approach, are reviewed in the following sections.

2. Functional Requirements of Pavement Foundations

Pavement foundation is defined as the granular layer or layers placed over the subgrade or admixture-modified soil layer. For pavements with asphalt bases, this implies the subgrade (cut or fill), probably a capping layer and the subbase. For a pavement with a granular base and asphalt surfacing, the base could be considered as part of the foundation. The reason for considering all the unbound granular material with the soil is that both obey the principles of soil mechanics (2). On the other hand, the pavement formation is defined as the partial structure that contains the natural and compacted subgrade and the capping layer laid on this subgrade.

The pavement foundation performs several functions during construction and in service, which can be summarized as follows (1):

- It must support construction vehicles during the construction of the overlaying layers, frequently acting as haul routes. Thus, they typically experience a small number, usually no more than 1,000 vehicle passes, of moderately high stress applications, around 500 kPa (72.5 psi), applied directly to the foundation. They must therefore possess sufficient resistance to permanent deformation so as not to deform excessively and have sufficient stiffness to reduce the stresses transmitted to the subgrade to a level that will not cause it to deform (i.e., rut).
- It must provide an even and stiff base for the placing and compaction of the overlaying layers (i.e. it must not undergo large resilient deformations under the action of the compaction stresses such that it reduces the effectiveness of the compacted structure of the overlying layers). This entails a small number

- of high stress applications, in the range of 1,000 kPa (145 psi), applied by the compaction equipment.
- It must provide sufficient stiffness and strength of support in the long term to the overlying (bound) layers when the road pavement is in service to prevent fatigue cracking of the structural layers. It will therefore support many millions of small stress applications, in the range of 10 kPa (1.45 psi), and must distribute these to an acceptably low level at the subgrade to limit accumulated deformation that could also lead to tensile cracking at the base of the structural layers.

To perform these functions, the pavement foundation must possess the two primary performance parameters of adequate stiffness and resistance to permanent deformation, and any overlying materials must be sufficiently thick so that the composite pavement structure performs adequately.

The most unfavorable loading conditions occur during construction because the stresses are much higher. It is for these conditions, while satisfying the requirements of an adequate construction platform, that the foundation layers are primarily designed.

3. Use of Capping Layer for Subgrade Improvement

A capping layer (between the subgrade and the subbase) is used to improve and protect weak subgrades. The aim is to increase the stiffness modulus and strength of the formation, on which the subbase will be placed. It is suggested that a capping layer having a laboratory California Bearing Ratio (CBR) value greater than 15 should provide an adequate platform for construction of the subbase when compacted to the appropriate thickness (3).

a. Thickness Design

The thickness design of the capping as well as the subbase layer (i.e., foundation layers) in the UK is based on an empirical approach according to the equilibrium CBR. This design follows the HD 25/94 (DMRB Vol.7) manual which is a recipe approach. Figure 1 is used for this purpose (3).

The subbase may be omitted on hard rock subgrades that are intact or, if granular material with a laboratory CBR of at least 30 is used. For a subgrade having a CBR greater than 15, the thickness of subbase is 150 mm (6 in.), this being controlled by the minimum practicable thickness for spreading and compaction. When the subgrade CBR is between 2.5 and 15, for flexible and flexible composite construction, there are two options available (3):

- 1) 150 mm (6 in.) of subbase can be used on a varying thickness of capping depending on the CBR value or,
- 2) an increasing thickness of subbase can be used with the decreasing CBR, with no requirement for capping.

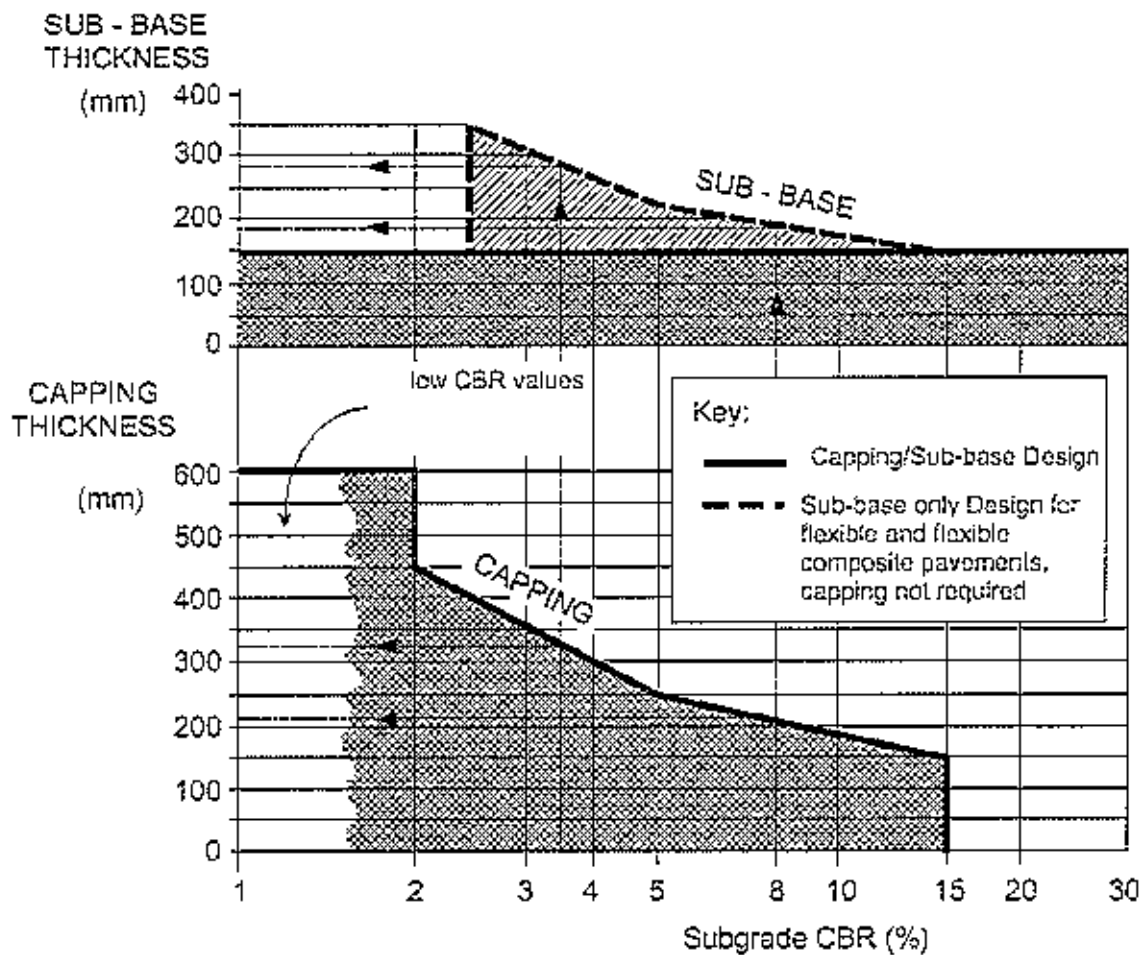


Figure 1.

