Predicting Performance of Bituminous Mixes by Using Coconut Fibers

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Abstract

Usually the top layers of roads are failed with the change in temperature. Normally, the temperature of top surface of flexible pavement in Bangladesh varies from 35^0C to 45^0C. Due to higher temperature variations, different types of cracks are occurred in the top layer of the flexible pavement. There are different methods that can be adopted to protect the road against failure. Waste coconut fibers may behaves against protection of such types of cracks, which are available in Bangladesh. These types of fibers are low cost and most important additives of bitumen for road constructions. The aim of this study is to know the variations of softening point, penetration value, ductility and Marshall Stability of bitumen by mixing different lengths (8mm, 10mm, and 12mm) of coconut fibers with different percentages (1.5%, 1.75%, 2.0%, 2.25%, 2.5%) of optimum bitumen content. When percentage of coconut fiber is 2%, Marshall Stability, softening point, penetration value and ductility show better performance. On the other hand, penetration and ductility show better performance when length of coconut fiber is 12mm. Similarly, Marshall Stability and softening point represent acceptable result at length of coconut fiber of 8mm.

Keywords: *Ductility; Marshall Stability; Penetration value; Softening point; Waste coconut fibers.*

1. Introduction

Sometimes roads are failed by plastic deformation with the sudden variation of temperature. Mixing additives with bitumen are one of the methods to protect the roads against failure. Waste coconut fibers as a mixing additive with bitumen are available in the environment in Bangladesh. Previous researches have expressed the characteristics of coconut fiber and bituminous mixer. Asphalt obtained from refineries is too soft for paving in high-temperature areas in the summer and too brittle for subzero temperatures in winter in various parts of the country (Attaelmanan *et al*., 2011). Damage to highways mostly occurs in the top layer, in the binder and erosion layers, rather than the foundation and lower layers (Hadiwardoyo, 2013). Damage to the binder and erosion layers generally includes surface cracks, deformations, wheel ruts, and potholes (Ozgan, 2011). Damage to roads in Indonesia is caused by environmental factors such as overloading and construction (Hadiwardoyo, 2013). Environmental factors such as rainfall and change in road surface temperature are often difficult to predict (Hadiwardoyo and Fikri, 2013). Standard-sized coconut fibers have been utilized in the coir industry, but short waste fibers have not yet been utilized (Hadiwardoyo, 2013). A study conducted by Oda *et al*.,

(2012) showed that, the addition of coconut coir fiber increased the resilient modulus by approximately 14%. The coconut is comprised of several parts including exocarp which is a very thin layer covering the fibrous mesocarp (Hadiwardoyo, 2013). Their use as a construction material to improve the properties of the composites costs very little when compared to the total cost of the composites (Ali *et al*., 2012). Efforts to improve the performance of asphalt by the addition of natural materials are expected to reduce the ever-increasing need for asphalt as a road construction material (Hadiwardoyo, 2013). Aggregate and binder from old asphalt pavement retain their value even after these pavements have reached the end of their service lives (Xiao, 2009). At high temperatures, the asphalt binder tends to flow more easily due to the natural decrease in viscosity associated with higher temperatures. This condition creates a "softer" asphalt mixture, which is prone to rutting (Fontes *et al.*, 2010). After mixing coconut fibers with bitumen, some changes occurred. In most cases, ductility decreases and softening point increases. Ductility and softening point are most important parameters for construction of road pavements. So, it is most important to evaluate the ductility and softening point for exclusive construction of roads. Therefore, the aim of this study is to evaluate the properties of bitumen in some laboratory tests by mixing waste coconut fibers with bitumen.

