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# UTILIZATION OF BAGASSE ASH FOR SERVICEABILITY ENHANCEMENT OF BITUMINOUS PAVEMENTS

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***Abstract-*** The serviceability of bituminous pavements can be enhanced by controlling the amount of deterioration. The filler of bituminous concrete has a vital role in reducing its deterioration. Stone dust is one of the materials that are commonly utilized as a filler in bituminous pavements. Numerous researches are carried out to replace the stone dust with suitable material. Sugarcane bagasse ash (SBA) can be used as a filler because of its low thermal conductivity compared to stone dust. Therefore, the overall aim of the research work is to select the best appropriate filler material for the serviceability improvement of bituminous pavements. The specific aim is to investigate sugarcane bagasse ash as a filler for reducing the degree of degradation in bituminous concrete. The rutting depth of the bituminous concrete incorporating SBA as a filler is evaluated. Various tests, i.e., softening point, grade penetration, flash and fire point, and wheel tracking test, are performed. AASHTO standards are followed to perform the tests. For the wheel tracking test, the percentage of coarse aggregates, SBA, and asphalt of grade 60/70 is 90.70%, 5%, and 4.30%, respectively. While two other samples with the same ratio instead that SBA is replaced with stone dust in the same amount are also prepared for comparison. It is concluded that replacing stone dust with SBA as a filler decreased the rutting depth of bituminous concrete. Based on the research results, the serviceability of bituminous pavements is expected to be enhanced by replacing the stone dust with sugarcane bagasse ash.

***Keywords-*** Bituminous pavements, Serviceability, Deterioration, Sugarcane bagasse ash as a filler.

## 1 Introduction

The serviceability of the bituminous pavements is considerably related to the rate of deterioration. Therefore, the rise in the rate of deterioration is a serious issue, which needs special attention. One of the main factors that increase the deterioration is the increasing rate of rutting in bituminous pavements. Causes of the rutting include an upsurge in heat conductance of asphalt. Deteriorated bituminous pavements result in various damages like wear and tear of the tires and reduce the road's load-carrying ability. Furthermore, it might not be possible to drain out the rainwater from rutting deteriorated bituminous pavements [1,2].

The adhesion and cohesion of the bituminous mix were improved by adding the filler [3]. The filler upgrades the resistance of bitumen to water entrance due to its chemical affinity to asphalt mix [4,5]. The durability and serviceability of the bituminous mixtures are substantially related to filler type [6,7]. Sugarcane bagasse ash (SBA) is discarded out of factories and worthy terrains nearby that mills are used for dumping SBA, giving rise to several geo-environmental issues [8]. As sugarcane bagasse ash has pozzolanic and binder properties, it could enhance the engineering properties of soil and concrete [9,10]. Besides, the thermal conductance of the sugarcane bagasse ash (i.e., 0.046 W/mK) is much tiny as compared to that of stone dust (i.e., 1.7 W/mK) [11].

The rate of deterioration can be decreased by incorporating sugarcane bagasse ash (SBA) in bituminous pavements. The sugarcane bagasse ash is unique among the available types of fillers because of its cementitious properties and low-cost raw material. Therefore, the general aim is to evaluate the efficiencies of available fillers for serviceability upgrading of bituminous pavements. In this paper, the role of sugarcane bagasse ash as a filler for minimizing the deterioration of bituminous concrete is investigated in terms of the rate of rutting. Thus, the current study can help explore the effectiveness of the sugarcane bagasse ash as a filler.

# 2 Test procedures and specimens casting

## *2.1 Materials, mix design, and casting procedure*

To obtain bitumen and bituminous concrete, the Durrani asphalt plant Nowshera, Khyber Pakhtunkhwa, Pakistan, is selected as a source. Gadoon Amazai Industrial Estate, located in district Swabi, Khyber Pakhtunkhwa, Pakistan, is chosen as an examination area with an average annual air temperature between 7 $^{o}$C to 24 $^{o}$C. The sugar mills are the best option for collecting sugarcane bagasse ash (SBA), where a considerable amount of sugarcane bagasse is used to run the boiler [12]. Therefore, SBA from the Khazana sugar mill (KSM) Peshawar, Khyber Pakhtunkhwa, Pakistan, is used in the current study. From the sugar mill, about 15 Kg SBA is collected in bags, and then to remove the dust and other impurities, it is passed through sieve No 200. To avoid moisture interference, SBA is stored in a dry place. Bitumen of grade 60/70 is used. For the wheel tracking test, four samples are cast. BC1 and BC2 are prepared by mixing the bitumen, aggregates, and sugarcane bagasse ash (SBA) in percentages of 4.30%, 90.70%, and 5%, respectively. While samples of BC3 and BC4 having the same ratio with 5% of stone dust at the place of SBA are also prepared. The samples are prepared according to AASHTO R-30 [13]. The aggregates are mixed with bitumen at 120 $^{o}$C.

