PERFORMANCE EVALUATION OF E-WASTE IN FLEXIBLE PAVEMENT – AN EXPERIMENTAL APPROACH

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ABSTRACT

The objective of this study is to investigate the effect of e-waste and fly ash, as a filler replacement, on the strength parameters of bituminous concrete road. It is observed that there is definite increase in Marshall stability and flow value with increase in percentage of e-waste by replacing up to 10 percent aggregates. The use of fly ash as filler cannot increase the strength but helps to attain it nearly equal to that of control mix.

Here in an attempt is made to use the waste products like flyash and e-waste in flexible road construction which affect the environment and are difficult to process.

The study concludes that e-waste and fly ash could be used as filler material in bituminous mixes.

KEY WORDS: E-waste, Fly ash, Flexible pavement.

INTRODUCTION

The use of modified asphalt concrete mixes in surface bound layers creates a demand for evaluation of the performance of those modified mixtures. Asphalt modification is done by adding modifiers in asphalt or by adding the modifier directly in the mixture of bitumen and aggregate during mixing process. The importance of using waste materials (here e-waste and fly ash) in the modification of asphalt aggregate mixture is one of the vital area of research. Together with economic consideration, using e-waste, and fly ash in asphalt–aggregate mixture behaves in beneficial way.

In developing countries like India, considerable amount of e-waste and fly ash is generated every year. This huge amount of waste creates significant amount of problems with respect to handling and storage, which are important both from the economic as well as environmental point of view. Nations were forced to search for more suitable ways to recycle these waste materials. Since a long time researchers have been investigating the use of fly ash in construction to enable better management of this important waste material and to improve the properties of construction material. This study aims to provide a suitable means for the utilization of e-waste and fly ash in bituminous concrete.
HISTORICAL BACKGROUND

Normally stone dust produced during the aggregate crushing is used as filler in asphalt aggregate mixture. It is common practice to use hydrated lime, Portland cement and some other material to replace stone dust when it is not available in required amounts. The influence of mineral fillers comes from the fact that although small in weight with respect to total mix, its surface area is quite large. In some cases reduction in the demand for bitumen can be accomplished by the addition of mineral filler because it fills the voids in aggregate mass. However in other cases due to increase in the surface area there may be larger demand for bitumen may be necessary. In this study e-waste and fly ash were selected as mineral filler to investigate the effect on characteristics of bituminous mixture.

In usual practice, the mineral filler used in asphalt concrete is the tail end product obtained during the crushing process of natural rock that conforms to aggregate specification. The use of fly ash, Portland cement, or other suitable material in place of natural mineral filler is universally accepted. The mineral filler, whether artificial or natural, can affect hot mix asphalt concrete in number of ways. It may:

1. Stiffen the asphalt mix
2. Alter the moisture resistance of mix
3. Affect the ageing characteristics of mix
4. Affect the workability and compaction characteristics of mix.

OBJECTIVES

The main objectives of this study are:

1. To study the effect of e-waste and fly ash as reinforcement in flexible pavement.
2. To develop a general methodology for analysis.
3. To study the cost effectiveness of modified mix as compare to control mix.

SCOPE OF WORK

This experimental program consists of 63 tests which were conducted by varying percent of bitumen content, e-waste and fly ash respectively to study their effect on bituminous mix. The overall testing program consists of

1. Sieve analysis
2. Selection of gradation
3. Study of physical properties of aggregate, bitumen and aggregate replaced by e-waste.
METHODOLOGY

Steps for Sample Preparation

The current study evaluates the performance evaluation of e-waste in flexible pavement. The marshal test procedure as per ASTM D 5581 is used to conduct the test.

1. Selection of Material

(a) Bitumen: In this study 60/70-penetration grade bitumen was used as binder as it is widely used in testing. The physical properties of bitumen are shown in table 1.

(b) Aggregate: The aggregates conforming to IS: 383-1978, were chosen and possessed physical properties within range decided by MORTH-2001. Physical properties of aggregate are shown in table 2.

2. Proportioning of Aggregates

The mix design was decided on the basis of sieve analysis and the required amount of aggregates should be oven dried for 4 hrs at about 102 to 110°C temperature so that free moisture of aggregate if present is removed. The oven-dried aggregates are then weighed as per blending percentage and transferred to mixing pan.

