



Rutting performance of hydrated lime modified bituminous mixes

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HIGHLIGHTS

- Two methods of lime modification, wet and dry were considered for evaluating the rutting performance of bituminous mixes.
- Wet mixes (with 30% lime in binder) showed better resistance to rutting compared to dry mixes (with 1.5% lime as filler).
- Lime modification has been found to be more effective in improving the rut resistance at higher temperatures.

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ABSTRACT

Hydrated lime has conventionally been used in bituminous mixes primarily for improving the moisture damage resistance of bituminous mixes. Most of the available literature is about studies conducted on mixes in which lime was added as filler. The present study explores the effect of different proportions of hydrated lime added by two different methods (wet and dry) on the rutting performance of bituminous mixes. The rutting characteristics of unmodified and lime modified binders were evaluated in terms of superpave binder rutting parameter ($G^*/\sin\delta$) and non-recoverable creep compliance (J_{nr}). Mix rutting performance was measured in terms of E^* , $E^*/\sin\phi$, flow number and accumulated strain measured in dynamic creep test. Rutting performance of mixes improved significantly by lime modification. Wet method of addition of lime has significantly higher beneficial effect than the dry method. Flow number determined at 60 °C demonstrated the beneficial effect of lime more distinctly compared with the dynamic creep test conducted at 40 °C. It was also observed in this study that the beneficial effect of lime addition in reducing rutting (which is a high temperature phenomenon) was realized more at higher mix temperatures.

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1. Introduction

Rutting of bituminous mixes is one of the major modes of failures in bituminous pavements. While subgrade rutting has traditionally been considered to be the major contributor to the total pavement rutting observed at the pavement surface, a majority of rutting failures in pavements with thick bituminous layers occur in bituminous layers. In addition to aggregate skeleton, the rutting at high temperature can be attributed to the type of binder used in the mix. Besides using aggregate gradations designed for greater rut resistance, the use of modified bitumen [1,2] is one of the options commonly selected for improving the rutting resistance of bituminous mixes. The effect of modified binders on the rutting resistance of bituminous mixes was investigated by a number of

researchers in the past [3–20]. Hydrated lime (HL) has been used extensively to improve the moisture damage resistance of bituminous mixes. However, very limited research work has been reported on the use of hydrated lime (HL) for modifying bitumen [21–23]. The relative rut resistance of bituminous mixes prepared using lime modified binder (wet method) in comparison to that of mixes in which lime is added directly to the aggregates (dry method) has not been investigated adequately. Atud et al. [21] compared the rutting performance of bitumen modified with 10%, 20% and 30% HL (by weight of bitumen) with that of SBS modified bituminous mixes. The superpave rutting parameter $G^*/\sin\delta$ was found to increase with increase in the percentage of HL. The creep and recovery test performed by Atud et al. [21] at 50 °C and 100 Pa stress level indicated that the rate of strain accumulation reduced with addition of lime as well as polymer.

Addition of different fillers such as fly-ash, cement, silica fume, bag-house fines and HL is known to improve the rut resistance of bituminous mixes [24]. Mineral filler characteristics and their

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impact on the permanent deformation characteristics of bituminous mixes vary with the type and amount of filler added to the mix [25]. Two current Indian guidelines on the specifications of road construction practice in India: (i) Specification for Roads and Bridge works [26] and (ii) Specifications for Dense Graded Bituminous Mixes [27] recommend replacement of mineral filler with 2% HL for increasing the resistance of bituminous mixes to moisture damage. The rutting performance of bituminous mixes gets improved significantly by addition of lime as filler due to its stiffening effect [28–35] as observed in different field and laboratory studies. Lesueur and Little [38] concluded that HL is a multi-functional additive and showed that mixes with HL have greater resistance to deformation, low-temperature fracture toughening, and age hardening. Little and Petersen [39] conducted laboratory tests on mixes prepared with HL and concluded that HL added as filler significantly impacts the rate and level of micro-crack-induced damage, micro-damage healing in both mastics and mixes across a wide range of temperatures. Vansteenkiste et al. [40] concluded that use of natural limestone as filler has a large beneficial effect on the water sensitivity of Stone Mastic Asphalt (SMA) mixes. Lesueur et al. [41] found that the interactions between HL and the other components of asphalt mixes are quite intense. They reported improvement in the resistance to moisture damage and ageing and improvement in mechanical properties.