## *2.2 Testing procedure and specimens*.

All tests are made following AASHTO standards. The grade penetration test is performed according to AASHTO M-208 [14]. The entire procedure for the grade penetration test is according to AASHTO M-208, except the depth of bitumen is kept 10 mm more than the expected depth of bitumen. As per the requirements of the AASHTO M-208, the test is repeated for three samples. The consistency of bitumen is determined by using softening point of bitumen. The softening point of bitumen is carried out according to AASHTO M-81, and M-82 and tests are repeated for two specimens [15].

*Figure 1. (a) Sample for wheel tracking test before placing (b) after placing in the wheel tracking test apparatus*

AASHTO M-20 is used to conduct flash and fire point tests for finding the temperature at which a flash will appear at the bitumen surface, and then it takes fire [16]. The rutting depth of bituminous concrete is determined by using the wheel tracking test. The maximum reduction in-depth (depression) caused by repeated passes of a loaded wheel at any location on specimen along wheel track is taken as the rutting depth [17]. Four samples (two of SBA and two stone dust) are cast for a wheel tracking test. The separate sample and pair of samples after placing in the wheel tracking test apparatus are shown in Figure 1.

# 3 EXPERIMENTAL RESULTS AND ANALYSIS.

## *3.1 Grade penetration test*

This test is utilized to determine the penetration grade of asphalt, which is helpful to select bitumen of appropriate grade keeping in mind the climate condition of the project area. According to AASHTO M-208, the temperature-wise distribution of bitumen penetration grade is recorded in Table 1.

*Table 1. Temperature-wise distribution of bitumen penetration grade*

| Serial No. (1) | Average Annual Temperature of air (2) | Penetration grade of bitumen (3) |
|---|---|---|
| 1 | Equal to or less than 7 °C, cold | 80/100 grade |
| 2 | 7 to 24 °C, Medium | 60/70 grade |
| 3 | More than 24 °C, hot | 40/50 grade |

Since the test area is Gadoon industrial estate with an average annual air temperature between 7 °C to 24 °C, bitumen of grade 60/70 is right to use in the above site area.

The outcomes of the grade penetration test are given in Table 2. The penetrations for the tested samples of bitumen in the 10th of mm are 67, 65, and 70. Therefore, the average penetration depth for the tested three samples is 67.33. This complies with the range (i.e., 60 to 70) for grade 60-70 bitumen. Therefore, as per the test results, the grade of the selected bitumen is 60/70.

*Table 2. Results of the grade penetration test*

| Details | Actual | AASHTO M-208 | |
|---|---|---|---|
| Bitumen pouring temp (°C) | 90 | 90 | 90 |
| Cooling room temp (°C) | 26 | 0.06 | 0.06 |
| Water temp (°C) | 24.9 | 24 - 26 | 24 - 26 |
| Loads in gm | 100 | 100 | 100 |
| Time duration in seconds | 5 | 5 | 5 |
| Penetration (10th of mm) | Sample 1<br>67 | Sample 2<br>65 | Sample 3<br>70 |
| Average Penetration (mm/10) | 67.33 | | |
| Bitumen Grade | 60 - 70 | | |

## *3.2 The softening point of bitumen*

The softening point of sample 1 and sample 2 is carried out. The average softening point for the tested bitumen is noted at 48.5 °C. This complies with the specifications of AASHTO for bitumen of grade 60/70, i.e., 47 °C to 54 °C. This proves that the selected bitumen is suitable to be used in pavements.

## *3.3 Flash and fire point test*

The results of flash and fire point tests are shown in Table 4. The flash and fire points for the tested bitumen are 232 °C and 415 °C, respectively. The flash and fire points specified by AASHTO M-20 for grades 60-70 are 232.22 ºC and 416 ºC, respectively. The deviations of flash and fire points of tested bitumen from that specified by AASHTO M-20 are within the allowable ranges. This shows the suitability of the selected bitumen for pavements.

*Table 3. Results of flash and fire point test*

| Details | Actual | AASHTO M-20 |
|---|---|---|
| Flash point (ºC) | 232 | 232 |
| Fire point (ºC) | 415 | 416 |

### *3.4 Wheel tracking test*

The wheel tracking test is performed to check the suitability of replacing of filler of the stone dust with sugarcane bagasse ash (SBA). So, the samples of both SBA and stone dust are prepared and tested for rutting. The rutting depths of the tested samples for the wheel passes of 15000 and 20000 are outlined in Table 4. The rutting depths of 12 mm and 15 mm are noticed for BC1 and BC2, respectively. Whereas for BC3 and BC4, the rutting depths of 16 mm and 20 mm are noted.

