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Use of Non-Conventional Fillers on Asphalt-Concrete Mixture

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ABSTRACT: Stone dust and cement are usually used as filler in asphalt-concrete mixture in Bangladesh. This study has made to prepare asphalt-concrete mixtures using non-conventional fillers which are locally available. Bangladesh is a developing country, where cost is the main concern for any type of constructions. From this point of view, the prime aim of this investigation has been set out to examine the effect of non-conventional filler such as non-plastic sand, brick dust and ash as a filler replacement on the performance of asphalt-concrete mixture and to compare the characteristics of asphalt-concrete mixtures with conventional ones according to the test procedure specified by AASHTO. From the experimental data, it is observed that the value of Marshall Stability is comparatively higher by using non-plastic sand than other non-conventional filler materials. It is also observed that brick dust and ash requires higher asphalt content because of their higher absorption capabilities. The retained strength of the asphalt-concrete mixture using non-plastic sand, brick chips and ash are approximately 89%, 87% and 84% respectively which satisfies the limiting value 75%. Based on this experimental program, it is verified that inclusion of non-conventional filler can be efficiently used in asphalt-concrete mixture as a filler replacement from the viewpoint of stability, deformation and voids characteristics.

KEYWORDS: Asphalt-Concrete mixture, deformation, non-conventional filler, stability, retained strength.

1 INTRODUCTION

Asphalt concrete is a mixture of binder, aggregate and air in different relative amount that set up the substantial properties of the mix. The superiority and stability of asphalt mixtures are influenced by several features together with gradation of aggregates and type and amount of filler materials. Filler acts as one of the major constituents in asphalt-concrete mixture. Fillers not only fill voids in the coarse and fine aggregates but also affect the aging characteristics of the mix. Generally, the aggregate materials those are finer than 75 µm in size is referred to as filler. Filler is defined as consisting of finely divided mineral matter, such as rock dust, slag dust, hydrated lime, hydraulic binder, fly ash, loess, or other suitable mineral matter [1]. In an asphalt-concrete mixture the filler, whether artificial or natural, may stiffen the asphalt-concrete, extend the asphalt cement and affect the workability and compaction characteristics of the mix [2]. Filler imparts a considerable importance on the properties of asphalt-concrete mixture. The amount of filler influences the optimum asphalt content [3]. The workability during the operation of mixing and compaction of asphalt-concrete mixture a consequential property of asphalt-filler mastic also affected by filler materials [4]. The addition of mineral filler increases the resilient modulus of an asphalt-concrete mixture [5]. On the other hand, a disproportionate amount of filler may weaken the mixture by raising the amount of asphalt [6].

Different types and quantity of filler have an effect on the performance of asphalt-concrete mixture [7]. Filler provides better resistance to micro cracking so that it can increase the fatigue life of asphalt-concrete mixture [8]. Structural characteristics of asphalt-concrete mixture are improved by using hydrated lime and phosphogvypsum as filler material [9]. Significant improvement in fatigue life of the asphalt-concrete mixtures can be obtained by using fly ash from oil shale [10]. Waste cement dust as filler on the asphalt-concrete mixture enhances the mechanical properties of the mix, and the laboratory results indicate that the cement dust can totally replace limestone powder in the asphalt paving mixture [11].

Four types of industrial by-product wastes filler namely, limestone as reference filler, ceramic waste dust, coal fly ash, and steel slag dust increases the stiffness and fatigue life of Stone Mastic Asphalt (SMA) Mixtures [12]. Hydrated lime is more effective in stiffening binders than limestone fillers [8]. The temperature susceptibility and durability of the asphalt binder and asphalt-concrete mixture can be improved by using filler materials ([13]-[14]). Using fly ash as filler on asphalt-concrete mixture provides better resistance against low temperature cracking and fatigue cracking [15]. Various conventional materials such as cement, lime, granite powder are normally used as filler in asphalt-concrete mixtures in Bangladesh. Cement, lime and granite powder are expensive and are used for other purposes more effectively. With the economic point of view, the present investigation has been taken in order to study the performance of asphalt-concrete mixtures with non-conventional filler such as, non-plastic sand, brick dust and ash and to compare with the conventional filler materials.