Table 1: Physical properties of bitumen

<table>
<thead>
<tr>
<th>Sr. no.</th>
<th>Name of Test</th>
<th>IS Standard</th>
<th>Results obtained</th>
<th>MORTH Permissible Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ductility</td>
<td>IS: 1208:1978</td>
<td>79.33 cm</td>
<td>75 cm minimum</td>
</tr>
<tr>
<td>2</td>
<td>Softening Point</td>
<td>IS: 0334:1982</td>
<td>46.50 ºC</td>
<td>40 ºC to 55 ºC</td>
</tr>
<tr>
<td>3</td>
<td>Penetration</td>
<td>IS: 1203:1978</td>
<td>66.00</td>
<td>60/70</td>
</tr>
<tr>
<td>4</td>
<td>Specific Gravity</td>
<td>IS: 1202:1978</td>
<td>01.00</td>
<td>1 - 2</td>
</tr>
</tbody>
</table>

Table 2: Physical properties of aggregate

<table>
<thead>
<tr>
<th>Sr. no.</th>
<th>Name of Test</th>
<th>IS Standard</th>
<th>Results obtained</th>
<th>MORTH Permissible Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Impact Value</td>
<td>IS : 2386-Part IV:1963</td>
<td>13.60%</td>
<td>24% maximum</td>
</tr>
<tr>
<td>2</td>
<td>Water Absorption</td>
<td>IS : 2386-Part III:1963</td>
<td>1.30%</td>
<td>2% maximum</td>
</tr>
<tr>
<td>3</td>
<td>Los angels Abrasion</td>
<td>IS : 2386-Part IV:1963</td>
<td>16.76%</td>
<td>30% maximum</td>
</tr>
<tr>
<td>4</td>
<td>Specific Gravity</td>
<td>IS : 2386-Part III:1963</td>
<td>2.66</td>
<td>2 - 3</td>
</tr>
</tbody>
</table>
3. Preparation of Specimen

Approximately 3kg aggregates are required for a specimen. The aggregates are taken as per mix design and required percent of aggregates are replaced by e-waste by total volume. Bitumen is added to the aggregate by percent of total weight and mix thoroughly at 170-180°C temperature. After mixing thoroughly the mix is fill in to Marshall mould and compacted by giving 75 blows on either side in Marshall compactor. After compaction the mould is cooled for 10 to 12 hrs at atmospheric temperature. The specimen is removed from marshal mould after cooling.

4. Curing Specimen in Water Bath

The sample specimen, after cooling at room temperature is extracted from mould. The sample is then weighed and placed in water bath for 30 minutes at 60°C. Constant temperature should be maintained for entire duration of 30 min as the weakest condition for bitumen is achieved by keeping and maintaining 60°C temperatures in water bath.

5. Testing in Marshall Apparatus

The sample is then placed in Marshall testing machine. The stability is measured in terms of strength and resistance to plastic deformation of cylindrical specimen is measured in mm on dial gauge when it is loaded at rate of 5 cm per min.

RESULTS

On basis of Marshall Stability and flow value the suitability of mix for paving is decided, but some other parameters like bulk density of mix, percent air voids and voids in mineral aggregates are important to take in to consideration durability criteria. Therefore proper record of data is needed during testing of sample for calculation of these important parameters.

By using result obtained for the two different types of mixes, namely control mix and modified mix, the graph of bitumen content verses stability is plotted as shown in fig.1. The bitumen content at maximum stability is taken as optimum bitumen content. It is presented in graphical form as shown in fig below. From graph it is observed that at 10% e-waste and 5.5% bitumen content maximum stability is achieved. The stability at 5% and 15% e-waste content and 5.5% bitumen content is near about same, which is 20.37 for 5% e-waste and 20.86 for 15% e-waste. As e-waste percentage increases stability also increases and latter goes on decreasing. The behavior of flexible pavement is as shown in fig.1. It is noted that at 5.5% bitumen content and 10% aggregate replacement by e-waste there is 11.28% increase in strength is achieved.
Fig. 1: Stability Vs bitumen content

Fig. 2: Flow vs. bitumen content
Fig. 3: Bulk density Vs bitumen content

Fig. 4: Percent air voids vs. Bitumen content
The flexibility or resistance to deformation is measured in terms of flow value. The graph of flow with varying bitumen content is plotted as shown in fig.2. It is noted that as bitumen content in mix increases the flow value also increases. Similar behaviour was obtained here with respect to flow value in case of modified mix with e-waste. From graph it is seen that as percentage of e-waste increases the flow value also increases. The flow values for reinforced mix are slightly higher than control mix because as percentage of e-waste increases the cohesive property of mix decreases. There are three volumetric parameter namely bulk density, percent air voids and percent voids in mineral aggregate, of which the graph for bulk density with respect to bitumen content are shown in fig.3.

In real practice the bulk density should be as high as possible. For bituminous concrete the bulk density should 2.4gm/cc. Here the average bulk density obtained is 2.405gm/cc for control mix. After the addition of e-waste it was observed that as percentage of e-waste increases the bulk density goes on decreasing. In this case the mix is optimum at 10% e-waste and 5.5% bitumen content. The bulk density of modified mix was decreased by 3.12%.

