

DOI: <https://doi.org/10.63332/joph.v5i6.2022>

## Impact of Using Dust / Fiber in Flexible Pavement

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### Abstract

*Flexible paving is the most popular type of paving used in road building and one of the biggest problems facing the world's paving business is the rising demand for scarce natural resources. Uncontrolled. Numerous studies have shown that secondary materials reduce the need for traditional materials, offer efficient waste disposal technology and lower the overall cost of paving. The current study aimed to evaluate the efficiency of both fibers and dust on the sustainability and cost of flexible pavement by studying each of polyester fibers as a waste of the textile industry and fibers or rubber particles as one of the rubber waste products, in addition to studying the efficiency of using cement dust and marble dust on the paving process. Flexibility by conducting laboratory tests and examinations as major factors contributing to the analysis of pavement performance. On the other hand, waste rubber particles (WRP) generally enhances flexible pavement performance, promotes environmental compliance when used in asphalt and asphalt mixtures, and decreases associated pavement issues including thermal cracking, fatigue and permanent deformation (cavitation), especially in hot regions. The results indicated that the use of marble dust by 10% of the flexible paving mixture increases the strength and stability of the layers and when using cement dust in the flexible paving in different proportions, the addition of 3-5% of cement dust was important in reducing the cost of building the paving structure compared to using materials traditional class.*

**Keywords:** Bitumen, Dust, Fiber, Flexible pavement, Marble.

### Introduction

Sustainable development is urgently needed in this era of rapid progress and enormous growth. The overuse of natural resources has become a serious environmental problem and the highway sector is a crucial pillar of the construction industry. The term "pavement" describes a layered construction that is located above the subgrade and below the wearing surface. Its primary goal is to simplify the process of transporting loads from moving vehicles to the subgrade and the soil beneath the subgrade. The two types of pavements are rigid and flexible, respectively, according to design concerns. Due to their distinct qualities, each of these pavements are appropriate for particular situations [1, 2].

**Most Roads are Flexible:** Around 95% of the world's roads use a type of pavement called "flexible pavement." This pavement sits on a foundation layer called the subgrade, with additional layers (sub base and base) for drainage and support. The top layer, called the surface course, provides a smooth path for vehicles [3, 4].

**The Importance of Aggregates:** A key component of flexible pavements is aggregate, crushed rock obtained from quarries. However, traditional extraction methods like drilling, blasting, and crushing can generate significant waste that disrupts the environment [5].

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**Flexible vs. Rigid Pavements:** Pavements come in two main types: flexible and rigid. Flexible pavements, typically made of asphalt, are more common and can be seen in various forms like surface treatments on low-traffic roads or thicker asphalt layers on highways. They're called "flexible" because the entire structure bends slightly under traffic loads [6, 7]. This flexibility is achieved by using multiple layers of different materials.

**Rigid Pavements for Strength:** In contrast, rigid pavements use a concrete surface course (PCC) and are much stiffer than flexible pavements due to the concrete's properties. They may also incorporate steel reinforcement to minimize cracks or eliminate them altogether.

### **How Pavements Distribute Weight**

Pavements come in two main types: rigid and flexible. Each handles weight differently to protect the subgrade (the layer below the pavement).

-**Rigid Pavements:** Made of stiff concrete slabs (PCC stands for Portland cement concrete), these pavements spread weight over a large area of the subgrade. The concrete itself provides most of the structural strength.

-**Flexible Pavements:** These pavements use a more flexible surface layer and distribute weight over a smaller area. The load is transferred through multiple layers before reaching the subgrade.

### **The Importance of Pavement Materials**

Many countries are looking for ways to use recycled or waste materials in pavements. This reduces reliance on virgin materials and promotes sustainability. Some countries have even created guidelines for using recycled materials in construction projects.

### **Finding Alternatives**

With the increasing focus on sustainability, exploring alternative materials for pavements is crucial. Different countries have different standards for what materials can be used in pavement construction.