2 Materials and Methods

In this study the asphalt-concrete mixture composed of aggregates and binder. Aggregates are divided into three categories namely, coarse aggregate, fine aggregate and filler according to their individual size. Aggregates have to bear load stresses occurring on the roads and have to defend against wear due to the abrasive action of traffic. Binder content in mix ensure proper bond together with durable pavement under suitable compaction. Thus the properties of mineral aggregates and binder are of considerable impact of proper asphalt-concrete mix design.

2.1 Coarse Aggregate and Fine Aggregate

In the laboratory test program, crushed stone chips which are smaller than 25 mm and larger than 2.36 mm in size were regarded as coarse aggregate and the coarser sand smaller than 2.36 mm and larger than 75 µm in size were used as fine aggregate [16]. The coarse aggregate and fine aggregate were collected from Panchagarh, Bangladesh and Padma River, Rajshahi, Bangladesh respectively. Properties of coarse aggregate and fine aggregate are shown in Table 1 which were determined according to the test procedures specified by AASHTO.

Table 1. Properties of coarse aggregate and fine aggregate

Properties	Coarse aggregate	Fine aggregate
Dense unit wt. (Kg/m^3)	1670	1570
Loose unit wt. (Kg/m^3)	1535	1440
Bulk specific gravity	2.846	2.461
Apparent specific gravity	2.949	2.637
Water absorption, %	0.9	2.720
Loss angles abrasion value, %	12	…
Aggregate impact value, %	6	…
Aggregate crushing value, %	12	…

2.2 Filler

Three types of non-conventional filler, non-plastic sand, brick chips and ash which is finer than 75 µm in size are used in this investigation. The properties of this non-conventional filler along with two types of conventional filler stone dust and cement were ascertained according to the test procedure specified by AASHTO and test results are given in Table 2.

Table 2. Properties of mineral filler

Properties	Filler material				
	Stone dust	Cement	Non-plastic sand	Brick dust	Ash
Dense unit wt. (Kg/m^3)	1520	750	1200	1320	476
Loose unit wt. (Kg/m^3)	1270	1020	1000	1050	370
Apparent specific gravity	2.630	2.722	2.438	2.333	1.765

2.3 ASPHALT BINDER

Asphalt binder having a wide range of consistency from fluid to hard and brittle for flexible pavement construction. The asphalt was of 80/100 penetration grade asphalt cement used in this study which was purchased from local distributors. Properties of asphalt used in this investigation shown in Table 3 which were performed according to the procedures specified by the AASHTO.

Table 3. Properties asphalt binder

Test	AASHTO designation	Test value
Penetration, (1/10th mm)	T49	98
Specific gravity	T229	1.002
Ductility (cm)	T51	107.5
Solubility, %	T44	99.75
Softening point, ^{o}C	T53	46.5
Loss on heating, %	T47	1.8
Flash point, ^{o}C	T48	293

2.4 MIX TYPES AND AGGREGATE GRADATION

One of the main objectives of this research is to make a comparative study of the asphalt-concrete mixture with different types of filler material. Five types of mixture were studied and these were designated as A, B, C, D and E which contain stone dust, cement, non-plastic sand, brick dust and ash respectively. Coarse aggregate, fine aggregate and binder were remaining same for all types of mixture.

The changing the proportions of fine and coarse aggregates with the same nominal maximum aggregate size did not affect the permanent deformation significantly [8] and there is no significant difference between the rutting resistance of coarse and fine graded Super pave mixtures [6]. But it can be seen that the mix becomes finer for the given gradation size, the asphalt content increases [17]. On the other hand, excessively small maximum sizes of the particles cause instability and excessively large maximum size particles may result in poor workability and segregation [18]. The asphalt-concrete mixture with medium graded aggregate size provides better resistance to rutting than asphalt-concrete mixture with coarse graded aggregate size [19]. In the continuously graded asphalt mixture, the aggregate blend is designed to be evenly graded from coarse to fine so as to arrive at a dense mix with a controlled void content, hence producing a stable and durable paving. Aggregate gradation used in this study shown in Figure 1.