*Table 4. Rutting depth*

| Samples | No. of Passes (Nos) | Rutting Depth (mm) |
|---|---|---|
| With Bagasse ash | ------ | ------ |
| BC1 | 15000 | 12 |
| BC2 | 20000 | 15 |
| With Stone dust | ------ | ------- |
| BC3 | 15000 | 16 |
| BC4 | 20000 | 20 |

The highest rutting depth of 20 mm is noticed for the stone dust specimen BC4 for 20000 passes. This is 5 mm greater than that of the BC2 sample of bituminous concrete with SBA as a filler for the same number of passes. For each number of passes, the rutting depth of each bituminous concrete sample having SBA as a filler is less than the samples possess stone dust as a filler. The average rutting depth of the samples with SBA as a filler is 13.5 mm, whereas that of the specimens incorporating stone dust as a filler is 18 mm. The mean rutting depth for the SBA samples as a filler is 4.5 mm lower than bituminous concrete samples incorporating stone dust. This could be because of the bagasse ash's cementitious nature, which decreases the conductance of the heat by a strong packing effect among the particles.

Figure 2 displays the percentage comparison of the rutting depth of both types of examined samples. On the contrary to the rutting depth of samples containing stone dust, the rutting depths of sugarcane bagasse ash samples are 25% less for the similar wheel passes of 15000 and 20000, respectively. In each case, the rutting gets decreased for the SBA sample than the stone dust samples in the significant amount.

The bituminous concrete specimens which possess SBA as a filler outperformed their companions with stone dust to reduce the rutting depth. The cementitious composition of materials helped improve the bond strength among the neighbouring materials in the same mix. So, the decreased rutting depth of SBA samples might be attributable to the cementitious nature of sugarcane bagasse ash by enhancing the bond strength. SBA increased resistance to the passage of heat transfer from one part to another of the bituminous concrete sample by its binding effect, and thus the rutting did go to more depth. This ensured that sugarcane bagasse ash could be utilized usefully as a filler for bituminous pavements compared to the stone dust for serviceability enhancement by controlling the rate of deterioration.

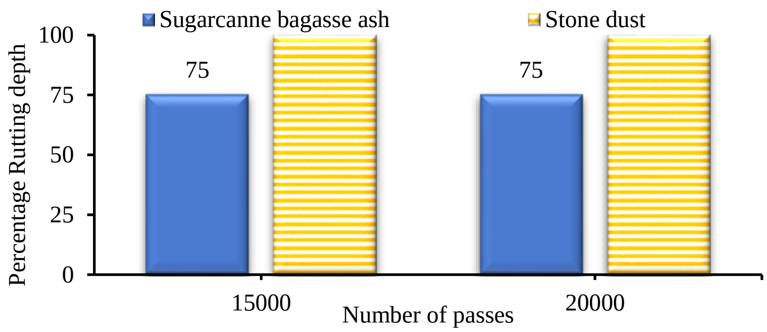


*Figure 2. Comparison of rutting depth of sugarcane bagasse ash*

## 4 DISCUSSIONS

The serviceability of bituminous pavements intensely relies on filler materials' characteristics, reliability, and chemical bond [5]. Various types of filler materials are accessible nowadays. As a filler, stone dust is the most commonly used material in bituminous pavements. Similar to fine aggregates (sand), stone dust possesses small cementitious properties [18]. Because of this tendency, the chemical bonding of stone dust with surrounding aggregates in the bituminous concrete needs to be enhanced. This will help to make bituminous concrete more compelling in opposing abrasion triggered by the movement of various types of traffic. Hence, it is needed to utilize such filler to make a solid bond with the aggregates. Therefore, it is crucial to explore the efficiency of filler materials for the serviceability improvement of bituminous pavements. Sugarcane bagasse ash with cementitious properties [19, 20] might be useful in this regard.

Thus, initial research is aimed to examine the rutting depth of bituminous concrete incorporating sugarcane bagasse ash as a filler for the enhanced serviceability of bituminous pavements. It is deduced that bituminous concrete specimens that possess sugarcane bagasse ash as a filler outdone the samples of bituminous concrete comprising stone dust to decrease rutting depth. Accordingly, the deterioration of the bituminous pavements can be less in sugarcane bagasse ash samples; convincingly, it is highly expectable to upsurge the serviceability of bituminous pavements.

## 5 CONCLUSIONS AND RECOMMENDATIONS

Sugarcane bagasse ash and stone dust are investigated as a filler for the possible use in improving the serviceability of bituminous pavements by reducing the amount of deterioration. Following conclusions are made from this research work:

- The average rutting depth of 13.5 mm and 18 mm is noted for the bituminous concrete samples of sugarcane bagasse ash and stone dust, respectively.
- By comparing the rutting depths of stone dust samples and sugarcane bagasse ash samples, the rutting depth for the stone dust is 25% lesser for the similar number of wheel passes of 15000 and 20000, respectively.

Based on the experimental outcomes, sugarcane bagasse ash as a filler is likely to be more advantageous in improving the serviceability of bituminous pavements by reducing the deterioration in terms of reduced rutting depth. Therefore, it is recommended to evaluate other types of filler materials for the serviceability enhancement of bituminous pavements.

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