Varying countries have set varying standards for the materials that must be used in paving. Materials that have been recycled go through the same testing as new materials before being used in construction. The mixtures made by mixing waste resources with virgin materials, either fully or in part, must adhere to the minimum requirements for strength, durability, stability and other characteristics [5, 10]. Changes in the outside temperature, the weight of the vehicles, and other elements are what most affect asphalt pavement. An enormous economic benefit and sustainability are brought about by an increase in the useful life of road pavements.

To enhance the performance qualities of flexible pavement, waste rubber particles are recommended as asphalt and asphalt mixture modifiers. Tire disposal has become a serious concern as a result of the recent global boom in automotive production, which has resulted in a large number of tires going to waste. Burning and landfilling are the two methods for disposing of used rubber, respectively [11]. Burning used tires for disposal produces smoke and pollution, while land capacity is reduced when tires are dumped in landfills. Emphasis was placed on the fact that environmental sustainability is assured if discarded or used tires are used as an additive in asphalt for improving the qualities and discarding the tires [12].

### **Polymer Fibers and Recycled Rubber for Stronger Pavements**

One innovative approach to improving pavements is the addition of polymer fibers. These fibers

not only reduce damage but also extend the pavement's lifespan. This method also offers a sustainable way to utilize waste polymer fibers.

By incorporating these fibers, pavements require less asphalt and become more durable, leading to lower maintenance costs and a longer service life.

### Recycled Rubber for Improved Durability

Another promising option is the use of recycled rubber in asphalt pavements. This "rubberized asphalt" has been shown to be more resistant to cracking and deformation compared to conventional asphalt. It allows the pavement to withstand greater loads, making it ideal for high-traffic areas.

### The Importance of Design Considerations

To further enhance pavement life, it's crucial to consider factors that cause deterioration during the design stage. By taking these factors into account and utilizing innovative materials like recycled fibers and rubber, pavements can be built to last longer and require less maintenance.

### Types of Pavements

There are three main categories of road paving [16, 17]:

- (a) Flexible pavements (upper layers of Asphalt)
- (b) Rigid pavements (upper layers of Concrete)
- (c) Composite pavements
- (d) Flexible Pavements, types of flexible pavements include:
  - (1) Conventional layered flexible pavement
  - (2) Full-depth asphalt pavement
  - (3) Contained rock asphalt mat (CRAM).

Flexible pavements consist of six layers with their approximate thickness of layer:

- (1) Surface course (2 - 5 cm)
- (2) Binder course (5 - 10 cm)
- (3) Base course (10 - 30 cm)
- (4) Sub-Base course (10 - 30 cm)
- (5) Compacted sub-grade (15 cm)
- (6) Natural sub-grade

### Advantages & Disadvantages of Flexible Pavements

Mostly bituminous materials, such as bitumen or asphalt, are used to make this kind of pavement. As a pavement made of compacted aggregates and bitumen, it can also be described in that way. Sub Base, Base Course, Sub Grade, and Surface Course are the four layers that make up flexible pavement. To keep it from collapsing under the weight of high loads, this pavement needs routine maintenance that is closely watched. Low flexural strength is a characteristic of flexible pavement that is dependent on the structural response to applied vehicle stresses; wheel load

stresses in the flexible pavement are transmitted to the bottom layers. Through a number of layers, the load is carried to the subgrade. Over a larger region, the wheel load is dispersed. Notably, the strains get smaller as you go deeper. The top layer experiences the greatest compressive stress, whilst the lower levels experience less severe stress [16, 17, 18].

The following are some advantages and disadvantages of flexible pavements:

#### A –Advantages

- 1 - Laying can be done before construction even begins.
- 2- It is simple to make repairs and patch up the pavement.
- 3 - The materials required to construct the flexible pavements are affordable.
- 4 - Frost heave and other flaws are simple to fix.
- 5 - Provides significant resistance to the development of ice glaze.
- 6 - A brief period of curation implies that traffic is not blocked for an extended period of time.
- 7 - Flexible pavement installation does not require the use of joints.
- 8 - It is feasible to build stages.