2. Materials

Three types of aggregates are used in this study. Aggregates are 696 gm of coarse, 456 gm of fine and 48 gm of mineral filler. Bitumen is used in this experiment of 80/100 grade. Optimum bitumen content has been found to be 4.85%. Waste coconut fibers are using as additives with bitumen. Smooth waste coconut fibers are used for better performance. Different percentage of coconut fibers are taken for a fixed length. These lengths are 8mm, 10mm and 12mm and percentages are 1.5%, 1.75%, 2.0%, 2.25% and 2.50% of optimum bitumen content. Some main components of materials are shown in Figure 1.

(i) ordinary sand (ii) stone chips (iii) 80/100 grade bitumen (iv) short coconut fibers

Figure 1: Various types of aggregates, bitumen and additives (coconut fibers)

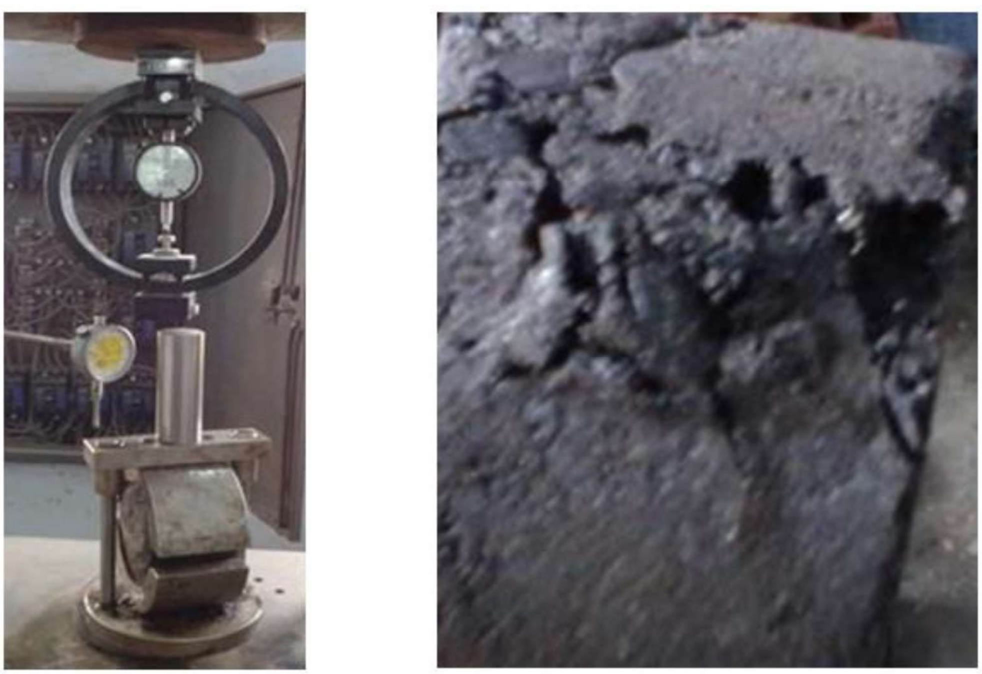
Physical properties of bitumen are influenced on the overall performance of mixer (bitumen and additives). Such types of properties are shown in Table 1.

Table 1: Physical properties of bitumen

Properties of Materials	Standard Values
Penetration grade	80/100
Penetration (25^0C, 100 gm, 5s)	89
Specific gravity	1.02
Softening point (^{0}C)	48.5
Flash point (^{0}C)	290
Ductility (25^0C, 5cm/min.)	106

3. Methodology

Penetration test was performed in the laboratory for pure bitumen. The penetration value of pure bitumen was found to be 89 which was within the standard range of 80/100 grade bitumen. Different length coconut fibers were mixed with different percentages of bitumen in that case penetration value was decreased. Softening point for pure bitumen was found to be 48.5^0C. When coconut fibers were mixed with bitumen, the softening point was increased. Ductility was found to be 100+ for bitumen. When additives were mixed with bitumen, ductility value was decreased. Finally, Marshall Stability test was conducted. During this test, all specimens were heated within 60^0C temperature up to 30 min and were placed in the testing machine. When load carrying capacity exceeded from its maximum value, the specimen was cracked and it was lost its original shape. Positive results were found for Marshall Stability when coconut fibers were mixed with pure bitumen. Marshall Stability testing procedure is shown in Figure 2.



during test　　　　after test

Figure 2: Marshall Stability test procedure and specimen.

