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Applications of plastic waste materials in bituminous mixes pavement for increasing the strengthen of pavement materials

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Abstract

The yearly production of plastic garbage is rising in the current environment as a result of the fast population rise. Recycling and reusing plastic trash is essential for sustainable development. The need of the hour is to utilize waste polythene for various supporting reasons since it is not biodegradable. These materials are made of polymers like polyethylene, polypropylene, and polystyrene. Due to the enhanced performance and elimination of the environmental issue, adding plastic waste to flexible pavement has emerged as a desirable choice. A composite material known as bituminous concrete (BC) is often utilized in construction projects such as road paving, airport terminals, stopover areas, etc. It includes mineral aggregate and black top or bitumen, which are combined, laid down in layers, and then compacted. The bituminous mixture in this research article was combined with plastic to use a chemical stabilizer. The ideal bitumen content is replaced by 0, 15, 27, and 36% plastic, as well as the bitumen's weight, stability, and Marshall values, to create hypothermal. A linear scale is used to compare the flow rates to the bituminous mixture. There have been several studies on the addition of trash to bituminous mixes, but this is focused on the use of plastic waste as a modification in a bitumen binder for flexible pavement. According to research, bituminous mixes containing up to 4 percent plastic waste are excellent for sustainable development.

1. Introduction

Energy conservation is highly valued in the contemporary day since it aids in reducing the need for and expense of non-renewable fuels, among other aims. Lightweight materials are in high demand since using them may help save energy. Composites made on polymer matrices are one such. From 2014-19, the market for lightweight materials grew to $133.2 billion, with a compound yearly growth rate of 8.5 percent. It is expected to reach $189.077 billion by 2022. Plastics fall under the category of lightweight materials; furthermore, they are employed in a range of applications and are mass-produced due to their strength, affordability, and flexibility. In addition, 8310 million metric tons of new plastic have indeed been produced as of 2017; if the plastic waste system does not improve, 12 billion million tons of plastic will be released into the environment by 2050 finding the right technique to discard plastic garbage is a serious challenge in today's world since many plastic materaisl are abandoned after about a year of use and end up in municipal refuse [1-2]. Plastic garbage has a great deal of additional problems in addition to its enormous volume. Because plasticizers are present in waste plastic, they have the greatest harmful effects. Plasticizers are introduced to plastics to give them flexibility and to make them easier to work with; since they do not create a covalent link with plastic, they are readily absorbed by the environment. These plasticizers disturb the reproductive system in animals. The presence of plastics in our food supply chain is scary. Their presence has been confirmed in the air, soil, water, animals, and even human physiological fluids. Another issue with plastic garbage is that it takes up a lot of precious space in landfills when rubbish is just deposited there without being compacted or separated. Second, landfills have a water content of approximately 21-23%, which attracts mosquitoes and houseflies. Plasticizers may also readily enter the soil from landfills, which can pollute groundwater and generate an unpleasant odor. Plastic debris is also thrown into waterways as a means of disposal, and cause pollution of the atmosphere of our seas and rivers, obliterates life of marine, and that creates ocean garbage patches. Along with ocean dumping, drainage from the land, damaged fishing equipment, and plastic debris from ships are also to blame for the presence of plastic in the seas. The 60-80% of trash in the water is made up of plastic garbage [3–4]. First, plasticizers affect marine animals' internal organs. Second, marine species ingesting or becoming entangled in plastic waste suffer injury and may perish. Figure 1 illustrates several techniques for disposing of solid waste. According to Gawande et al., 4.8–12.7 million tons of plastic flooded the ocean in 2012. Plastic has a low population density, and thus it floats on the water. Because of water currents, it builds up at a place called an "ocean garbage patch." There are more than 80 million tons of plastic in this 1.6 million km^2 waste dump. The pie graph of such statistics reveals that just 10% of plastic trash gets recycled globally, and that 82 % of it is dumped in landfills or marine garbage patches. Plastic debris that is not recycled ends up in landfills, ocean garbage patches, or is burned, which creates a variety of environmental issues. If pollutants of incineration facilities are regulated, the plant will no longer be affordable for all nations [2, 5–6].

1.1 Plastic Material

Plastics are typically classed based on the backbone and side chains of the polymer's chemical structure. Some essential groups within these classes include:

I. Acrylics
II. Polyesters
III. Polyurethanes
IV. Halogenated plastics
V. Silicones

1.2 Types of Plastic

1.2.1 Thermoplastics:

These are indeed the plastics that can be heated without changing their chemical makeup and that can be shaped repeatedly. Polytetrafluoro ethylene, polystyrene, polypropylene, polyvinyl chloride, and polyethylene are among examples of PTFE.