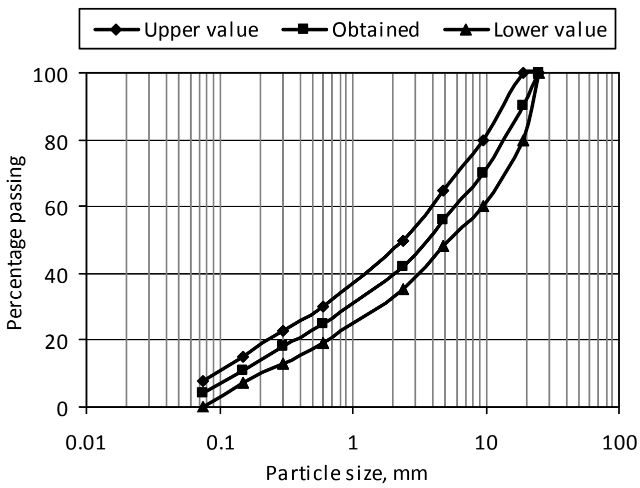

Fig. 1. Gradation of aggregate

2.5 DESIGN AND TESTS OF ASPHALT-CONCRETE MIXTURE USING MARSHALL TEST METHOD

In order to study the effect of different filler materials on asphalt-concrete mixture, specimen from Mix A, Mix B and Mix C, Mix D and Mix E were prepared with 5.0%, 5.5%, 6.0%, 6.5% and 7.0% Asphalt content (AC). Marshall test specimens were prepared using different types of mix separately according to the selected aggregate grading. Marshall test specimens of 101.6 mm diameter and 63.5 mm thick were prepared for medium traffic which requires 50 blows in each side of the specimens as per AASHTO T245-82 by varying asphalt content. The bulk specific gravity of compacted specimens was determined according to the test procedure specified by ASTM 2726. After determination of the bulk specific gravity, the specimens were then subjected to Marshall stability and flow test as per AASHTO T245-82. The cylindrical specimens were then compressed on the lateral surface at a constant rate of 2 in/min. (50.8 mm/min.) until the maximum load (failure) is reached. The load resistance and the corresponding flow value were recorded. Voids analysis was made for each series of test specimens after the completion of the stability and flow tests. Then the optimum Asphalt content (OAC) was determined according to the following Equation 1.

$$OAC = \frac{AC \text{ at maximum stability} + AC \text{ at maximum unit weight} + AC \text{ at } 4\% \text{ air voids}}{3} \quad (1)$$

3 TEST RESULTS AND DISCUSSION

3.1 VOLUMETRIC PROPERTIES OF THE MIXTURE

The type of mineral filler in an asphalt-concrete mixture significantly influences the volumetric properties [4]. To determine the effect of non-conventional filler materials on volumetric properties of the mixtures, the properties were investigated at different amount of asphalt content separately shown in Figures 2, 3, 4 and 5. The laboratory test result shows that the bulk density of the mixture with the inclusion of non-plastic sand gives higher value than other non-conventional fillers. On the other hand, the total voids in the mix (VTM) and voids in mineral aggregate (VMA) is higher when brick dust is used as filler in asphalt-concrete mixture. Using of ash in the asphalt-concrete mixture gives higher value of voids filled with asphalt (VFA).

Brick dust and ash has a relatively higher surface area so that they absorb more asphalt than non-plastic sand. Non-plastic sands gives higher bulk density but not so higher than conventional fillers. The value of VFA by using non-conventional filler remains within the range by using conventional fillers.

