Effect of using fly ash as alternative filler in hot mix asphalt

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Summary This study investigates the effect of using fly ash (FA) in asphalt mixture as replacement of common filler. In view of the same, samples were prepared for different bitumen content (3.5–6.5% at 0.5% increments) by using 2% hydrated lime (HL) in control mix as well as varying percentage of FA ranging from 2 to 8% as alternative filler in modified mixes. The optimum bitumen content (OBC) was then determined for all the mixes by Marshall mix design. Experimental results indicated higher stability value with lower OBC for the mixture having 4% FA as optimum filler content in comparison with conventional mix and standard specification. So this study discuss the feasibility of using FA as alternative filler instead of HL in asphalt concrete mix by satisfying the standard specification.

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Introduction

The construction and maintenance of highway pavement in India requires a large quantity of good quality materials. On the other hand, fast growth in continual heavy axel traffic demands better quality material for paving application. The development and use of modified asphalt mix can meet the needs of the communities. Asphalt modification, can be realised primarily through polymer modification; however, this method is expensive due to the cost of raw polymer, skilled persons and special equipment. In the other method, asphalt mix modification can be done by replacing common filler (i.e. stone dust, lime or cement); a fine material that mostly passes through 75 μm sieve (Ministry of Road Transport and Highways, 2013), with other suitable materials. Nowadays, due environmental and economic concern researchers have extensively investigated the use of recycled waste materials in place of common filler (Choudhary, 2006; Kuity et al., 2014). Also recycling supports global sustainability.

Fly ash, a mineral by-product of coal ignition in thermal power plant, generally dumped nearby land, poses a threat to environment and human health. In India, the volume of fly
ash that are generated every year is so high (approximately 170 million tonnes) that effective recycling of this waste has become national interest. Although fly ash has been used in concrete research for years, there is very limited application in asphalt pavement.

The present study was carried to observe the effect of fly ash and their content on Marshall properties of dense bituminous macadam (DBM). Based on the experimental results, the feasibility of fly ash as filler in optimum proportion is assessed comparing with control mixture.

Materials and methods

Materials

Aggregate
Locally available aggregates having specific gravity of 2.89 and 2.73 for coarse and fine aggregate, respectively, were used in this study. The continuous aggregate gradation of DBM gr-2 set by MORT&H specifications was selected.

Bitumen
VG 30 grade paving bitumen collected from Haldia petrochemicals, India was used in this investigation to prepare HMA mixes after confirming to (IS 73, 2013).

Filler
Conventionally used hydrated lime (HL) collected locally and fly ash (FA) obtained from Kolaghat thermal power plant situated in West Bengal, India were used as fillers. The chemical and physical properties were determined and shown in Table 1. The physical appearance and SEM image of fly ash are shown in Fig. 1.

<table>
<thead>
<tr>
<th>Fillers</th>
<th>Chemical compositions</th>
<th>Physical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SiO₂</td>
<td>CaO</td>
</tr>
<tr>
<td>HL</td>
<td>3.2</td>
<td>72.4</td>
</tr>
<tr>
<td>FA</td>
<td>49.6</td>
<td>12.3</td>
</tr>
</tbody>
</table>

* LOI—loss on ignition, ** specific surface area (SSA).

Method

Design of DBM mix
In this study, the Marshall mix design method was used to design the HMA mixes. The standard Marshall specimens were prepared by applying 75 blows on each face according to ASTM: D6926 (ASTM D6926, 2010) having seven different bitumen content between 3.5 and 6.5% by total weight of aggregate at 0.5% increments for control mix (i.e. the mix that contain 2% HL as filler) as well as mix containing 2, 4, 6 and 8% FA as filler.

Marshall stability, flow and Marshall quotient tests
The main purpose of Marshall mix design is to determine the optimum bitumen content (OBC) relative to various mix proportions. For these reason, it is required to perform Marshall stability and flow test on each sample under a loading rate of 50.5 mm/min at 60°C based on ASTM: D6927 (ASTM D6927, 2010). Marshall quotient, which is a kind of pseudo stiffness, can be calculated as the ratio of stability to flow.