For all pavements on subgrades with CBR values below 2.5, and for rigid and rigid composite construction on CBRs less than 15, 150 mm (6 in.) of subbase on the varying thickness of capping must be used. When the subgrade CBR is below 2, such that capping with subbase becomes unsuitable as a pavement foundation, then different options are available (3):

- 1) The material can be removed and replaced by more suitable material. If the depth is small, all can be replaced but it may only be necessary to replace the top layer. The thickness removed will typically be between 0.5 and 1.0 m (19.7 and 39.4 in.). Although the new material may be of good quality, the subgrade should be assumed to be equivalent to one of a CBR value just under 2 (i.e., 600 mm (23.6 in.) capping in Figure 1), in order to allow for movements in the soft underlying material. A total construction thickness about 1.5 m (59 in.) thick will often result.

- 2) If the soil is cohesive, a lime treatment may be an economic alternative. The UK soil treatment practice is given in HA 44/91 (DMRB 4.1.1). The overlying capping is again designed on the basis of a subgrade with a CBR just under 2 (i.e., 600 mm (23.6 in.) capping in Figure 1).
- 3) If the soil is reasonably permeable, a deeper than normal drainage system may be considered, together with a system of monitoring the improvement expected. Design of the main foundation may then be based on whatever conditions are achievable after this procedure.

On subgrades with CBR less than 15, the minimum thickness of a layer of aggregate (either capping or subbase) placed directly on the subgrade will be 150 mm (6 in.). At and below CBR 3, the first layer of aggregate will be at least 200 mm (8 in.) thick.

The thickness resulting from Figure 1 is used to design foundations to limit deformation caused by construction traffic to a maximum of 40 mm (1.6 in.) for 1,000 passes of a standard axle (Single axle load of 80 kN (18 kips)). This has been defined as the maximum that can be tolerated if the subbase surface is to be effectively reshaped and recompacted (4).

The experience in the UK has demonstrated that foundations constructed to the current specifications (MCHW 1) are generally adequate (4). However, this empirical approach is unlikely to result in the efficient use of materials and equipment and does not easily allow for the use of new and marginal materials (1).

b. Analytical Design

The UK HD 25/94 (DMRB Vol.7) manual also proposes an analytical design approach although as an alternative non-standard procedure which is explained below.

The analytical design inputs are the stiffness modulus of the subgrade, capping and subbase (when used), and makes assumptions regarding Poisson's ratio. A linear elastic calculation is made using a layered system analysis. From this computation, the maximum compressive subgrade strain under a standard axle load is calculated and related to rut development. When this method is followed, a considerable number of sensitivity analyses must be carried out to assess the effects of material variability. The aim should be to provide a design with an 85% probability of achieving the required design life.

Unless information to the contrary is available, a construction traffic loading of 1,000 standard axles should be used.

The allowable subgrade strain may be taken from Figure 2 or from the following equation and compared with the subgrade strain obtained from the layered system analysis:

$$SS = 0.0183 \cdot CT^{-0.2632}$$

where:

SS = Subgrade Strain

CT = Cumulative Traffic (80-kN (18-kip) Standard Axle)

When the calculated compressive subgrade strain for the layered system being analyzed is higher than the allowable subgrade strain, a new layered system has to be proposed (e.g. increased thickness) and checked again until the criterion is met.

Permissible Compressive
Subgrade Strain

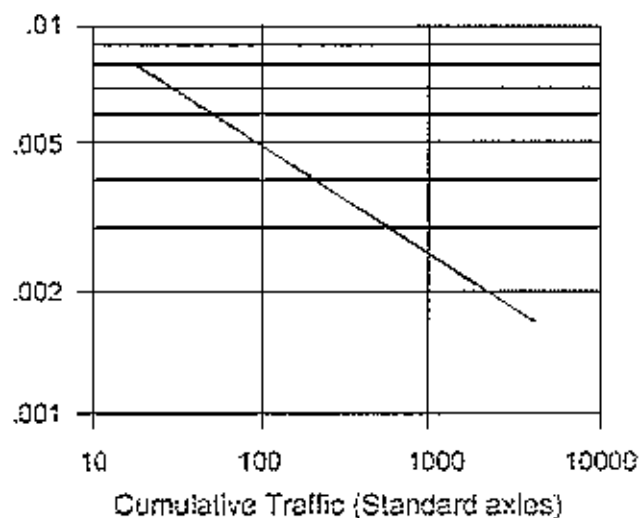


Figure 2.

c. Capping Materials

The materials of the capping layer are based on the UK specification MCHW1 (Series 600). This specification (see Table 1) allows a fine graded material (6F1) and a coarser graded (6F2) (both with a laboratory CBR value of at least 15). The latter can be considered as relatively free draining and is thus most suitable for sites with a shallow water table. It should, however, be noted that capping layer is not required to be a drainage layer as long as contained water does not prevent it from satisfying its primary function of load spreading. The specified gradings also do not guarantee adequate shear strength and a demonstration area should normally be placed and tested to check on properties of the material by trafficking with normal site vehicles and construction equipments (3). Any material, or combination of materials, other than unburnt colliery spoil may be used for both 6F1 and 6F2 (5).

Alternatively, cemented and lime treated soil are permitted. In the case of stabilization with cement, the class 6E material should be used, which would be any material, or combination of materials, other than unburnt colliery spoil and argillaceous rock (5). Details are given in HA 44/91 (DMRB 4.1.1).

Reuse of crushed excavated road pavement materials as capping may also be carried out provided the compacted material complies with the specification MCHW1.

Although it is permitted to replace some or all of the subbase by bituminous material, this technique must not be applied to capping layers.

Table 1 and Figure 3 show the requirements for granular capping layer materials.

Table 1.