1.2.2 Thermosetting:

An irreversible chemical reaction takes place during the thermosetting process. Rubber is made of flexible by a thermosetting process. It is a sticky, somewhat fluid substance prior to heat with Sulphur, but after being vulcanized, it becomes hard and non-tacky.

1.3 Classification of Plastic Waste:

1.3.1 Polyethylene:

Low density polyethylene is a kind of plastic garbage that is often seen in supermarkets as carrier bags. These bags are extremely thin and simple to find and collect in large amounts. High-density poly-ethylene plastic garbage is often sold in carry bags and is simple to find on the market.

1.3.2 Polypropylene:

Depending on the application and requirement of the sectors, these plastics could well be offered as solid plastic or carry bags. It comes in the shape of mat sheets, plastic containers and other things.

1.4 Flexible pavement

The majority of highways in the world have flexible pavements, which fail due to peeling, pits, fatigue cracks, stampeding, overweight vehicles, etc. It costs a lot of money to maintain these pavements by adding anti-stripping chemicals, for example in Fig. 2 depicts the four levels of flexible pavement: the subgrade, subbase, base and top layer. The efficiency of the pavement may be impacted by the thicknesses within each layer, with a rise in the bitumen surface generating a reduction in stress concentration on the subgrade layer, for example. The weight that the pavement must support, the state of the region at which pavement will be built, and the substances utilized in each layer are the factors that determine the thicknesses of each layer [7-8]. To explain the change in layer thickness in flexible pavement depending on whether the ground is solid or unstable, wear and pavement surface performance were utilized as criteria to improve layer thickness. Thus, it is impossible to determine the exact thickness of each layer. The natural ground is compacted to provide a solid foundation for the building of the pavement at the lowest layer of the pavement, termed as subgrade layer. The subbase layer, which is the second-to-last unbound layer, is made of less-than-ideal materials since its primary function is to drain any water that has seeped into the pavement. Its thickness also is increased, giving the pavement a more stable foundation. The bottom layer is the top layer, also known as the load-bearing layer, and it contains high-quality aggregates since it needs to give the pavement its rigidity. The surface layer, which is the top layer and is in direct contact with traffic, was required to sustain its stress inside the elastic region. Each layer receives the accumulation of solid wastes, but this article will only pay attention to the top layer [9–10].

On the basis of a thorough examination into the use of plastic pollution in bituminous mixtures for the building of flexible pavements, literature has been produced. Vasudevan et al. claim that the disposal of waste plastic poses a serious risk to the environment and contributes to climate change and pollution. The characteristics and strength of bituminous mixtures are improved by the addition of plastic waste. Additionally, it will be a fix for numerous pavement flaws like potholes, corrugation, ruts, etc., as well as a way to dispose of plastic. Polyethylene, Polystyrene, and Polypropylene make up the used waste plastic. Shredded waste plastic is spread over gravel, combined with hot bitumen, and then used to create a mixture for paving roads [3]. According to Habib et al., since landfill space is limited and unsustainable, plastic garbage cannot biodegrade, making its disposal a major problem today. It can be effectively used in bituminous concrete (BC) mixtures for flexible pavements, according to studies. There are two techniques for including plastic wastes in BC mixes: the dry method and the wet method (WM). In this work, a comparison has been done using flexible low-density polyethylene low-density polyethylene shredded plastic trash carry bags from BC mixtures [4]. The majority of the roads built in India, as per Chakroborty and Das, have flexible pavement structures. These pavements are vulnerable to various types of roads, which has an impact on how well they operate. Today, bitumen is often modified with waste plastic to improve the quality of the pavement. The cost of construction has decreased, and there is now a more environmentally responsible way to dispose of the garbage thanks to the use of plastic wastes to alter the bitumen's characteristics, that will be used to build roads [5]. LDPE that has undergone pyrolysis may be used as a modification for asphalt paving materials, according to research by Baha et al. Five distinct mixes, including conventional mix, were put through a variety of homogeneity tests and binder testing, including rheological tests. Additionally, its impact on stone matrix asphalt (SMA) combinations' moisture sensitivity and low-temperature performance was investigated. According to research findings, modified binders had a greater softening point [6]. Colonna et al. claim that adding recycled waste products as modifier additives to asphalt mixes may have a number of positive economic and environmental effects. The major goal of this study was to determine how *polyethylene terephthalate* (PET) from used plastic bottles affected the stiffness and, in particular, the fatigue characteristics of asphalt mixtures at 5 and 20 °C. The impact of PET was also contrasted with that of styrene butadiene styrene (SBS), a traditional polymer addition that has been extensively utilized to alter asphalt [7]. According to the literature study above, it is advantageous to include plastic debris into bituminous mixes while building flexible pavements. The primary goal of this project is to find effective, constructive ways to repurpose waste plastic so that they may benefit society. The primary goals of the research projects are to cover the aggregates for pavements with waste plastic components before evaluating the characteristics of different bitumen mixtures. Examine the bitumen mix's characteristics after coating the recycled plastic materials, and then contrast it with the typical bituminous coatings.

