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Marshall stability and flow of lime-modified asphalt concrete

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Abstract

The purpose of highway pavement is to provide smooth surface over which vehicles can move safely from one place to another. The two major types of pavement (flexible and rigid) have been mostly selected for the highway pavement to fulfil this function and they must be capable of transferring the wheel load to the subgrade such that its bearing capacity is not exceeded. However, the flexible pavements normally show defects like rutting, fatigue failure, low skid resistance and so on, causing the pavement to fail before its design life. Therefore, it is important to modify the asphalt concrete to make it more resistant to rutting and fatigue failure. Lime-modified asphalt has been observed to have better resistance to rutting, cracking and stripping, as well as having improved aging behavior. Therefore, this study looks at the Marshall properties of hydrated lime-modified asphalt mixture and the conventional asphalt. The conventional asphalt mixture was made using 10% mineral filler while for the lime-modified asphalt, the mineral filler was replaced with hydrated lime. The bitumen with penetration grade 60/70 was used and the content varied from 5.0 to 7.5%. Marshall stability and flow tests were carried out on the samples. The results show that the Marshall stability for the asphalt concrete with mineral filler ranges from 5.89 – 7.90 kN while that with hydrated lime ranges from 5.9 to 8.2 kN. The flow values for the asphalt concrete with mineral filler range from 2.3 mm – 3.3 mm, while that with hydrated lime range from 2.4 – 3.4 mm. The optimum bitumen content for both mixtures was found to be 6.5%. The stability and flow for the mixture with mineral filler were 7.9 kN and 3.3 mm, respectively, while for the mixtures with hydrated lime they were 8.2 kN and 3.4 mm, respectively. This indicates the replacement of the mineral filler with lime improves the stability of the mixtures, while there was slight increase in the flow of the mixture with hydrated lime. The slight increase in stability and flow values may be attributed to the complete replacement of the mineral filler with lime and the high lime content used in the study. More studies are being carried out to evaluate the Marshall properties for mixture with the mineral filler partially replaced with lime and for varying proportions of the lime content in the asphalt mixture.

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1. Introduction

The two principal modes of failure in pavements are fatigue cracking and permanent deformation. Engineers seek to hold these forms of failure to acceptable limits within a pavement design life. Fatigue resistance of an asphalt mixture is the ability of the mixture to withstand repeated bending without fracture. It is one of the common forms of distress in asphalt pavements and manifests itself in the form of cracking under repeated traffic loading or a series of temperature fluctuations/variation in the pavement. Fatigue cracking initiates at the bottom of asphalt base and appears on the pavement surface as interconnected tracks of different forms and it may also start at the surface and grow downwards as is the case for thermal (fatigue) cracking. Some forms of fatigue cracking include longitudinal cracking, transverse cracking, and block cracking. The published studies on fatigue resistance indicate that hydrated lime improves the fatigue resistance of asphalt mixtures in 77% of the cases (EuLA, 2010).

Permanent deformation and rutting are used interchangeably. Permanent deformation is caused by gradual build-up of irrecoverable strains under repeated loading which develop into a measurable rut (permanent depression along the wheel path). These strains are due to the visco-elastic response of bituminous materials to dynamic loading. Figure 1 shows the visco-elastic response to millions of wheel loadings. Rutting causes hydroplaning and safety concern for road users. It can develop into potholes/structural failure of the pavement if not corrected. In the past, subgrade deformation was considered to be the primary cause of rutting and many pavement design methods applied limiting criteria on vertical strain at the subgrade level also. However recent research indicates that most of the rutting occurs in the upper part of the asphalt surfacing layer. According to Brown (1997), a common misconception is that the subgrade strain criterion only refers to permanent deformation in the subgrade.

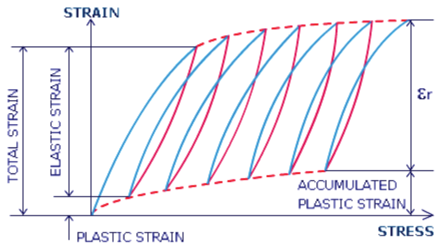

Fig. 1. Accumulated Plastic strains in Pavements (Asphalt Institute, 1996).

Eisemann and Hilmar (1987) studied asphalt pavement deformation phenomenon using wheel tracking device. They measured the average rut depth as well as the volume of displaced materials below the tyres and in the upheaval zones adjacent to them and found that, at the initial stages of trafficking, the increase of irreversible deformation below the tyre is distinctly greater than the increase in the upheaval zones and concluded that at the initial phase, traffic compaction or densification is the primary mechanism of rut development (See Figure 2a), while after the initial stage, the volume decrease below the tyre is approximately equal to the volume increase in the adjacent upheaval zones, which implies that most of the compaction under traffic is completed and further rutting is caused essentially by shear deformation, i.e., distortion without volume change (See Figure 2b). Thus, they concluded that, shear deformation is considered to be the primary mechanism of rutting for the greater part of the lifetime of the pavement.

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