Sieve Size		% Passing					
		6F1		6F2		6E	
mm	in.	Min	Max	Min	Max	Min	Max
75	3	100	100	65	100	80	100
37.5	1.476	75	100	45	90		
10	0.394	40	95	15	60	25	100
5	0.197	30	85	10	45		
0.6	0.0236	10	15	0	25	10	100
0.075	0.00295	0	10	0	12	0	10

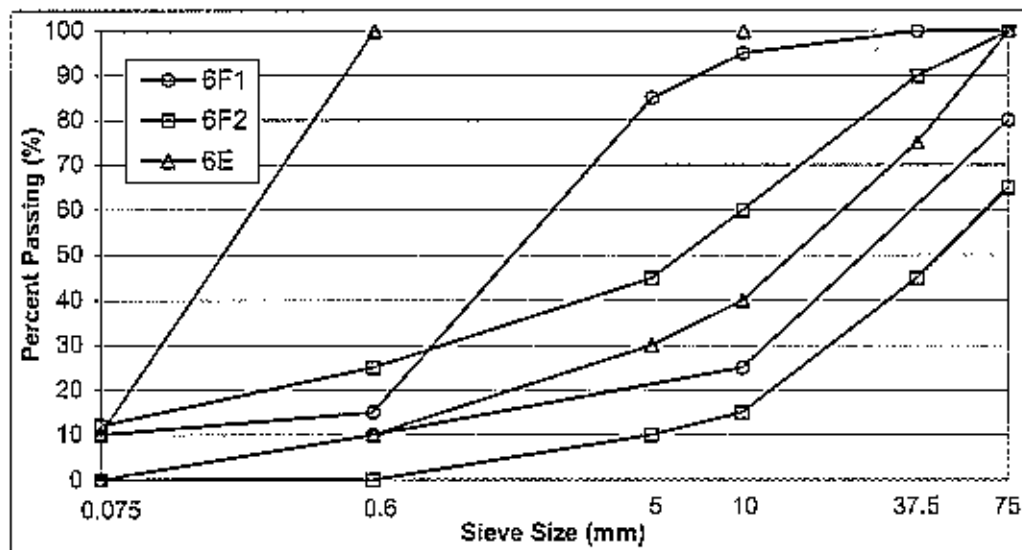


Figure 3.

4. Comparison of Thickness Design Using Other Approaches

In 3.a. the UK approach to determine the thickness of the capping and the subbase layer is presented. In this section, that thickness will be compared with the Modified Corp of Engineers CBR-Based Design Method, used in the IDOT Subgrade Stability Manual 1982, and another approach presented by Van Gorp et al. (6) (Figure 4).

In the Van Gorp approach, the starting point is the subgrade characteristics and the maximum level of rutting in the base and subbase course in the construction stage.

As seen in Figure 4, the total thickness of base and subbase (h_d) (whose characteristics are not specified in (6)) can be calculated applying the equation below the plot. Although that equation is function of the "undrained shear strength" (f_{undr} , which is cohesion; in this case, $f_{undr} = C * 1000$ (Pa)) of the subgrade, two correlations between f_{undr} and CBR are also given, a factor of 20 ($C = 20 * CBR$ (kPa)) is used for situations with a high groundwater table level, whereas a factor of 30 ($C = 30 * CBR$ (kPa)) is used for conditions in which the groundwater table level is deeper than 0.5 m (19.7 in.) below the bottom of the base course (6).

Figure 4 shows eight applications of the equation for “ h_d ”, according to the combination of variables (RD, N, groundwater table level, and P) shown in Table 2.

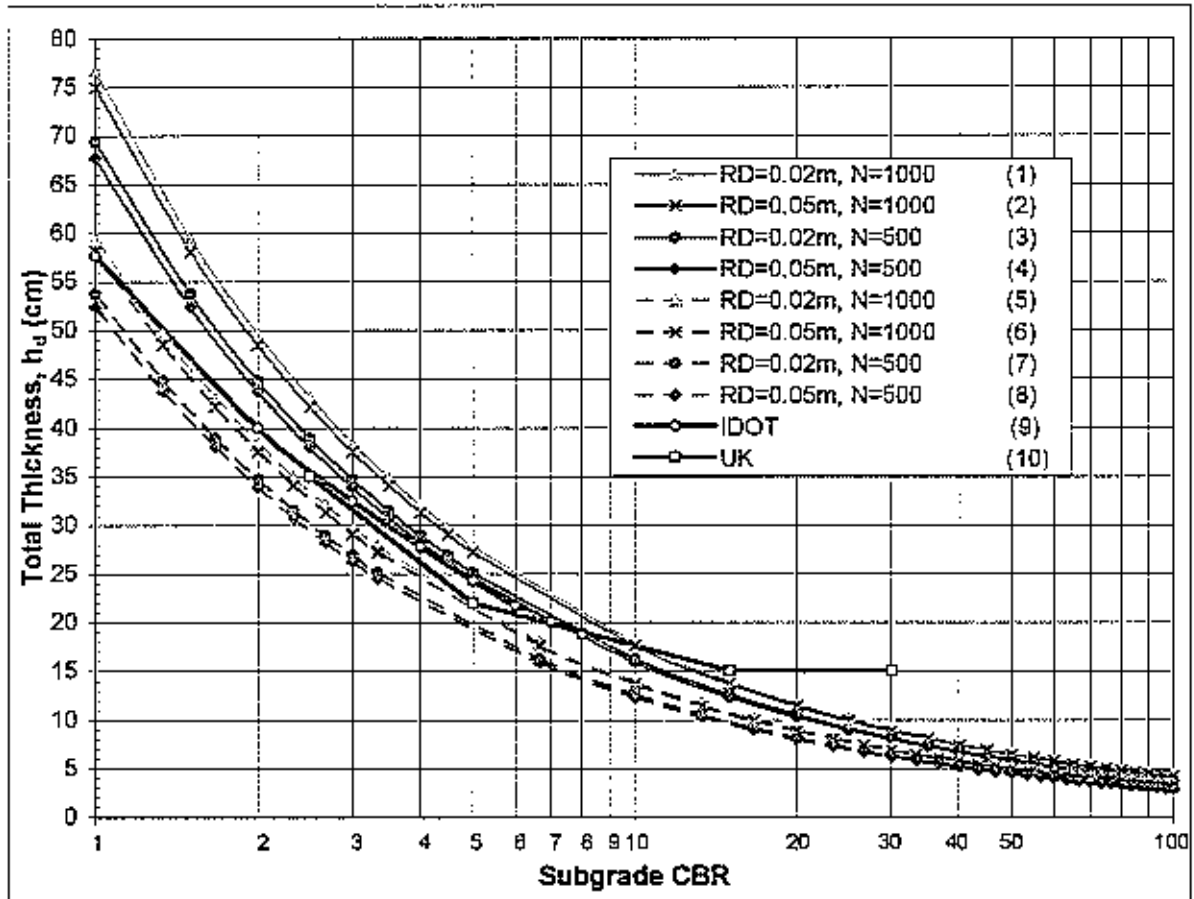
The 8 curves tend to decrease and converge as the CBR increases. The method is not sensitive to a change in rut depth in the range analyzed. The largest difference is 1.8 cm (0.7 in.) when the CBR is 1, the number of axle loads is 500, and the groundwater table level is less than 0.5 m (19.7 in.) from the surface (curves 1 and 2). When comparing only the number of axle loads, the largest difference is 7.4 cm (2.9 in.) occurring when the groundwater table level is less than 0.5 m (19.7 in.) for a CBR of 1 (curves 2 and 4). Comparing only the effect of the groundwater table level, the largest difference is 17.3 cm (6.8 in.) when rut depth is 0.02 m (0.8 in.), the number of axle loads is 1000, and the CBR is 1 (curves 1 and 5). Therefore, for the analyzed range and load, the most sensitive variable is the groundwater table level, followed by the number of axle loads, and being practically insensitive to the rut depth.