4. Results and Discussions

Penetration value, softening point, Marshall Stability and ductility vary with the variations of percentage of coconut fibers because percentages of coconut fibers are the function of optimum bitumen content. Also, lengths of waste coconut fibers effect on the variations of penetration, softening point, Marshall Stability and ductility.

Penetration values are decreasing with the increment of percentage of coconut fiber contents and it increase with the increment of length of fiber contents. These variations are represented by the Figure 3. At first, softening point increases with the increment of fiber contents and lengths of fibers and its decreases after crossing a certain value. Figure 4 represents these variations.

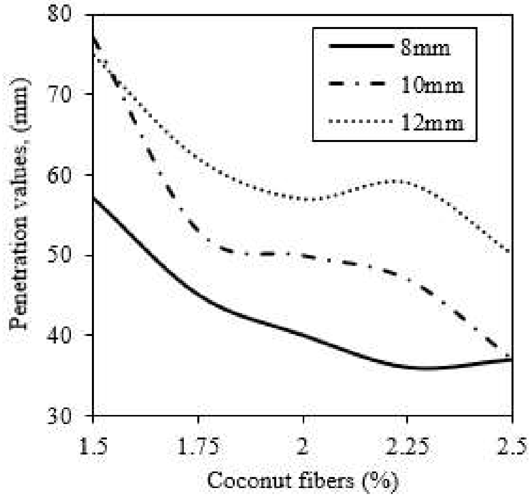


Figure 3: Variations of penetration values with the various percentages and lengths of waste coconut fibers

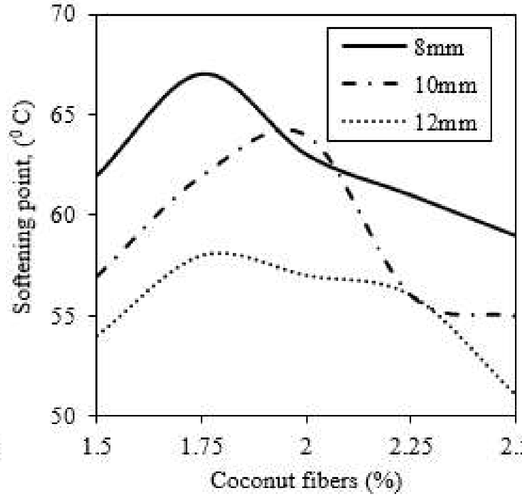


Figure 4: Variations of softening points with the various percentages and lengths of waste coconut fibers

Minimum penetration value is 36mm at 2.3 percent waste coconut fiber and at a length of 8mm. Maximum penetration value is found to be 78mm at 1.5 percent coconut fiber and at a length of 10mm. Difference of penetration values among 8mm, 10mm and 12mm are nearly close at 2 percent waste coconut fiber. This common difference is 7mm. Maximum difference has been found to be 16mm between 10mm and 12mm lengths of fiber and at a percentage of 2.25. Maximum softening point is 67^0C at 1.8 percent fiber and at a length of 8mm. Minimum value of softening point is 52^0C at 2.5 percent of fiber and at a length of 12mm. Maximum difference of softening point between 10mm and 12mm lengths of coconut fiber is 17^0C at 2 percent fiber content.

Ductility decreases gradually with the increment of waste coconut fiber and it also decreases with the increment of length of fiber. Firstly, Marshall Stability increases with the increment of coconut fiber and it decreases after a crossing a certain percentage of waste coconut fiber. Marshall Stability decreases with the increment of length of waste coconut fiber. Figure 5 and Figure 6 represent the variations of ductility and Marshall Stability for various percentage and lengths of waste coconut fiber.