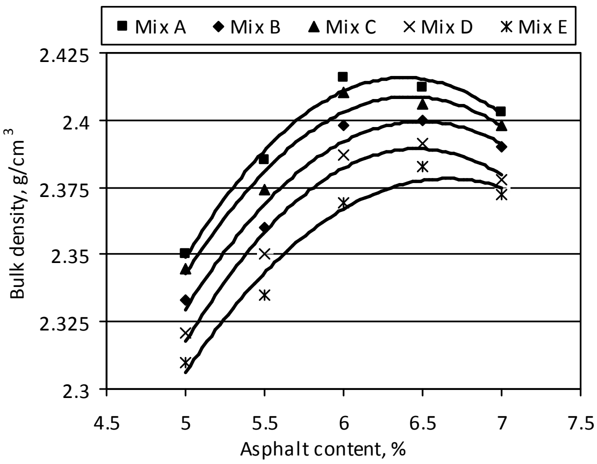

Fig. 2. Bulk density of asphalt-concrete with different filler materials

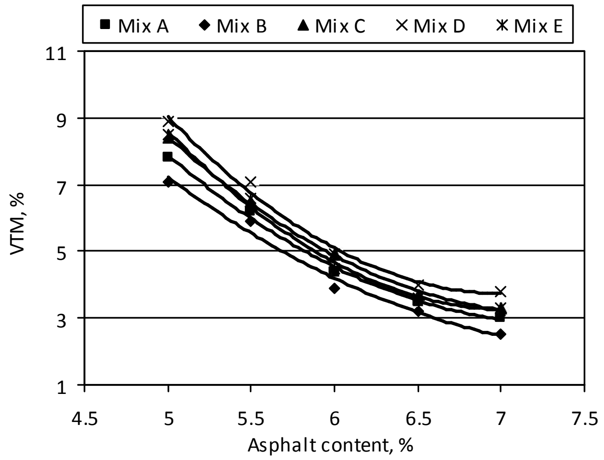

Fig. 3.   Voids in total mix of asphalt-concrete with different filler materials

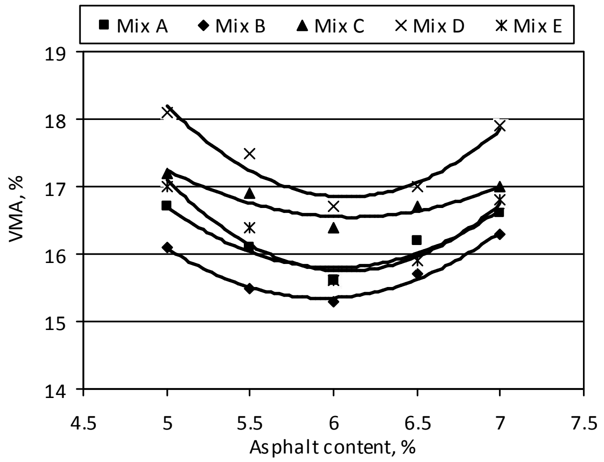

Fig. 4.   Voids in mineral aggregate of asphalt-concrete with different filler materials

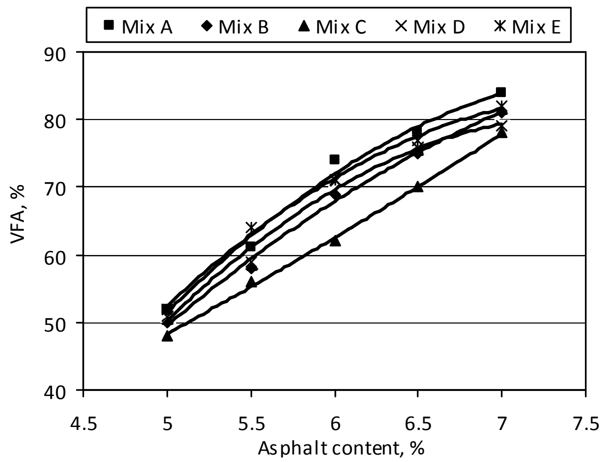

Fig. 5.   Voids filled with asphalt of asphalt-concrete with different filler materials

3.2 Marshall Stability and Flow Value

The use of non-conventional filler has immense influence on Marshall stability and flow value of the asphalt-concrete mixture which shown in Figure 6 and Figure 7. In the experimental program, non-plastic sand shows higher stability than brick dust and ash. But all types of non-conventional filler possess stability which is higher than the specific value recommended by the Asphalt Institute. It can be seen that the flow value of the asphalt-concrete mixture by using ash gives higher value than non-plastic sand and brick dust. The average flow value is approximately same as the cement dust by using brick dust in the asphalt-concrete mixture.