In Figure 4, the IDOT CBR-Based Design Curve and the UK Empirical Method for Subbase Thickness have also been superimposed in the same plot (curves 9 and 10 respectively). Both curves closely follow each other in the range in common (from CBR 2.5 to CBR 8). The largest difference is around 2.3 cm (0.9 in.) when CBR is 5. In this same range, both curves are just between the group of curves for groundwater table level less than or equal to 0.5 m (19.7 in.) (1 to 4) and that of curves for groundwater table level greater than 0.5 m (19.7 in.) (5 to 8). Even for lower CBR values (< 2.5) the IDOT curve follows in between the two groups mentioned, except for CBR 1 where is a little lower than curves 5 and 6.

It must be noted, however, that the UK Empirical Method curve shown in Figure 4 corresponds only to subbase material (CBR > 30). Then, according to 3.a.1), if using a combination of capping (CBR > 15) and subbase (CBR > 30) materials the total thickness will increase significantly (e.g.: for CBR 3.5, 15 cm (6 in.) of Subbase + 33 cm (13 in.) of Capping, instead of only 28 cm (11 in.) of subbase and for CBR 8, 15 cm (6 in.) of Subbase + 21 cm (8 in.) of Capping, instead of only 19 cm (7.5 in.) of subbase).

Table 2.

RD (m)	N (axles loads)	Groundwater Table (m)	P (N)	Curve Number
0.02	1000	≤ 0.5	80000	(1)
0.05	1000	≤ 0.5	80000	(2)
0.02	500	≤ 0.5	80000	(3)
0.05	500	≤ 0.5	80000	(4)
0.02	1000	> 0.5	80000	(5)
0.05	1000	> 0.5	80000	(6)
0.02	500	> 0.5	80000	(7)
0.05	500	> 0.5	80000	(8)



$$h_d = \frac{125.7 \cdot \log(N_{constr}) + 496.52 \cdot \log(P) - 294.14 \cdot RD_{constr} - 2412.42}{f_{undr}^{0.63}}$$

h_d = Total Thickness (Sub)Base in Construction Stage (m)

N_{constr} = Number of axle loads in construction stage

P = Average axle load in construction stage (N)

RD_{constr} = Allowable rut depth at surface in construction stage (m)

f_{undr} = Undrained shear strength subgrade (Pa) (Cohesion)

f_{undr} = $C \cdot 1000$ (Pa)

C = Cohesion (Undrained shear strength subgrade) (kPa)

C = $20 \cdot CBR$ (Groundwater table < 0.5 m from surface) (Curve 1,2,3,4)

C = $30 \cdot CBR$ (Groundwater table > 0.5 m from surface) (Curve 5,6,7,8)

CBR = California Bearing Ratio

Van Gurp et al.: (Curve 1,2,3,4,5,6,7,8)

IDOT : (Curve 9)

UK : The UK Empirical Method for Subbase Thickness (Curve 10)

Figure 4.

5. Performance Parameters and Target Values for Road Foundation Construction

In recent years, the UK has been moving away from empirical design of road foundations and method specifications toward analytical design and performance based specification assured by end product testing during construction.

The use of a recipe specification gives assurance of the performance of closely regulated materials that are known to be adequate. This approach to design and construction precludes the use of functional soil and granular material performance parameters, which are required for analytical pavement design and for a truly performance based specification for road foundation construction. However, such a specification is desirable to permit the use of alternative materials and/or alternative construction methods (7).

For a performance based specification, the material performance parameters should be measured in the laboratory before design using representative samples both of the subgrade and of the proposed foundation material, at anticipated environmental conditions. The same parameters should then be measured in situ on the same materials during construction to confirm that the desired (design) properties have been achieved (1).

Design targets for in situ assessment should include performance parameters that will ensure that the overlying layers can be adequately compacted (a target stiffness) and that acceptable trafficking performance will be achieved during construction (control of rutting). Therefore, both stiffness and resistance of permanent deformation of the composite foundation must be assessed.

Thus, target values for stiffness and shear strength must be determined for construction compliance. The target values will be specific to the device used to measure them due to variations in their operation (7).

Many countries, such as Germany and France, specify minimum elastic stiffness values, in addition to minimum density requirements, at the top of the subgrade and on the surface of the completed foundation.

In Germany, the foundations are constructed having a minimum static plate-bearing modulus, termed a deformation modulus (E_{v2}), of 45 Mpa (6,527 psi) at the top of the completed formation. E_{v2} is calculated from the amount of deflection under the second loading of the plate. The thickness of the subbase necessary above the formation level is determined by the amount of frost resistance required. A surface modulus (E_{v2}) requirement using the plate-bearing test is also mandatory at the top of the subbase, 120 Mpa (17,405 psi) for light traffic and 150 Mpa (21,756 psi) for heavy traffic (8).

In France, there is both a long and short-term requirement for the foundation. In the short-term, which implies the construction traffic, the foundation must comply with one of the following (9):

- The surface modulus (E_{v2}) determined from a plate static load test, or the equivalent modulus from the Dynaplaque test, of greater than 50 Mpa (7,252 psi).
- The deflection of less than 2 mm (0.079 in.) measured under an axle load of 13 tonnes (28,660 lb).

The long-term requirement for the foundation, in the completed road, is the strength of the subgrade. These leads to a number of classes of pavement foundation (4, 9):

- PF4: over 200 Mpa (29 ksi).
- PF3: 120 to 200 Mpa (17.5 ksi to 29 ksi).
- PF2: 50 to 120 Mpa (7.2 ksi to 17.5 ksi).
- PF1: 20 to 50 Mpa (2.9 ksi to 7.2 ksi).

In the UK, several values of target stiffness have been suggested. For example, a stiffness of 50 to 60 Mpa (7,252 to 8,702 psi) measured on the completed capping and 100 Mpa (14,504 psi) on the completed subbase have been suggested by Fleming et al. (7). Chaddock and Brown suggested a value of 80 Mpa (11,603 psi) as an acceptable stiffness on top of the capping, as measured by the Falling Weight Deflectometer with a 450 mm (17.7 in.) plate and 200 Kpa (29 psi) contact stress.