#### B – Disadvantages

- 1 - Its lifespan and service life are limited.
- 2 - The requirement for frequent repair in flexible pavement raises overall costs.
3. This pavement is vulnerable to oil stains and can sustain harm from other chemicals.
- 4 - This pavement needs curb because the ends are weak.

### **Materials and Methods**

In this part, various methods of flexible pavement are applied using different types of fibers, including polyester fibers and waste rubber particles, in addition to types of aggregates, as shown by the work steps.

#### **Test Method**

The Marshall Properties, indirect tensile strength test, moisture damage test, resilient modulus test and permanent deformation test were used to evaluate the properties and performance of the asphalt mixture. The Marshall stability was defined as the highest load that could be supported by a compacted specimen at a standard test temperature of 60° C. Explained how stability is a key component of evaluating the effectiveness of an asphalt mixture under traffic stress. The pavement's higher stiffness value is shown by its greater stability value, but there are some boundaries where flexibility is still present, and this is where the flow as the deformation value comes into play [19, 20].

#### **Fibers Used in Flexible Pavement**

##### **1 – Asphalt**

The wet approach will be used in this investigation to create flexible pavement samples from polyester waste. According to the weight of the asphalt, polyester is added in different amounts,

ranging from 0% , 2.5%, 5% , 7.5%, and 10% respectively. In order to accomplish this, 150 samples were created, 30 of which were compacted, and the remaining 120 were not. According to the weight of the aggregate sample weights, which are 4%, 4.5%, 5%, 5.5% and 6%, asphalt was also used in various weight fractions. To assess how well asphalt/polyester composites performed in comparison to samples without polyester, all the samples were put through the Marshall Test apparatus. Asphalt, aggregate and polyester are the three components that are necessary to create a Marshall Specimen.

## 2 – Bitumen

Due to a variety of qualities and advantages bitumen provides over other pavement construction materials, it is employed in road construction. During the manufacturing process, bitumen acquires several special qualities that are integrated into it. Bitumen has a number of benefits that encourage its widespread usage in road building, including as a raw material in flexible road construction and as a mix (composing other materials like aggregates/pozzolans). The 60/70 grade asphalt utilized in this study has the specifications shown in Tab 1.

Property	Unit	Value
Softening point	°C	49.56
Penetration	25 °C, 0.1 mm	64.92
Penetration grade	0.1 mm	60/70
Flash point	°C	232
Specific gravity	-	1.01-1.06
Ductility	cm	100
Loss of Heating	%	0.2 (max)

Table 1: Components of the Asphalt Used in The Study

## 3 – Polyester Fiber

Waste polyester fiber (textile waste) having the following characteristics was utilized as shown in Fig 1 and Tab 2.



Figure 1: Polyester Fiber as Textile Waste

Polyester properties	Unit	Values
Specific gravity	-	1.4
Tenacity	g/d	3.5 – 7.0
% Elongation at break	%	15 – 45
Moisture regains	%	0.4 – 0.8
Shrinkage in boiling water	%	0 – 3
Elastic recovery	% at 5%	93
Glass transition Temp.	°C	80
Softening Temp.	°C	230 – 240
Melting point	°C	260 - 270

Table 2: Characteristics of Waste Polyester Fiber

#### 4 – Waste Rubber Particles

Prior to blending with the aggregates in the wet process, the waste rubber particles are mixed with the asphalt component. The waste rubber particles inflate and soften after being combined with the other ingredients. The rubber particle response is influenced by the mixing temperature, reaction duration, type and volume of mechanical mixing, rubber waste particle size and texture, asphalt cement, and mechanical mixing [21]. The engineering qualities of flexible pavement can be improved by replacing a portion of the traditional material with waste rubber. The breadth of what the engineer intends to accomplish determines the design mix of waste rubber particles as a partial replacement of aggregates and bitumen. However, each choice would increase the requirement for mechanical qualities for a specific road mix design [22].

Indirect Tensile Strength (IDT) strength is a crucial test that is very helpful in determining the performance of porous asphalt mixtures because it measures how well the bitumen layer adheres to the material. In Figures 1 & 2, the IDT's vibrations with waste rubber are described for all three sizes. The IDT strength was dramatically reduced by the addition of waste rubber particles, with the exception of the 10% content of the waste rubber particles.

