HIGH MODULUS BITUMINOUS LAYERS
FOR DURABLE INDIAN HIGHWAYS

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More than 95% of the road infrastructure in India consists of flexible pavements with several layers and the top
two to three layers are generally built as bituminous layers. Thicknesses of the bituminous layers vary from 200 to 250
mm for heavy high tyre pressures and high temperatures of Indian highways. The share of cost of construction of
bituminous layers is nearly 70% of the total cost of entire pavement as these layers require good quality road aggregates,
dense graded mixes, high quality binder and construction practices. Any reduction in the thickness of bituminous layers
can result in huge savings. Road quality aggregates are becoming progressively scarce on account of environmental
concerns as well as legal restrictions on quarrying while the construction activity has expanded phenomenally with more
quantities of materials being consumed in the asphalt layers. Any approach that can result in the reduction of layer
thicknesses and hence reduced consumption of construction materials such as aggregates and bitumen can result in
better sustainability of road construction.

In Mechanistic-empirical pavement design, thickness of pavement structure comprising a number of layers
including bituminous layers, suitable materials in each layers is arrived at based on well-defined failure criteria and
given traffic (usually millions of standard axles). Material characteristics i.e elastic/resilient modulus of the pavements
layers will be one of the main inputs for the pavement design. Selecting bituminous mixes with higher stiffness can result
in reduction in thickness of layers and reduced life cycle cost of the road.

In the recently revised flexible pavement design guidelines IRC: 37 (2012), it is recommended that the
bituminous layer should be both rut and fatigue resistant. In order to achieve this, conventional asphalt mixes such as
bituminous concrete (BC) and dense bituminous macadam (DBM) are recommended as the top two layers (surface and
base course) with the average elastic modulus of these mixes prepared with VG-40 Viscosity grade bitumen being 3000
MPa at 35°C. VG-40 is the highest quality of normal binder available in Indian market. Aggregate gradations
recommended by the Ministry of Road Transport and Highways (2013) are generally adopted for construction of these
bituminous layers. A typical pavement design done with these materials for national highway traffic (150 million
standard axle load repetitions) for a subgrade having 30 MPa elastic modulus, suggests that the combined thickness of the two bituminous layers will be 220 mm.

Increasing the modulus values of bituminous layers would reduce the thickness of these layers and can result in significant saving in the cost of construction and help in the reduction of consumption of good quality aggregates. This is possible through innovative technology that uses binders that are stiffer compared to VG-40 that is currently being used in India and different aggregate gradation that would accommodate higher binder content and finally low air void content. The resultant mix with this combination is expected to have high modulus that would not only reduce the thickness of layers but also meet the requirements such as rut and fatigue resistance resulting in high performing bituminous mix.

**APPLICATIONS OF HiMA MIXES FOR PAVEMENTS**

Since last decade, it is observed that several pavement research groups around the world are developing high modulus asphalt (HiMA) mixes for base course and using them to construct high volume roads with a thin wearing course on it. French engineers working on pavements have developed high modulus asphalt mix (HiMA) in early 1970’s (Serfass et al, 1997) titled as *Enrobe* ‘a Module E’leve’ (EME), an asphalt mix with high modulus. The name Enrobes Modulus Eleve is a generic name given to these mixes (Delorme et al, 2007). EME is described as a high modulus, long life asphalt layer complying with the European specifications for Asphalt Concrete (AC) (CEN, 2006 a). It is used as a base layer for achieving longer life or heavy duty asphalt pavement with a design life of more than 40 years. The exceptional feature of EME 2 mix is that it possesses very high resistance to fatigue cracking by reducing tensile strains at the bottom of the bituminous layer (Lee et al, 2006) and thereby the potential thickness of conventional pavements can be reduced to a greater extent (Brosseaud et al, 2012; Hernández, 2015). When compared to the conventional asphalt bases, EME mixes are highly resistant to permanent deformation, moisture susceptibility and good fatigue resistance (APT283-14, 2014). It requires hard bitumen with a penetration grade of 10/20 or 15/25 along with an aggregate gradation with good interlocking properties and accommodating the high amount of bitumen, nearly 6% (Geng et al, 2013). It is used normally as a basecourse and later is being used as a wearing course (Serfass et al, 1997). The applications of EME mixes include the following:

- Pavements carrying high traffic volumes such as National highways, Expressways, state highways and some of other major roads carrying traffic in the similar pattern.
- Urban Intersections carrying slow moving vehicles at higher volume, Haul roads with heavy axle loads etc.,
- Where the pavement requires structural strengthening and with restricted thickness limits (Petho and Dennenman, 2013).