Finally, Nunn et al. (4) have suggested an Light Drop Weight stiffness value (measured with the German dynamic Plate Bearing Tester) of 30 Mpa (4,351 psi) and a Falling Weight Deflectometer stiffness of 40 Mpa (5,802 psi), measured on top of the completed formation, and 50 Mpa (7,252 psi) or 65 Mpa (9,427 psi), respectively, measured on top of the completed foundation.

Current UK specification for foundation design states that the formation of ruts in the subbase, when used as a haul road, must be limited to 40 mm (1.6 in.). A similar approach for capping has been proposed, thus requiring that the formation surface rut be monitored. The proportion of the surface rut that will occur in the subgrade will clearly depend on the nature of the capping used. This is difficult to predict and thus the general recommendations given in Table 3 have been suggested to limit rutting in the subgrade to 20 mm (0.8 in.) (7).

Table 3

Capping Thickness, t		Maximum Permissible Surface Capping Rut	
(mm)	(in.)	(mm)	(in.)
$t \leq 250$	$t \leq 9.8$	20	0.8
$250 \leq t \leq 500$	$9.8 \leq t \leq 19.6$	30	1.2
$t > 500$	$t > 19.6$	40	1.6

6. Threshold Stress Approach to Control Permanent Deformation of the Subgrade

The complex nature of the formation of rutting, caused by the influence of layer interactions and material stress dependencies, implies that one acceptable method of assessment in the field is to monitor the effects of trafficking and to impose limits on the amount of rutting produced (as the limits proposed in Table 3). However, for design and specification purposes, a threshold stress approach has been suggested to guard against permanent deformation. In this approach, the subgrade strength is measured

and compared with the threshold, then the thickness of the overlying layers is adjusted to reduce the applied subgrade stress to a level below the threshold value (1). Thus if the applied stresses are maintained below the threshold value, by providing adequate thickness of placed materials that have appropriate strength and stiffness, the formation and progression of rutting should remain within a stable zone. It must be recalled, as explained in Section 2, that the foundation layers typically support no more than 1,000 vehicle passes of relatively high stress applications (around 500 kPa (72.5 psi)).

Frost et al. (1) found, from the data of the repeated load triaxial test (RLTT) on a subgrade composed of a very soft sandy silty clay with occasional gravel, that a threshold stress at 1% permanent strain appears to be a suitable, although conservative, method for assessing the point where the permanent strain of the subgrade starts to become unstable. Figure 5 shows the data. The gradual accumulation of permanent deformation is followed by a significant increase in permanent strain above a certain deviator stress level (the threshold stress). Although certainly a threshold appears to exist, they indicate that further research is required to assess the formation of permanent deformation and to control rutting.

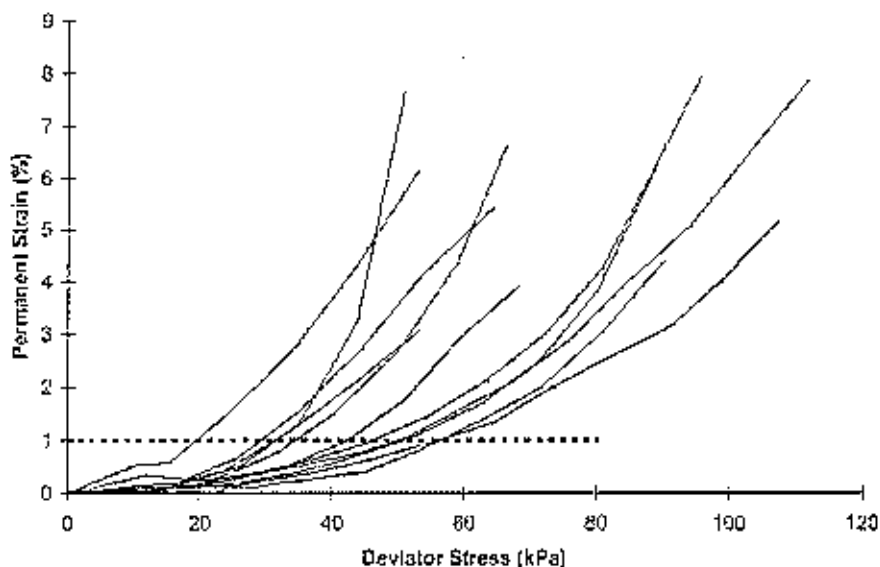


Figure 5.

Additional research by Frost et al. (10) assessed the performance parameters for a range of fine grained subgrade materials typical of those found in the UK, using the repeated load triaxial test. Figure 6 shows the permanent strain behavior of the samples where can be seen the direct stress dependency of the material.

Two approaches were used by the researchers to assess threshold stress relative to sample strain. In the first, they defined the threshold as the deviator stress at which 1% sample permanent strain was reached (as in the previous research (1)). In the second approach, the threshold was defined at the point of maximum curvature assessed from plots of stress versus permanent strain (Figure 6). The threshold stresses resulted from this two ways were plotted against the undrained shear strength

of each sample (Figure 7). The lines of best fit show that both approaches give similar lines of correlation.

Figure 7 also shows two other lines which were plotted applying shear strength to define the threshold. The first represents a threshold equal to 0.5 the shear strength ($0.5 q_{max}$), that is, one half the deviator stress at failure, which is equal to the undrained shear strength (C_u) of the sample. This approach gives a line similar to the correlation lines for the two strain approaches. The second line is suggested conservative design threshold approach at 0.25 the shear strength (i.e., a threshold of $0.5 C_u$) is also shown in Figure 7. This line passes below the most of the data points. If the applied subgrade stress is kept below this level the permanent deformation should be well within the stable zone.

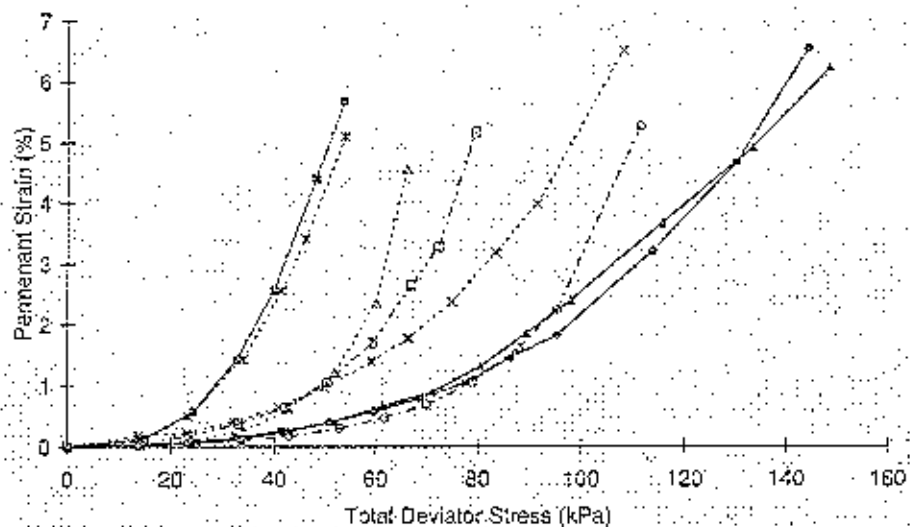


Figure 6.