#### Cement Dust and Marble Dust Used in Flexible Pavement

In the production process of the pavement, two different types of fillers were used: cement dust and marble dust as a main additive.

##### 1 – Cement Dust

Cement dust is the residue left over after producing Portland cement. Chemical comparisons between Portland cement and used cement dust from the same facility revealed that the major amount of cement-forming oxides in the used cement dust is roughly two thirds that of Portland cement. This creates hazards for safety, storage problems, and potential pollution sources.

##### 2 – Marble Dust

Marble dust – as shown at Fig. 2, is a semi-liquid substance made up of particles from the sawing and polishing processes as well as water used to lubricate and cool the sawing and polishing machinery [23].



Figure 2: Marble Dust

## Results and Discussion

### Effect of Polyester Fibers as Textile Wastes

As a control or reference sample, the bituminous aggregate mixture without polyester is used. By adding polyester to bituminous aggregate at rates of 2.5%, 5%, 7.5% and 10%, respectively, on the weight of the mix, modified samples were created.

### Effect on Air Voids and Density

The percentage of air spaces in a bituminous asphalt mix reveals the fundamental physical property of the mixture. According to Fig. 3(a), when polyester is added at a specific level, air spaces steadily decrease. There is a very slight fluctuation in air spaces between the bands of 0 and 5%, as can be shown. There is a considerable shift in the air voids% between 5% and 7.5%, though. From 5% to 7.5% and from 7.5% to 10%, respectively, are taken out of the air spaces. When polyester constitutes 10% of the mix, there are more air voids, which lower the asphalt content. With a rise in polyester content, all Marshall Samples' densities vary, as shown in Fig. 3(b). As polyester is lighter than asphalt, the results demonstrate that density decreases as polyester concentration increases. The drop in density was explained by the fact that in the current study, the amount of asphalt falls as the amount of polyester rises. The density is abnormally enhanced when the polyester content approaches 10%. Fig. 4 showed the optimum asphalt content for different percentages of polyester fibers.

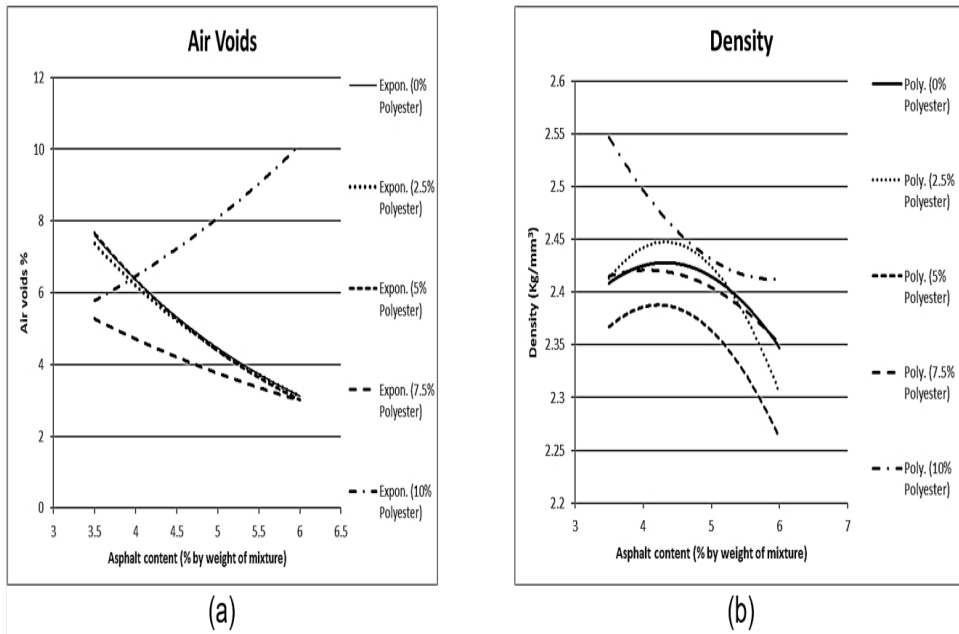


Figure 3: (A) Percentage of Air Gaps for Various Levels of Polyester and (B) Density Values at Flexible Pavement for Various Levels of Polyester.

