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Pavements on Highly Expansive Clays

1 Purpose

The purpose of this PIN is to explain the design and construction requirements for pavements on highly expansive subgrades. Many Engineers have an unwarranted fear of this condition which is probably due to ignorance and having seen pavement distress or failures that may have required rehabilitation

Opportunity is also taken to illustrate the benefits of rigid pavements over flexible pavements when highly expansive subgrades are encountered.

2 Moisture Changes during Service Life

The strength of subgrade materials is influenced by compaction and moisture content. Because of the nature of some materials, significant swelling and shrinkage can occur as the material is wetted up or dried out.

While compaction of clay subgrades to specified density may be achieved at very low moisture contents, this practice, however, results in an open soil structure which is likely to weaken considerably on wetting. The weakening will be compounded by density loss due to the swelling of the clay.

Placing of a sealed pavement surfacing isolates the subgrade from some of the influences which affect moisture changes, especially large quantities of surface water and evaporation. Generally the central region of the pavement maintains at a reasonably constant equilibrium moisture condition (EMC), but the moisture condition in the flanking outer regions will vary with seasonal climatic influences, this is termed "edge effects". Edge effects generally occur under the outer 1 – 2 m of the sealed surfacing.

Proximity of the ground water table or local perched water table to the pavement wearing surface may also play a significant role in influencing the subgrade moisture conditions.

The theoretical solution is to stop the fluctuation of moisture content by controlling seasonal moisture ingress.

3 Classification of Expansive Soils

The loss of pavement shape due to moisture changes in expansive soils can lead to significant pavement distress and often the need for rehabilitation. A guide to the identification and quantitative classification of expansive soils is presented in the following table.

Expansive nature	Liquid limit (%)	Plasticity Index	PI x %<0.425 mm	Potential swell (%)
Very high	>70	>45	>3200	>5.0
High	>70	>45	2200 - 3200	2.5 – 5.0
Moderate	50 - 70	25 - 45	1200 - 2200	0.5 – 2.5
Low	<50	<25	<1200	<0.5

4 How to Minimise Volume Changes in Highly Expansive Soils?

- Compact at estimated Equilibrium Moisture Content (test adjacent road formations).
- Provide a low permeability selected fill capping layer above the expansive soil. (Minimum thickness 150 mm or 2½ times max particle size).
- The capping layer should have a swell less than 2.5%
- Pavement drains must be in the impermeable subbase and not extend to the expansive soils.
- Boxed pavements must not be used.
- No planting of shrubs or trees close to the pavement.
- Provide sealed shoulders and impermeable verge material. A seal of 1 – 1.5 m is required outside the edge of the traffic lanes to minimize subgrade moisture changes under the outer wheel path.
- Use controlled construction techniques when placing expansive soil.
- Lime stabilization may be used to reduce the plasticity and increase the volume stability of the upper layer of the expansive clay subgrade.

5 The Effect of Modulus of Rupture on Design

As the subgrade soil expands, it creates tensile stresses in the pavement layers. Recalling that the elastic modulus of a material is simply stress divided by the resultant strain and has the value when the material either cracks or snaps, ie when it can no longer accommodate the strain. Hence, regardless of the pavement material, as the stress due to the subgrade expansion will be identical, the modulus value can be regarded as a parameter for cracking potential. Unbound materials, as in flexible pavements, have a very low tensile strength and hence also a low modulus of rupture.

The listing in Section 6 illustrated the vast differences in the design moduli and hence the resistance to cracking under identical stress condition, eg a concrete pavement would require a cracking strain some 150 times that causing a gravel pavement to crack.

Hence it stands to reason, that a properly designed rigid pavement is a far more preferable option where highly expansive subgrades are encountered.

6 Design Moduli for Different Pavement Materials

- Subgrade materials - 10 x CBR% with max 150 MPa
- Base quality gravel - 350 MPa

- Crushed rock DGB - 500 MPa
- 2% Cement stab'd - 2,000 MPa
- Asphalt - 3,000 – 5,000 MPa (Average for design 3,500 MPa)
- 5% Cement stab'd - 5,000 MPa
- Rolled Concrete - 7,000 MPa
- 5 MPa LMC - 10,000 MPa
- 35 MPa base conc - 30,000 MPa

7 The Desirable Aspects of Concrete Pavement Design

The following is a summary of the attributes of concrete pavements that alleviate most of the concerns of likely pavement distress from highly expansive subgrades:

- The design subgrade strength is based on the Effective Subgrade Strength representing 1 m thickness of the subgrade.
- A Selected Material Zone (SMZ) layer of 300 mm thickness of minimum CBR 15% material is placed on top of the subgrade. The top 150 mm of this may be 2% lime stabilized.
- The SMZ is primer sealed as protection from weather during construction and also to prevent the ingress of rain water.
- A 150 mm thickness of 5 MPa Lean Mix Concrete (LMC) subbase is provided as a standard treatment. This has a number of roles, including the complete sealing off the access of any surface water to the subgrade.
- The concrete subbase is provided with a 7 mm bitumen seal to act as a bond breaker with the base layer.
- After placement of the 35 MPa base, special pavement drains of perforated pipes encased in no fines concrete are provided adjacent to the base layer to collect any water that may have entered through joints in the pavement.
- The concrete pavement design is done on the basis of having an in-situ subgrade strength of CBR 3% which results in an Effective Subgrade Strength of CBR 5% when the SMZ is included.
- This is an important parameter in that an Effective Subgrade Strength of greater than CBR 5% will not decrease the pavement thickness. This means that there are no further risks encountered with variations in the subgrade strength, nor is there a requirement of very detailed soil testing to be undertaken.