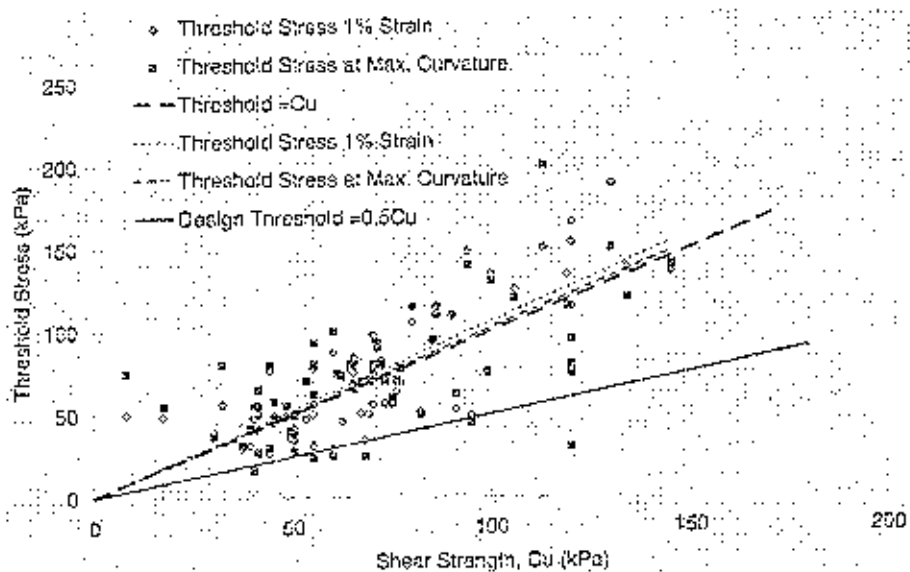


Figure 7.

Other results of the same research show the inverse stress dependency. The higher the deviator stress the lower the stiffness (Figure 8). On the other hand, Figure 9 shows the values of stiffness at a deviator stress of 0.5 the shear strength (C_u) which are compared to the asymptotic stiffness values assessed from the data (Figure 8). There is a linear relationship and a good correlation.

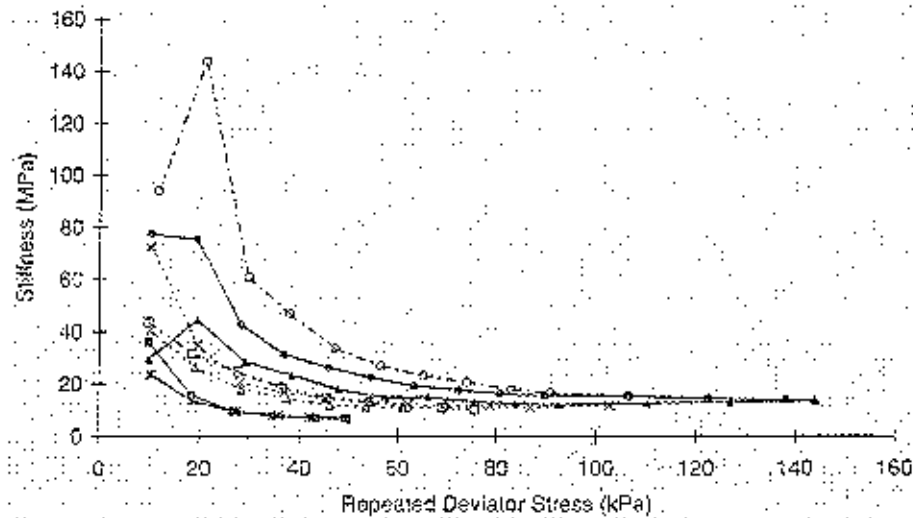


Figure 8.

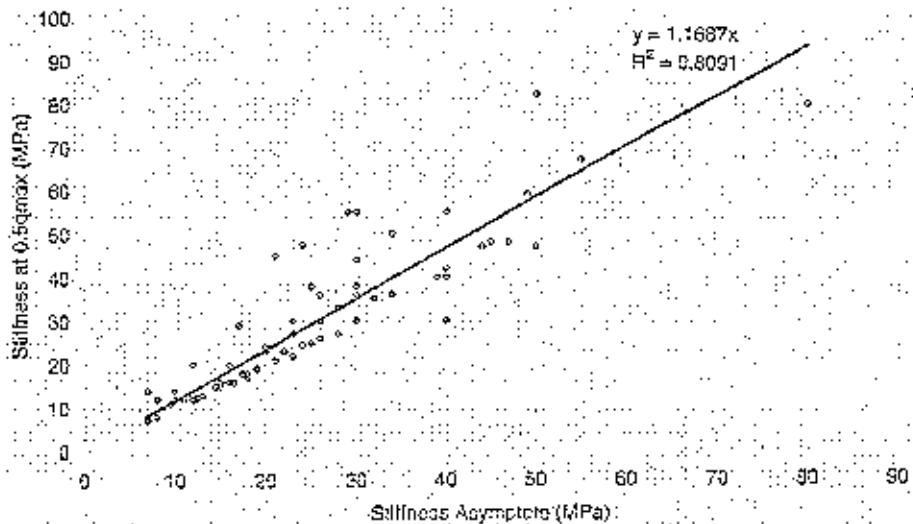


Figure 9.

They concluded that a value of applied cyclic deviator stress above which the permanent deformation becomes unstable was found to occur at approximately the deviator stress at failure (0.5 the shear strength). The stiffness at this deviator stress was shown to be approaching a minimum (i.e., a stiffness asymptote). This suggests

that for fine grained materials where permanent strain is becoming unstable, stiffness is tending to a constant value.

Finally they suggested a simplified design approach. If the strength of the subgrade samples can be accurately measured, this can be related to a limiting allowable applied subgrade stress by the threshold shear strength relationship. This limit can then be applied in design for the worst case construction condition, that is, to design foundation for construction traffic. It is suggested that stiffness values (and subgrade stress dependency) could possibly be assessed simply within a standard triaxial cell with monotonic loading and unloading, as stiffness is not significantly load rate or stress history dependent. Alternatively, a single value of stiffness measured at threshold stress (the asymptote) should be appropriate for short-term construction design. These subgrade data could be coupled with stress dependency of the overlying granular materials, potentially measured by dynamic plate tests or determined using standard relationships derived from a K- θ model. Simple analysis to derive foundation thickness can then be performed using iterative elastic analysis.