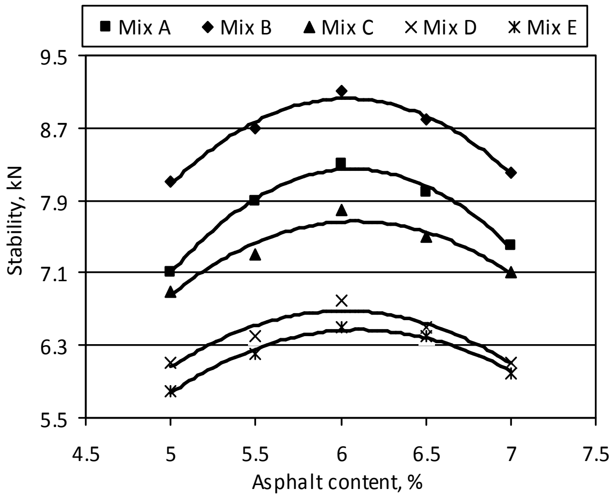

Fig. 6. Marshall stability of asphalt-concrete with different filler materials

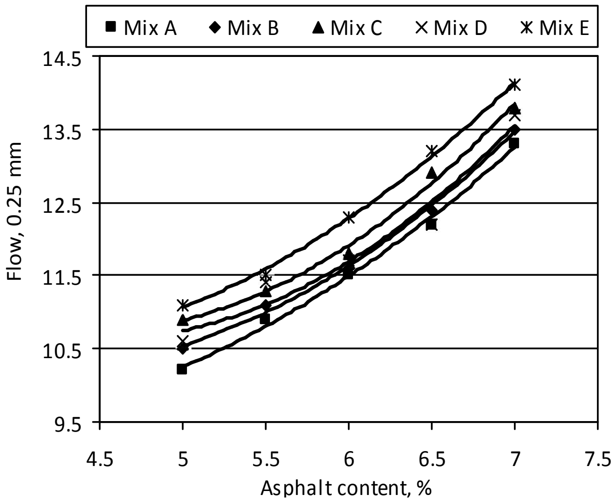

Fig. 7. Flow value of asphalt-concrete with different filler materials

3.3 Optimum Asphalt Content

Optimum asphalt content is appreciably affected by the mineral aggregates, binder and mix design. In this investigation optimum asphalt content significantly affected by different types of filler materials. Optimum asphalt content is strongly affected by the amount of asphalt absorption in the mixture. Ash absorbs higher asphalt than other non-conventional filler like non-plastic sand and brick dust that's why it requires higher asphalt content. Optimum asphalt content by using non-plastic sand is very much closer to conventional filler materials. The optimum asphalt content by using conventional and non-conventional filler materials are shown in Figure 8. At optimum asphalt content the Marshall characteristics of the asphalt-concrete mixture using different types of mineral fillers are tabulated in the Table 4.

Table 4. Marshall characteristics of Asphalt-concrete mixture at optimum asphalt content

Properties	Mix Type				
	A	B	C	D	E
OAC (%)	6.2	6.1	6.3	6.5	6.6
Unit weight (Kg/m^3)	2415	2405	2398	2390	2379
Stability (kN)	8.2	9.0	7.7	6.5	6.3
Flow (0.25 mm)	11.8	11.8	12.4	12.2	13.1
VTM (%)	4.1	4.0	4.4	4.1	3.6
VMA (%)	15.8	15.4	16.6	17.7	16.1
VFA (%)	75	69	67	75	79

3.4 Marshall Stiffness

The ratio between Marshall stability and corresponding flow value at optimum asphalt content is termed as Marshall stiffness which represents the combination of stability and flow in a single value. Marshall stiffness gives a sign about the resistance of asphalt mixture to plastic flow resulted from loading [20]. Higher values of Marshall stiffness are an indication of considerable resistance to permanent deformation of the asphalt-concrete mixtures which will be used in pavement construction. Non-plastic sand and brick dust give almost the same value of Marshall stiffness on the other hand ash provide lower value. In this investigation, it is seen that non-plastic sand provides higher resistance to plastic flow of the mixtures than the other non-conventional filler materials. Marshall stiffness of different types of filler materials at optimum asphalt content are shown in Figure 9.

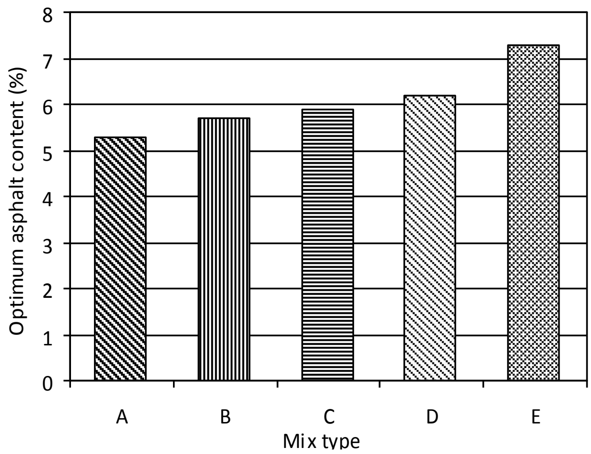

Fig. 8. Optimum asphalt content of asphalt-concrete with different filler materials