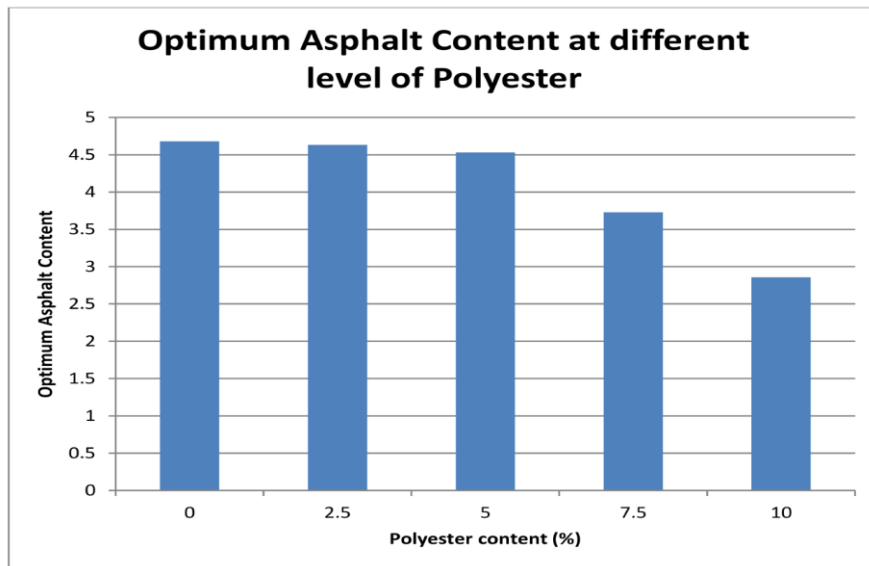


Figure 4: Optimal Amounts of Asphalt for Various Polyester Content Ratios

Polyester is added and in its molten condition, it demonstrates adhesion properties. The melting point of bitumen will rise due to polyester. Thus, one of the finest options for simple polyester disposal is to use polyester trash for pavement. The synergistic qualities of polyester and asphalt contribute to an increase in the service life of flexible pavement when polyester is added. A road's performance can be improved by combining polyester with bitumen and aggregates.

Reduced voids and moisture absorption are achieved when polyester is used with aggregates.

### Effect of Waste Rubber Particles (WRP)

There are two methods that WRP can be applied on flexible road pavement. The first way it works is to partially replace the rubberized asphalt (dry process) aggregates. Also known as asphalt rubberized binder (wet process), it serves as a partial replacement for asphalt. The wet technique has yielded encouraging results for both methods. Because of this, the wet technique has been used more frequently than the dry process. WRP generally enhances flexible pavement performance and upholds environmental compliance when used in asphalt and asphalt mixtures [24, 25]. The use of waste rubber particles (WRP) decreases associated pavement issues such heat cracking, fatigue and permanent deformation (rutting), especially in hot climates.

The waste rubber particles can be utilized in open-graded, gap-graded and dense-graded asphalt pavement, taking gradation restrictions into consideration. The performance of porous asphalt mixtures, which depend on the cohesiveness of bitumen film, may be determined by looking at the influence of WRP on moisture susceptibility and Indirect Tensile Strength (IDT) strength, as shown in Fig. 5 and Fig. 6, the IDT strength was dramatically reduced as a result of the inclusion of waste rubber particles.