7. Evaluation of IDOT's Current Subgrade Stability Manual

The current Illinois DOT Subgrade Stability Manual "Thickness Requirements" are presented in Figure 19 of the Manual (Figure 10 in this report). The thicknesses for a selected range of Subgrade CBRs were evaluated (Table 4). ILLI-PAVE (the computer program utilized in the development of IDOT's flexible pavement design procedure) was used to check the appropriateness of the Thickness requirements for current truck loading.

Current loading conditions are 20-kip single axles and 34-kip tandem axles. For ILLI-PAVE analysis purposes, the 20-kip single axle is represented by a 10-kip single wheel load at 115 psi tire pressure. This is the critical condition for pavement responses.

ILLI-PAVE material/subgrade property inputs are aggregate and subgrade moduli and strengths (Mohr-Coulomb shear strength parameters C and ϕ).

For this evaluation, the aggregate was assigned the following properties (typical for a medium quality granular material; IDOT CA-6):

$$E_R = 5000 \cdot \theta^{0.5} \quad (E_R \text{ and } \theta \text{ in psi})$$

$$\theta \text{ (First stress invariant)} = \sigma_1 + \sigma_2 + \sigma_3$$

A friction angle (ϕ) of 40° was assigned.

Subgrade CBR is converted to Unconfined Compressive Strength (Q_u) and Resilient Modulus (E_{R1}) by the following equations (presented in the IDOT Bureau of Local Roads & Streets Flexible Pavement Design Guide):

$$Q_u (\text{psi}) = 4.5 \cdot \text{CBR}$$

$$E_{R1} (\text{ksi}) = 0.307 \cdot Q_u (\text{psi}) + 0.86$$

$$\text{Subgrade Cohesion (C)} = Q_u / 2$$

$$\text{Subgrade Friction Angle } (\phi) = 0$$

The subgrade properties are shown in Table 4.

The controlling subgrade responses of interest in evaluating a "Construction Working Platform" are subgrade deviator stress (σ_{DEV}) at the top of the subgrade, Subgrade Stress Ratio ($SSR = \sigma_{DEV} / Q_u$), and surface deflection. High deviator stresses and SSRs indicate high "subgrade rutting potential" and large surface deflections lead to difficulty in compaction and perhaps "tension cracking/tearing" on the surface of AC layers. The pavement responses are presented in Table 4, Figure 11 and Figure 12.

The Surface Treatment Thickness Design procedure proposed to IDOT (Bureau of Local Roads & Streets) indicates an SSR of 0.75 is acceptable for "Light Traffic." "Light Traffic" is equivalent to "more than" 1,000 axle load repetitions. With the exception of the CBR 1 condition, the SSRs are ≤ 0.75 .

The surface deflection data in Table 4 (Figure 12) indicate good uniformity for the entire range of subgrade strengths and thicknesses. The values only range from 45.7 mils to 49.1 mils. Many aggregate-surfaced and aggregate bases + surface treatment roads show surface deflections greater than 50 mils.

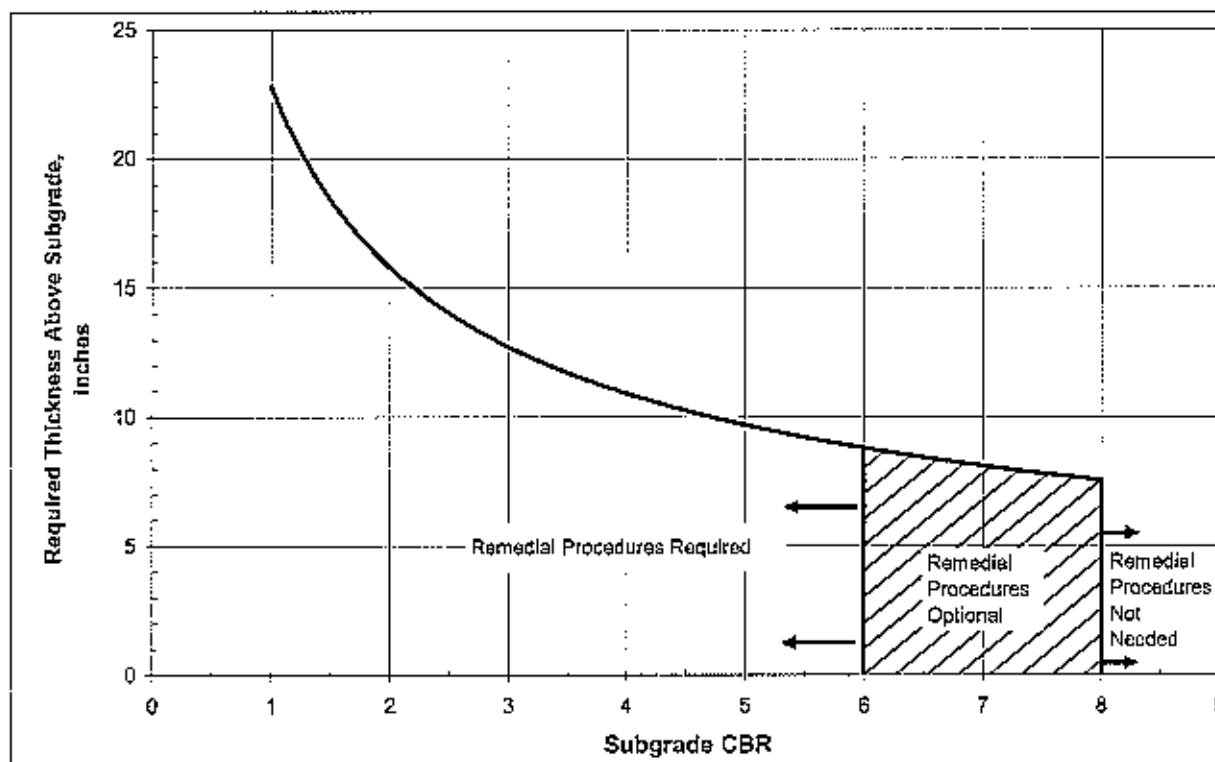


Figure 10.

Table 4.