Hydrated lime added as filler has “inert” as well as “active” roles [29]. The dry porosity of hydrated lime which is about 60–70% is much larger than that of ordinary mineral filler (30–34%) due to the internal porosity of lime particles. The reason for the relatively higher stiffening effect of hydrated lime compared to other mineral fillers is the higher dry porosity. Little and Petersen [37] suggest that the addition of lime does not necessarily make mix more brittle at lower temperatures as at low temperatures, the hydrated lime becomes less chemically active and will behave similar to other inert fillers. Compared to the stiffening effect of the filler observed at high temperatures the effect is significantly less at temperatures near the glass transition temperature of the bitumen. This phenomenon enables the binder to relax at low temperatures, causes dissipation of energy through deformation instead of fracture. Lesueur and Little [36] opined that it is important for mixtures to be able to relax at low temperatures to avoid thermal cracking while being stiff at high pavement temperatures. At low temperatures hydrated lime’s chemical activity is reduced and as a result it contributes to improved mix toughness, and an increased capacity for the mastic to relax at low temperatures.

It is seen from literature that the stiffening effect of addition of HL as filler in mixes and the corresponding improvement in rutting resistance, aging and water sensitivity have been observed in a number of studies. The effect of directly modifying the binder with HL has been evaluated in only a few studies [21–23] and the information available on the effect of HL on the rutting characteristics of mixes at different temperatures and loading frequencies is limited. In view of this, a study was taken up to experimentally evaluate the effect of HL added in wet and dry methods on the rutting characteristics of bituminous mixes. Considering that PMB and CRMB modifiers are commonly used in India for rut resistant mixes for highways subjected to high pavement temperatures and heavy traffic loading, it was also decided to compare the rutting performance of lime modified mixes with that of polymer and crumb rubber modified mixes. The following scope of work was selected for this purpose.

- (ii) One polymer modified binder PMB70 and one crumb rubber modified binder, CRMB55
- (iii) Four hydrated lime modified binders, VG30 and VG40 modified with two different proportions (20% and 30% by weight of virgin bitumen) of hydrated lime
- A total of twelve bituminous mixes were investigated. These include eight mixes prepared with the eight binders listed above and four additional mixes with the two virgin binders VG30 and VG40 having HL added as filler in two different proportions (1.5% and 2.0% by weight of total mix)
- HL was added to VG30 and VG40 mixes by two different methods, wet and dry. In the wet method, 20% and 30% hydrated lime by weight of bitumen was blended with bitumen. For the dry process, 1.5% and 2% lime by weight of dry aggregate was added as filler. The weight of 30% lime added in the wet method approximately corresponds to the weight of 1.5% lime added in the dry method
- The eight binders were characterized for routine consistency parameters and for rheological characteristics which were evaluated in terms of the superpave rutting parameter $G^*/\sin\delta$ and non-recoverable creep compliance (J_{nr}) parameter determined using Dynamic Shear Rheometer (DSR)
- Dynamic Complex modulus (E^*) and phase angle (ϕ) of the twelve mixes were determined at different temperatures and frequencies
- Rutting characteristics of the twelve mixes were evaluated by conducting flow number test at 60 °C and dynamic creep test at 40 °C

2. Materials and methods

2.1. Binders

Two viscosity grade (VG) binders VG30 and VG40, and two modified binders PMB70 (SBS Polymer modified) and CRMB55 (Crumb rubber modified) were used in the present study. HL was blended with VG30 and VG40 binders at 160 °C for a duration of 20 min with the help of a high speed blender [23]. The basic properties of the binders are presented in Table 1. It can be seen from the table that addition of hydrated lime to VG30 and VG40 binders increased the stiffness as reflected from the decrease in penetration, increase in softening point and viscosity measured at 60 °C.

2.2. Hydrated lime

Hydrated lime (HL) was prepared in the laboratory by slaking quick lime purchased from the local market of Kharagpur, India. Water to quick lime ratio was selected as 3:1 for slaking of quick-lime [51]. The properties of the hydrated lime are given in Table 2 [52].

2.3. Aggregates

Fig. 1 shows the details of the aggregate gradation adopted along with the specification range given by MoRTH [56] for Bituminous Concrete mix for a nominal maximum aggregate size of 19 mm. The physical properties of the coarse aggregates are given in Table 3. Aggregates used in the present study are of Basalt type and were obtained from Chatra stone quarry in the Birbhum district of West Bengal State, India. Details of the chemical composition of the aggregate determined by Scanning Electron Microscope (SEM) are given in Table 4 [52].

- Eight different binders were used as per the following details
 - (i) Two viscosity grade (VG) virgin binders, VG30 and VG40, were selected. “VG” denotes viscosity grade and the number in suffix indicates the absolute viscosity (divided by 100, Poise) of the binder measured at 60 °C temperature [40].

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