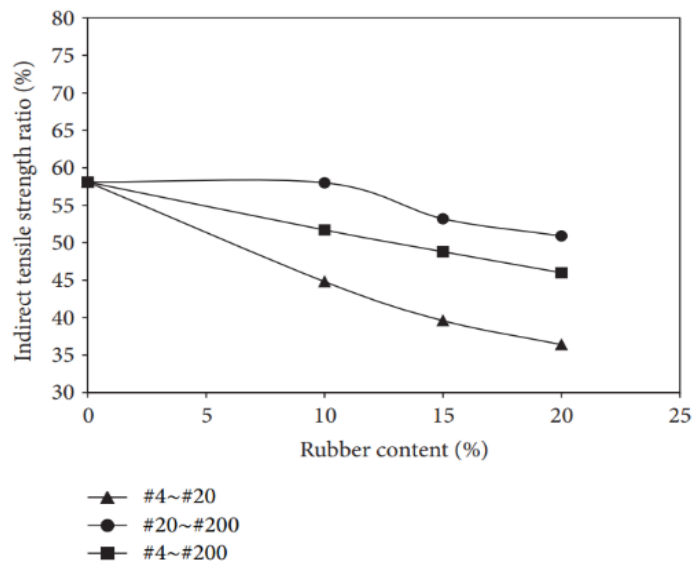


Figure 5: Effect of WRP and Content on Moisture Susceptibility

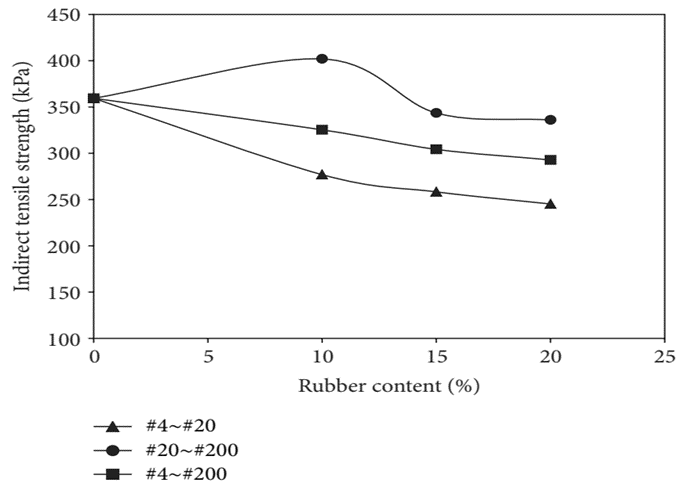


Figure 6: Effect of WRP and Content on IDT Strength

### Effect of Marble Dust Particles

Numerous researches have examined the use of marble debris as filler for concrete asphalt and to substitute sand in high-quality concrete pavement. Adding this substance to asphalt improves its performance in terms of flexibility [26]. In sub-grade preparations, marble dust can be used in place of 10 % of the soil, increasing the layer's strength and stability. In this study, five different marble dust addition rates were made to the pavement mixture: 5%, 10%, 15%, 20% and 25% by soil weight. A sample for the control sample was also created, but it was devoid of marble dust. Using five percentages of powdered marble dust, the standard proctor test was run on the soil sample. Five, 10, 15, 20 and 25 percent of marble dust, respectively, were mixed with the soil. When 10% of marble dust was used, the Maximum Dry Density (MDD) value was reached at  $1.72 \text{ g/cm}^3$ . MDD of untreated soils was  $1.7 \text{ g/cm}^3$ , as opposed to that. The test's findings for every sample are shown in Fig. 7. As the water content rises, the dry density rises for each sample individually until it reaches a maximum value, at which point it begins to slowly decline.