CBR	Qu (psi)	E _{RI} (ksi)	T _{Granular} (inches)	Dev. Stress (psi)	SSR	Surf. Deflec. (mils)
1 ¹⁾	6	2.7	23	4.8	0.80	46.3
1 ²⁾	6	2.7	24	4.5	0.75	45.7
2	9	3.6	16	6.7	0.74	49.4
4	18	6.4	11	11.3	0.63	49.1
6	27	9.1	9	16.4	0.61	46.5

1) From Figure 19 IDOT's Subgrade Stability Manual (1982)
 2) Figure 19 thickness + 1 inch

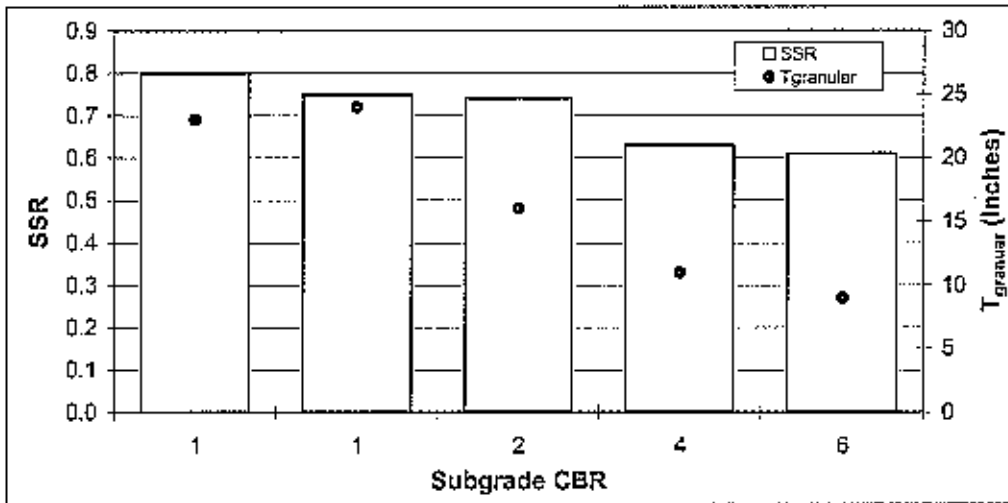


Figure 11.

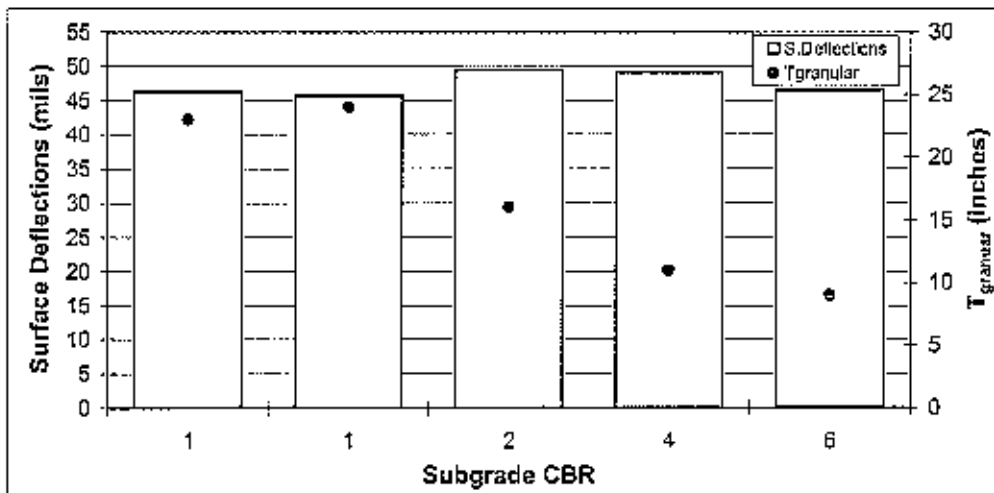


Figure 12.

Note in Table 4 that the one-inch additional thickness reduces the SSR by 0.05, but has little effect on surface deflection (0.6 mils).

For low subgrade strengths the aggregate option requires large thicknesses. For this condition, the use of Geosynthetics should be considered. A reduced aggregate thickness can be utilized and subgrade intrusion alleviated/prevented.

Another alternative to constructing a thick granular layer is to admixture-modify (e.g. a lime product) the subgrade and then add a granular surface layer (minimum thickness of 6 - 8 inches) to achieve the target thickness.

The current IDOT thickness requirements are reasonable for 10-kip wheel loading conditions. The requirements compare favorably with United Kingdom practice. Therefore, it is recommended that the current Subgrade Stability Manual thickness requirements be retained.

8. Summary

- A **WORKING PLATFORM** (typically composed of an aggregate layer(s) and/or an **Admixture Modified Soil** layer) provides support for subsequent paving operations. **WORKING PLATFORM** materials must have sufficient **STABILITY** (strength/modulus) to support paving construction operations traffic without developing excessive rutting (< 0.5 inches); be thick enough to "protect" the underlying subgrade (reduce the subgrade deviator stress to an acceptable level to minimize subgrade rutting); and not deflect excessively under construction traffic or paving operations.
- In this **WHITE PAPER**, **WORKING PLATFORM** thickness and material quality (primarily strength/rutting resistance) requirements have been considered and evaluated.
- The current **IDOT SUBGRADE STABILITY MANUAL** thickness design requirements (Figure 19 in the **IDOT MANUAL** - Figure 10 in this report) were compared to other procedures that have been proposed/used by various agencies. A comparison among the procedures indicated the current IDOT requirements are appropriate and should be retained for use in the Revised IDOT Manual.
- The following **WORKING PLATFORM** material quality recommendations are based on the information/data considered in the **WHITE PAPER**:
 - A minimum CBR of 15 is required for the aggregate layer. Some agencies require a "higher quality" aggregate for the surface of the **WORKING PLATFORM** (e.g the United Kingdom utilizes CBR >30 and a minimum thickness of 6 inches). The aggregate layer should not be "moisture sensitive" (experiences significant strength loss with small moisture changes). Dense-graded aggregates with high fines (- #200 sieve) contents and/or excessive PIs exhibit increased (perhaps high) moisture

sensitivity. IDOT CA-6 type materials may display unacceptable moisture sensitivity levels.

- A CBR of 10-12 is a reasonable/typical AMS stability requirement. This is approximately equivalent to an unconfined compressive strength of 50 psi. Several admixtures (lime, quicklime, Lime Kiln Dust [LKD], fly ash, cement, Cement Kiln Dust [CKD]) have been successfully utilized to MODIFY fine-grained subgrade soils.
- An alternative to using only aggregate or an AMS layer to achieve an adequate WORKING PLATFORM is to admixture modify the subgrade soil and then construct an aggregate surfacing layer. This is a particularly attractive option when the WORKING PLATFORM thickness is large, the AMS strength is marginal, or aggregate and/or recycled materials (RAP and or crushed concrete) are available and economical.
- RAP and or crushed concrete typically have low fines (- #200 sieve) content and the PI of the fines are low (in many cases they are NP). Thus these materials may display "low" moisture sensitivities.

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