Results and discussions

As mentioned earlier, the Marshall mix design method was used to determine the optimum bitumen content (OBC) of mixes relative filler ratio in comparison with control mix. The OBC was calculated form the data shown in Fig. 2 and selected at 4% air voids. The Other Marshall properties like voids filled with bitumen (VFB), voids in mineral aggregate (VMA), stability, flow and Marshall quotient (MQ) were then checked to be within the specified limits of MORTH at that bitumen content.

Figure 1 (a) Physical appearance and (b) SEM image of fly ash used.
Table 2  Marshall properties of the mixes corresponding to OBC at various filler content.

<table>
<thead>
<tr>
<th>Filler type</th>
<th>Percentage Filler</th>
<th>OBC (%)</th>
<th>VMA (%)</th>
<th>VFB (%)</th>
<th>Stability (kN)</th>
<th>Flow (mm)</th>
<th>MQ (kN/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL</td>
<td>2</td>
<td>5.21</td>
<td>16.08</td>
<td>74.57</td>
<td>16.08</td>
<td>3.82</td>
<td>3.53</td>
</tr>
<tr>
<td>FA</td>
<td>2</td>
<td>5.07</td>
<td>15.58</td>
<td>73.58</td>
<td>13.98</td>
<td>3.09</td>
<td>4.54</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4.9</td>
<td>15.11</td>
<td>74.33</td>
<td>15.44</td>
<td>3.77</td>
<td>4.11</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>4.8</td>
<td>14.78</td>
<td>73.62</td>
<td>19.48</td>
<td>3.35</td>
<td>5.23</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>5.4</td>
<td>16.16</td>
<td>74.87</td>
<td>17.52</td>
<td>3.79</td>
<td>5.34</td>
</tr>
</tbody>
</table>

Figure 2  Variation of air void (%) vs bitumen content at different filler content.

Figure 3  Variation of MQ values vs bitumen content at different filler content.

Table 2 illustrates the Marshall properties of the mixes corresponding to obtain OBC values at studied filler content for control mix as well as mix modified with FA. As shown in Table 2, The OBC of control mix is 5.21%. Addition of FA at 2, 4, 6 and 8%, the OBC values are 5.07, 4.9, 4.8 and 5.4%, respectively. The OBC values decreases with the increases in filler content up to 6%. However, further increment in filler content increases the OBC value respective to control mix. Further, Table 2 gives the Marshall stability (MS) values of control mix of 13.56 kN. Whereas, the MSs of mixes containing 2, 4, 6 and 8% of FA are 13.98, 15.44, 19.48 and 17.52 kN, respectively. The flow values of all the mixes respective to OBC stayed in the specified range of 2–4 mm (Table 2). Moreover, the increase in MQ values is noticeable as the filler content increases and after 4% filler ratio, the same values exceed the maximum permissible specified value of 5 (Fig. 3). Because the sources of all material, aggregate gradation, are the same for all the mixes the changes in all the obtained properties are attributed to the type of filler and their content only.

Conclusion

The potential use of fly ash, collected from local thermal power plant, in hot mix asphalt was investigated through Marshall mix design. From the analysis of the laboratory test data, the following conclusions can be made:

- According to obtained Marshall parameters, the addition of FA up to 4% in DBM mix, by replacing conventional mineral filler like HL shows a 7.5% reduction in OBC compared to the control mix, which may provides a considerable economy of bitumen in resulting mixture.
- So, the replacement of HL by FA in HMA not only satisfies all the standard specification of MORTH but also gives better strength with lesser deformation compared to that of the conventional mix.
- Hence, especially in the areas where fly ash generally dumped may be used as replacement of common filler to support global sustainability.

Acknowledgement

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References

Ministry of Road Transport, and Highways (MORTH). Specifications for road and bridge works, fifth revision, Indian Roads Congress, New Delhi, India; 2013.