1.5 Methodology

A comprehensive review is conducted to get information of the works that are already accessible in literature in order to meet the study's key goals. Prior to shredding or cutting plastic garbage into little pieces, plastic waste collecting may be carried out. Following that, bitumen and aggregate may both undergo standard testing. Testing may be done by covering aggregate with plastic waste, mixing plastic with bitumen, and then doing tests in a lab. The test findings without and with plastic garbage may now be compared. The needed percentage of waste plastic is added with the bitumen after being crushed and converted into powder. Melted plastic trash is combined in a certain ratio with bitumen. The temperature at which blending normally occurs is 46°C, however when plastic is blended, the mixture is stable even at 54°C. Bitumen and plastic are both heated separately and combined thereafter. The appropriate percentage of this mixture is subsequently mixed with the aggregates [11–12].

2. Materials And Methods

2.1 Materials:

In addition to bitumen, which made up the majority of the binder, minor components included crushed plastic bottles, polythene bags, and old rubber tyres. The binder mix included shredded plastic waste with a specific gravity of 1.19 and particle size of around 750 m. All binders were separated into the A, B and C series. While Series C represents the tertiary mix with changing proportions of rubber and plastic both in bitumen, Series A and B respectively the binary mixes, i.e., bitumen (B) + Rubber (R) and Plastics (P) respectively. Bitumen Mix is the umbrella term for all mixtures with various ratios of the components of the binder (BM). To evaluate the physicochemical characteristics of different binders, penetration tests, ductility tests, softening point tests and specific gravity tests were carried out. In order to create the Skelton of modified and unmodified bituminous concrete mix, aggregates with 4 different sources were used. To assess the mechanical qualities of aggregate, including hardness, roughness, stiffness, water absorption capacity, etc., various physical tests were performed on the material. Then, the acquired findings were contrasted with the permitted limits according to the requirements. The outcomes were all confirmed to be within the parameters of the bituminous concrete mix [13-14]. Fig. 3 illustrates how different waste plastic materials were applied.

Blinder and aggregates are the two main constituents of bituminous mix. This section discusses some of the issues involved in selection of binder and aggregates.

2.1.1 Binder

Simple testing and other site-specific criteria are used to choose binders. The test might be affected by the various kinds of binder, such as modified binder, cutback, emulsion, penetration grade, etc. The requirements provide pre-determined testing settings for the majority of tests. Temperature is a crucial factor that directly affects the modulus and ageing of the binder. According to Superpave requirements, these acceptance tests should be conducted at comparative field temperature rather than at the temperatures stated in the lab. This factor must be taken into account since, whereas binders obtained from multiple sources may exhibit the same physical characteristics at a certain temperature, their performance may differ significantly at other temperatures. Only the permissible testing values, not the test temperatures, are recommended in the Superpave standards. The most common maximum and lowest temperatures in the field are used to derive the standard temperatures at the specified probability threshold. The suggested tests in Super pave Binder Selections include the Rolling Thin Film Test (RTFO), Bending Beam Rheometer, Dynamic Shear Rheometer, Rotational Viscometer, Pressurized Aging Vessel (PAV) and Direct Tension Tester [15-16].

2.1.2 Aggregate

Numerous tests, including those for strength, clay content, angularity, toughness, durability and hardness form characteristics, binders to adherence and others, are advised in the requirements to evaluate the qualities of aggregates. Due to aggregate joining, angularity is a feature that provides shear strength, and reducing flakiness ensures that aggregates would not break during compression and handling. Cement or bituminous materials are used to bind the aggregates. Sometimes, when combined with water, the stone powder itself creates slurry that functions as a binding agent. These aggregates can be divided into the following categories as natural aggregates and the coarse aggregates are made up of smaller rock fragments that have been crushed. Gravel and fine aggregates, as well as sand, are included in the category of artificial aggregates. For bituminous surfaces, stone aggregates in use for roads have to be hard, robust, long-lasting, and hydrophobic. Gravel should possess a fineness modulus of at least 5.80 and be properly graded (6.4 to 39mm). Sand should be clear of any silt, clay, and organic matter and it should be sharp and well-graded. For each 11 m^2 area with nominally 12 mm-sized particles, 0.15 m^3 of aggregate should be used in the initial application of surface treatment. In contrast, 0.15 m^3 of nominally 10 mm-sized aggregate should be used for each 10 m^2 of surface treatment in the second layer [17-18].