The main advantage of HiMA mixes is reduced thickness for the design traffic. Figure 1 shows the typical cross section of highway pavements used in India and France for high volume roads.
High Modulus Asphalt (HiMA) Mixes in France

HiMA mix specifications were developed based on extensive research work at Laboratoire Central des Ponts et Chaussées (LCPC). The salient features of HiMA mix include (i) Dynamic modulus at 15°C of 14 GPa (ii) Higher binder content (minimum richness modulus), high rut resistance, and superior fatigue resistance, impermeable and durability. Extensive research has been carried out in France on HiMA mixes and thereby mix specifications, gradations of France have been directly adopted and implemented by many countries. The influence of loading pattern on the field mixes without and with rest periods was investigated by De La Roche et al. (1997). They observed the significant change in the increment of fatigue life when the mixes are provided with rest periods and healing of hard bitumen was relatively less when compared to conventional 30/50 bitumen. Overall, an assessment on the performance of HiMA pavements was done in 1997 (Corte et al. 2001). Pavements with age from 2 to 14 years were evaluated and it was found that none of them required any kind of maintenance. As a result of the major research program carried out by France, Specifications for the EME mixes had been developed conforming both the hard bitumen and mixes. Table 1 shows the French specifications for design of HiMA mixes.

Table 1 French Specifications for Design requirement of HiMA

<table>
<thead>
<tr>
<th>Classification</th>
<th>AC-EME 1</th>
<th>AC-EME2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Sensitivity</td>
<td>Gyroratory Compactor</td>
<td>ITS 70</td>
</tr>
<tr>
<td>AC 10 EME</td>
<td>80 gyrations</td>
<td>V_{max}^{10}</td>
</tr>
<tr>
<td>AC 14 EME</td>
<td>100 gyrations</td>
<td>V_{max}^{6}</td>
</tr>
<tr>
<td>AC 20 EME</td>
<td>120 gyrations</td>
<td></td>
</tr>
<tr>
<td>Void Content of the slabs</td>
<td>AC EME-2</td>
<td>{V_i = 3%; V_s = 6%}</td>
</tr>
</tbody>
</table>

Figure 1 Typical cross section of highway pavements in India and France for high volume roads
<table>
<thead>
<tr>
<th>Classification</th>
<th>AC-EME 1</th>
<th>AC-EME 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel Tracking test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large device, 60 °C</td>
<td>Number of cycles</td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td>Category of rut depth</td>
<td>P 7.5 %</td>
</tr>
<tr>
<td>Stiffness</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 °C, 10 Hz or 0.02 s</td>
<td>Smin14000 MPa</td>
</tr>
<tr>
<td>Fatigue</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 points, 10 °C, 25 Hz</td>
<td>ε6-100</td>
</tr>
</tbody>
</table>

**NEED OF HIGH ASPHALT MODULUS MIXES FOR INDIAN HIGHWAYS**

In the context of Indian Highways, it will be beneficial to develop of road infrastructure with High Modulus Asphalt (HiMA) Mixes which will be long-performing and will result in significantly reduced life cycle costs. It will also serve the purpose of conserving natural good quality road aggregates for future generations. No such efforts are so far made in India to develop such mixes and the outcome of this effort would benefit the community to large extent.

Stiffer/harder binders for producing high modulus mixes can be developed by

i. Change of the bitumen production process in the refinery

ii. Addition of suitable polymers to refinery bitumen

iii. Air blowing of bitumen

Though air blowing bitumen gives hard/stiffer binder, but mixes will be brittle and crack prematurely. However other two methods are promising approaches for producing high modulus asphalt (HiMA) / high performing bituminous mixes.

**RESEARCH INITIATION ON DEVELOPMENT OF HIIMA MIXES IN INDIA**

Transportation Engineering section, Civil Engineering Department, Indian Institute of Technology Kharagpur has undertaken a research project sponsored by National Highways Authority India (NHAI), Government of India for development of high modulus asphalt (HiMA) mixes for Indian highways.

Development of hard bitumen binders using various additives (multi-component modified bitumen) and evaluates the performance of HiMA mixes produced with different hard bitumen is considered in this research work. Various binders including hard binder from refinery are being considered for developing HiMA mixes. Performance evaluation in terms of resistance to rutting and fatigue cracking of (DBM, EME gradation) mixes prepared with hard as well as modified binders for recommending of high performing mixes prepared with hard binders and modified binders along with specifications for possible use of these mixes in bituminous layers of Indian Highways.

**REFERENCES**


- Delorme, J. L., De la Roche, C., & Wendling, L. (2007). LPC bituminous mixtures design guide. Laboratoire Central des Ponts et Chaussées


