Design principles for design of bituminous pavement with stabilized/ cemented layer

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Introduction

A pavement designer wishes to design a pavement structure which is reliable and cost effective. Various materials have been used for pavement construction so as to economize the design. Depleting natural resources of construction materials and disposal problem of industrial waste products further necessitate use of alternative materials in pavement construction.

Subgrade is sometimes stabilized or replaced with stronger soil material so as to improve the strength it. Such stabilization is also suitable when the available subgrade is made up of weak soil. Increase in subgrade strength may lead to economy in the structural thicknesses of the pavement.

Good quality of aggregates involve large haulage cost at the places where it is not available. As an alternative, it may be possible to use locally available marginal aggregates in cemented form. Cement, lime, coal-flyash, pozzolanic materials, chemical polymers etc are some examples of cementing material, which can be mixed to the marginal aggregates to develop bound base/ sub-base layer (Austroads 2004, French manual 1997, Theyse et al. 1996). The stiffness of such layer may be superior to the conventional unbound granular layer, thereby reducing the overall stress level to the pavement structure (R-90 2009). Further, such bound material can additionally contribute to the fatigue life of the pavement structure. These factors are expected to contribute some economy to the pavement design (Little et al. 2000, Thoøgersen 2004, Thompson 1986).

The present article briefly discusses the current design principles used for design of bituminous pavement with stabilized/ replaced subgrade and cemented base/ sub-base.

Design principles

Mechanistic-empirical (M-E) method is currently being used for design of bituminous pavements (AI 1999; Austroads 2004, French manual 1997, IRC 2001, NCHRP 2004, Shell 1978, Theyse et al. 1996). As per M-E approach, fatigue and rutting, induced by traffic repetitions, are generally considered to be the main modes of pavement failures. The tensile strain at the bottom of the bituminous layer, and the compressive strain on the subgrade are generally considered to be indicative parameters for fatigue and rutting failures respectively. The same M-E pavement design principles can be used to design bituminous pavement with stabilized subgrade and cemented base / sub-base (Austroads 2004, Mallela 2004, Theyse et al. 1996). This has been discussed further in the following paragraphs.

Stabilized subgrade

The subgrade modulus is used as one of the input parameters to the pavement design. The subgrade modulus can be estimated from triaxial test, CBR test, plate load test etc (Das 2003).

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For a selected homogenous section, a single value of subgrade modulus is needed. A subgrade which has been upgraded by replacement of top layer of soil or by stabilization, can be modeled as a layered subgrade (refer Figure-1), rather than assuming it as a homogenous half-space. The equivalent modulus of the layered subgrade can be estimated from deflection or stress-strain equivalency concept (Reddy et al. 2001), or by using empirical formula (Japan manual 1989).

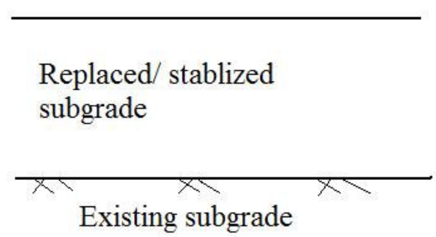

Figure 1: A layered subgrade situation

Cemented base/ sub-base

While designing a bituminous pavement with cemented base/ sub-base, it is generally assumed that the propagation of fatigue cracking is sequential. That is, the cemented layer undergoes fatigue cracking failure first, and after its fatigue life is exhausted, the fatigue cracks start propagating through the bituminous layer (Austroads 2004, Otte et al. 1992, Theyse et al. 1996). Thus, the fatigue lives of cemented layer and bituminous layer can be considered as additive for design purpose.

It is also assumed that the elastic modulus of the cemented layer, after it is completely fatigue cracked, drops substantially (refer Figure-2). Various guidelines recommend that the reduced elastic modulus can be as low as about 10% of the initial elastic modulus (Austroads 2004, Otte et al. 1992, Theyse et al. 1996).

Thus, the design steps can be summarized as follows (Das and Pandey 1998, R-90 2009):

- The elastic modulus values of the materials proposed to be used in various layers are assumed. Tentative thickness values of the pavement structure are assumed.
- The fatigue stress for the cemented layer is calculated. It is sometimes recommended to increase the calculated stress by a factor greater than one, so as to take into account the stress concentration generated due to shrinkage cracks present in the cemented layer (Mitchell and Monismith 1977). Subsequently, the fatigue life of the cemented layer is calculated from the fatigue performance equation of such material.
- The fatigue strain at the bottom of the bituminous layer is calculated and its fatigue life is estimated. While calculating the strain value, a reduced elastic modulus of the cemented layer (after its fatigue life is completely exhausted) is to be considered.
- If the sum of the two fatigue lives are close to the design fatigue life, the pavement design is finalized, else design iterations are continued.

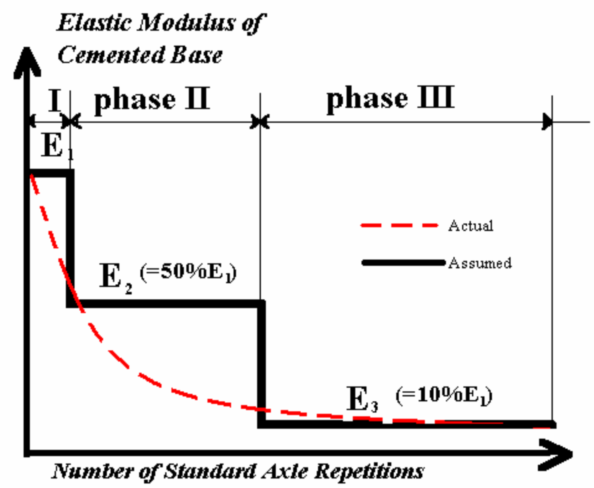

Figure-2: Varaiation of elastic modulus of the cemented layer with traffic repetitions (Das and Pandey 1998)

Closure

The M-E pavement design principles for bituminous pavement with stabilized/ cemented layer have been briefly discussed. It may be noted that the design is generally governed by fatigue failure. The compressive strain on subgrade is generally low, because of higher elastic modulus of the cemented material, and therefore, the pavement remains safe from rutting considerations (Theyse et al. 1996).

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