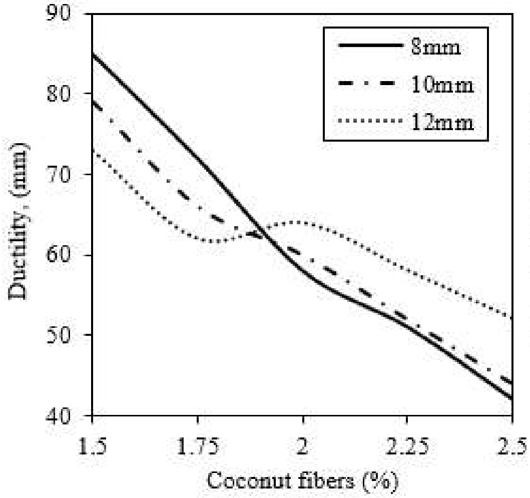


Figure 5: Variations of ductility with the various percentages and lengths of waste coconut fibers

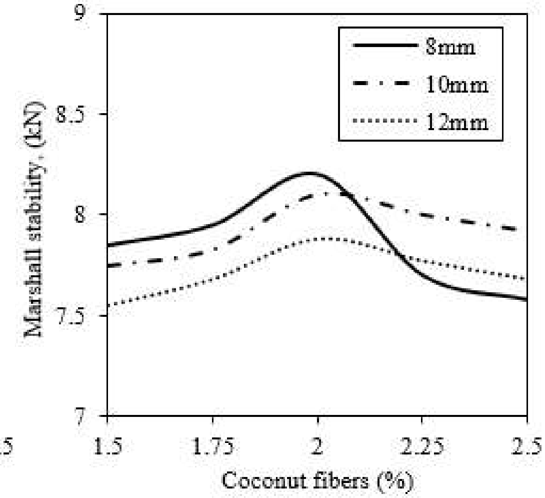


Figure 6: Variations of Marshall Stability with the various percentages and lengths of waste coconut fibers

The value of ductility is nearly close at 1.85 percent fiber content for various lengths of waste coconut fiber. This value is 63mm. Ductility difference is maximum between 10mm and 12mm lengths of coconut fiber. This difference obtains at 2 percent fiber content and its value is 3mm. When the length of coconut fiber is 12mm, the value of ductility is fluctuating. Maximum and minimum value of ductility are 85mm and 42mm at 1.5 and 2.5 percentage of fiber content and at a length of 8mm. Marshall Stability represents maximum value at 2 percentage coconut fiber for various lengths of fiber. This maximum value is 8.2 kN at 8mm length of coconut fiber. Minimum value of Marshall Stability is 7.6 kN at 2.5 percent fiber content and at a length of 8mm.

5. Conclusions

In this study, various percentages and lengths of coconut fibers are used. Penetration, softening point, ductility and Marshall Stability influence to the performance of road pavement. Higher penetration value, softening point, ductility and Marshall Stability represent stable condition of pavement against failures.

- Maximum difference between two (10mm and 12mm) various lengths of waste coconut fiber shows for penetration and ductility. Higher length of waste coconut fiber influences failure resistance capacity of pavement and its resists crack control of pavement.
- Maximum value of softening point (67^0C) and Marshall Stability (8.2 kN) at 8mm length of coconut fiber represent stability and longevity of pavement.
- Two percent waste coconut fiber represents similar difference of penetration values among various lengths of fiber, maximum difference of softening point between 10mm and 12mm length of fiber, maximum difference of ductility between 10mm and 12mm length of fiber and maximum value of Marshall Stability at 8mm length of fiber. Such type of criteria of two percent coconut fiber expresses stability of pavement.

- Coconut fibers influence the structural mechanism of pavement. Based on this research, 8mm, 12mm and 2% coconut fiber show better performance which may indicates protection against failure of pavement.

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