But in case of percent air voids and percent voids in mineral aggregate the test results vary and perfect zone of satisfaction is not achieved. The percent air voids for, all values of bitumen content and 10% e-waste replacement are above 4% because as quantity of reinforcing material increases the cohesive property as well as density of mix decreases. The voids in mineral aggregate are also lies in the permissible limits as per Ministry of Road Transport and Highway (MORTH)-2001. The performance of mix for percent air void and voids in mineral aggregate are as shown in fig.4 and fig.5.
Comparison of The Performance of Control and Modified Mixtures

In order to compare both the control and modified mixes, 12 samples of the control mix were prepared by using Marshall mixing procedure. The samples were prepared by varying bitumen content of 4.5%, 5.0%, 5.5%, and 6.0%. The samples were tested and it was found that at 5.5% bitumen content maximum stability is achieved. Additional 36 samples of the modified mixtures having e-waste were prepared. The prepared samples were subjected to Marshall Stability and it was observed that as e-waste increases the stability also increases up to 10% aggregate replacement by e-waste at 5.5% bitumen content. The comparison of variation of stability of modified mix and control mix is shown in table 3.

Fly Ash as Filler Replacement

The combined effect of e-waste and fly ash on paving mixes is also studied (fig.6). The maximum stability was achieved at 10% e-waste and 5.5% bitumen content before addition of fly ash, so this proportion is kept constant and fly ash was added by varying percentage.

Table 3: Comparison of stability

<table>
<thead>
<tr>
<th>Sr. no.</th>
<th>Bitumen content (%)</th>
<th>Percentage increase in stability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5% e-waste</td>
</tr>
<tr>
<td>1</td>
<td>4.5</td>
<td>-2.04</td>
</tr>
<tr>
<td>2</td>
<td>5.0</td>
<td>8.26</td>
</tr>
<tr>
<td>3</td>
<td>5.5</td>
<td>2.35</td>
</tr>
<tr>
<td>4</td>
<td>6.0</td>
<td>-2.28</td>
</tr>
</tbody>
</table>
Fig. 6: Comparison of control mix and fly ash mix.

It was observed that at 15% fly ash content the stability was maximum. But if we compare this stability with control mix the minimum was 14.78%. Also if we compare other parameters like bulk density, %air voids, %voids in mineral aggregate etc, test parameters are going out of the range and a common zone of satisfaction is not achieved for this modified mix. Hence use of fly ash along with e-waste is not technically feasible.

COST BENEFITS AND MARTIAL SAVING

From the point of view of economics, the aim is to minimize the cost of material, which can be achieved as follow:

Material Saving

Aggregate: We replaced e-waste by volume, from results it was observed that 10% aggregate replaced by Volume @ 5.5% bitumen content, attained maximum stability. i.e. 10% aggregate by total volume can be saved.

Bitumen: For 10% e-waste content & 5.5% bitumen content:

<table>
<thead>
<tr>
<th>a. Control mix: Material required</th>
<th>b. Modified mix: Material required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt. of aggregate/sample = 3000g</td>
<td>Volume of 10% e-waste =133 cc</td>
</tr>
<tr>
<td>Wt. of bitumen/sample = 165 g</td>
<td>Wt of 133cc e-waste =82 g</td>
</tr>
</tbody>
</table>
Wt of 133cc aggregate = 242 g
Wt of sample = 2840 g
5.5% bitumen by wt = 156.2 g
% saving in bitumen = 5.33%

On an average there is 10 percent aggregate and 5.33 percent bitumen saving is achieved.

CONCLUSIONS

Filler replacement with e-waste can improve the Marshall stability of modified mix. This is a cost effective option as it results in to considerable saving of bitumen as well as aggregates. The test results shows that at 5.5 percent bitumen content and 10 percent e-waste as filler replacement attains maximum strength, which is approximately 11 percent more than control mix. The density of modified mix is 2 percent lower than control mix.

The following conclusions are drawn regarding the use of e-waste and fly ash in bituminous concrete:

1. Experimental results proved that partial replacement of aggregates by e-waste is technically feasible; at 10% e-waste and 5.5% bitumen content, which attains 11.28 % higher stability than control mix.
2. The use of e-waste saves bitumen consumption by 5.33% and 10% aggregate by total volume.
3. The bituminous concrete mix having 10% e-waste was found to be the optimal mix.
4. The fly ash along with e waste as filler replacement cannot improve strength; it is found that 14.78% decrease in stability is seen as compared with control mix.

The use of e-waste in road construction will serve two purposes: firstly it will reduce the construction cost and secondly it will contribute towards an efficient waste management of this undesirable material.

REFERENCES