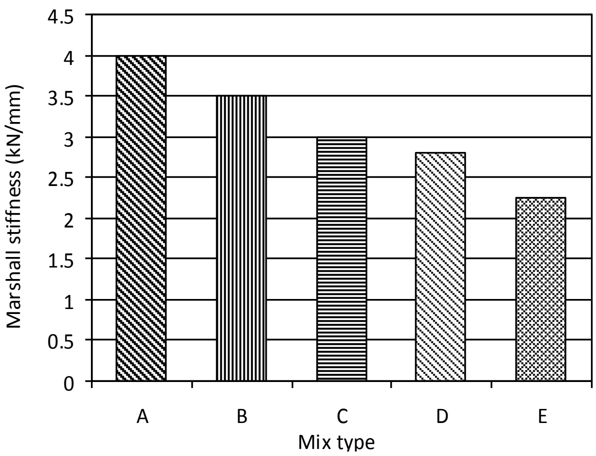

Fig. 9. Marshall stiffness of asphalt-concrete with different filler materials

3.5 MOISTURE SUSCEPTIBILITY OF THE MIXTURES

Water is the worst enemy of the asphalt-concrete mixtures. The premature failure of a flexible pavement may be caused by the presence of water [21]. To determine the moisture susceptibility of the mixtures, retained stability (RS) test were performed according to AASHTO T 283. RS is expressed as the ratio of average Marshall stability of the specimens which were immersed in water at 60 ºC for 2h to the average Marshall stability of the specimens which were immersed in water at 60 ºC for 30 minutes [4]. RS for different types of filler materials is shown in Table 5 and effect of soaking periods on an asphalt - concrete mixture for various filler materials is shown in Figure 10. In this investigation it can be seen that the non-conventional filler materials exhibit lower value than conventional filler materials. But all the values of the RS for both conventional and non-conventional filler satisfy the Indian Criterion of RS which is 75%.

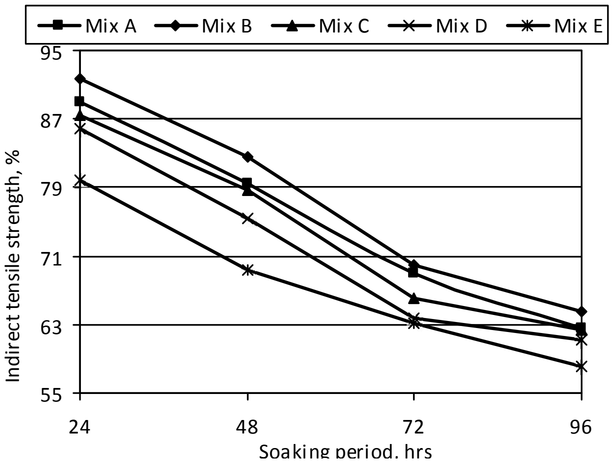

Fig. 10. RS of different filler materials at different soaking periods

Table 5. Retained stability of Asphalt-concrete mixture for different types of filler materials

Material Types	Retained Stability (%)
Stone dust	96.98
Cement	95.39
Non-plastic sand	88.92
Brick dust	87.22
Ash	83.59

4 CONCLUSION

Investigation was made to determine the volumetric properties and deformation characteristics of the asphalt-concrete mixture using different types of non-conventional filler materials. This investigation revealed that different types of filler exhibit significant progresses of the mixture. Volumetric properties of the mixture using non-conventional filler is not similar as the conventional fillers but it can be said that, the volumetric properties of the mixture using non-conventional filler is within the recommended range. Stability and deformation characteristics of the mixture using non-conventional filler are not so higher than the conventional filler but it can be seen from the experimental data that those values are well above the limiting values.

The main drawbacks of these non-conventional filler materials that, they require more asphalt than conventional filler that means they have higher optimum asphalt content compared to the conventional filler. But from the availability and economic (which is related to transportation cost) points of view, it can be said that non-conventional filler materials which have higher resistance to permanent deformation and premature failure, is a feasible option in the construction of flexible pavement.

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