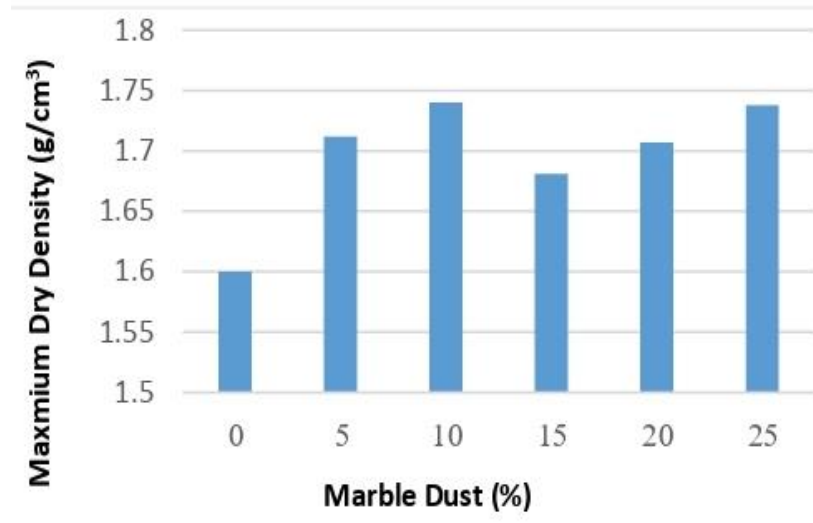


Figure 7: Impact of Marble Dust on MDD

### Effect of Cement Dust Particles

Five different types of pavement materials that are typically used to build the pavement layers of major highways were combined with cement dust as filler. The materials used in the researched pavement are divided into five categories:

- (1) Reclaimed Asphalt Pavement (RAP)
- (2) Crushed stone base aggregates
- (3) A mixture of 40% crushed stone aggregates and 60% RAP
- (4) crushed stone sub base aggregates

(5) Sandy subgrade soil. The percentages of cement dust added to each of the chosen materials were 5%, 5%, 3%, 4%, and 4%, respectively [27, 28]. According to the findings, adding 3-5% of cement dust increases the projected testing of the tested base/sub base materials and subgrades by 8–21% at the envisioned field loads. The structural layer coefficients are thus improved by 11–17%. Utilising 3-5% of cement dust extends both the fatigue life and the anticipated rutting life by up to 27% and 12%, respectively. According to a typical pavement structure, enhancing base/sub base layers and subgrade soils with 3-5% of cement dust reduces asphalt layer thickness from 11.20 to 12.40% and increases base/sub base layer thickness from 8.70 to 12.40% in order to maintain the typical structure's predicted rutting and fatigue lives. Along with the environmental advantages, this has a favorable impact on the entire cost of construction.

As demonstrated, adding 3-5% of cement dust reduces the cost of building a pavement structure compared to using the conventional layer materials. Additionally, by maintaining the same permitted number of load repetitions for AC fatigue and subgrade rutting for a typical pavement structure, the thickness of the asphalt concrete layer is reduced by approximately 11.25 to 12.50% at the expense of an increased base layer thickness of 8.75 to 12.50%, which is still more advantageous economically and environmentally. The performance of the pavement is significantly improved when RAP materials are used as the base layer as opposed to

## Conclusions

With increased vehicle weight, pavement deterioration increases quickly. Although there are several reasons why pavements deteriorate with time, traffic volume is a significant influence in the reduction of pavement life. The fact that roads are in such bad shape is largely due to heavy vehicle loads and inadequate structural capacity of pavements. The primary focus of this study is on the many types of stresses, particularly cracking and roughness, which are performance indicators of road conditions.

The current study examined the effectiveness of using polyester fibers as a waste product of the textile industry and fibers or rubber particles as a byproduct of the rubber industry, as well as the effectiveness of using cement dust and marble dust in the paving process, in order to assess the effectiveness of both fibers and dust on the cost and sustainability of flexible pavement. As one of the main aspects influencing the investigation of pavement performance, flexibility is tested and examined in laboratories.

The results showed that adding polyester to asphalt increases the service life of flexible pavement due to the synergistic features of the two materials. Combining polyester with bitumen and aggregate can improve the performance of roads. When polyester aggregates are employed, voids and moisture absorption are decreased. On the other hand, WRP generally enhances flexible pavement performance, promotes environmental compliance when used in asphalt and asphalt mixtures, and decreases associated pavement issues including thermal cracking, fatigue, and permanent deformation (cavitation), especially in hot regions.

On the other hand, using marble dust in the flexible paving mixture by 10% increases the strength and stability of the layers, and using cement dust in the flexible paving in various proportions, the addition of 3-5% of cement dust was crucial in lowering the cost of building the paving structure when compared to using materials from the traditional class.

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