2.1.3 Bitumen

In the building of pavements, bitumen is the adhesive that is used most often. According to the definition provided by the American Society of Testing Materials, bitumen is described as mixes of hydrocarbons of natural or pyrogenous origin, or mixture of all, commonly supported by its non-metallic derivatives, which could include gaseous, liquid, semi-solid, or solid, and which are totally soluble in carbon disulfide. This definition was provided by the American Society of Testing Materials (ASTM). A refinery uses a process called fractional distillation to separate the various components of crude petroleum as they go through the refining process. These components are separated in the order in which their volatility. Straight-run bitumen may be produced by distilling the bituminous residue that is left over after extraction. This bitumen is referred to as heat petroleum products bitumen or penetration grade bitumen. The grades 90/100 and 190/200 of bitumen are used extensively across the majority of India. The standard of horizontal run bitumen that is used for surface dressing is selected with consideration given to the weather patterns of the area in which the work will be carried out. The quality of the basic bitumen may be changed by either the process of controlled refining or through the addition of diesel fuel or even other oils. In the case of single treatments on Blended cement base course, the amount of bitumen required varies from 18 to 196 kg per 10 m^2 regions, but in the event of replacement of black top surfacing, the quantity ranges from 11 to 13 kg per 11 m^2 areas. The amount of bitumen required for the second layer of surface treatment varies from ten to twelve kilogram per ten sq meters of surface area. Bulk bitumen when transporting bitumen in bulk, lorries with tanks that have capacities ranging from 6,000 to 16,000 liters are typically used. According to PMC, the amount of bitumen that should be included in a mix must make up 5% of the mix's total weight. Pavement bitumen from Assam petroleum is signified as A-type and assigned as grades A35, A90, etc., and paving bitumen from other sources is denoted as S-type and identified as grades S35, S90, etc [19-20]. Both of these types of paving bitumen are available in India. The paving bitumen is divided into two categories.

2.2 Types of Bitumen used in India

This bituminous substance is derived by the steam distillation of organic materials such as wood, coal shale, etc. The carbonation step of destructive distillation results in the formation of crude tar, which is then purified by distillation.The 60/70 and 80/100 grade bitumen.

Cut-back bitumen: The asphaltic bitumen is frequently blended with relatively volatile solvents to increase the material's workability. The solvent evaporates, leaving the particles bound together. Depending on the type of solvent employed, this cutback bitumen is categorized as slow, medium, or rapid curing.

Emulsions: An emulsifier is a combination of two liquids that are typically incompatible. In the presence of emulsifiers, asphalt becomes dispersed into minute globules in water. It enhances the workability of asphalt or bitumen. As a result of emulsification, asphalt is available in liquid form at room temperature [21-22].

2.3 Plain Bituminous Mix:

Bitumen is a naturally occurring, black, oily and viscous substance that is an organic result of the decomposition of other organic material. It was created by nature. Bitumen, which is also known as asphalt or tar, was typically utilized as a sealant, adhesive, building mortar, incense and decorative application on pots, buildings, or human skin throughout prehistory and all over the world. This was typically done by mixing bitumen with a variety of other materials. Canoes and other forms of water transportation frequently benefited from the application of this material's waterproofing properties. It is generally accepted that a well-prepared design of bituminous mix will end up resulting in a mix that is satisfactory.

Table 1 contains a discussion of the many physical characteristics of coarse aggregate, fine aggregate, and both.

- Robust
- Long-lasting
- Resistant to Fatigue and Permanent Deformation
- Eco-Friendly
- Cost-Effective etc.

2.4 Proposed Methodology

Following tests are used to evaluate the characteristics of aggregate and bitumen:

Analyses of aggregates

I. Specific Gravity and Water Absorption Test for Aggregates [IS: 2386]
II. Aggregate Impact Value Test [IS: 2386(Part4)1963]
III. Test for Aggregate Crushing Value [IS: 2386 (part 4) 1963]

IV. Index of Flakiness and Elongation [IS: 2386 (Part1) 1963]

Tests on Bitumen

I. Penetration Test for Bitumen [IS 1203-1978]
II. Test for Softening Point [IS:1205-1978]
III. Test of Ductility [IS:105-1978]
IV. Fire Point and Flash Point
V. Marshal Stability evaluation

Preparation of Design Mix

Selection of Blend Components

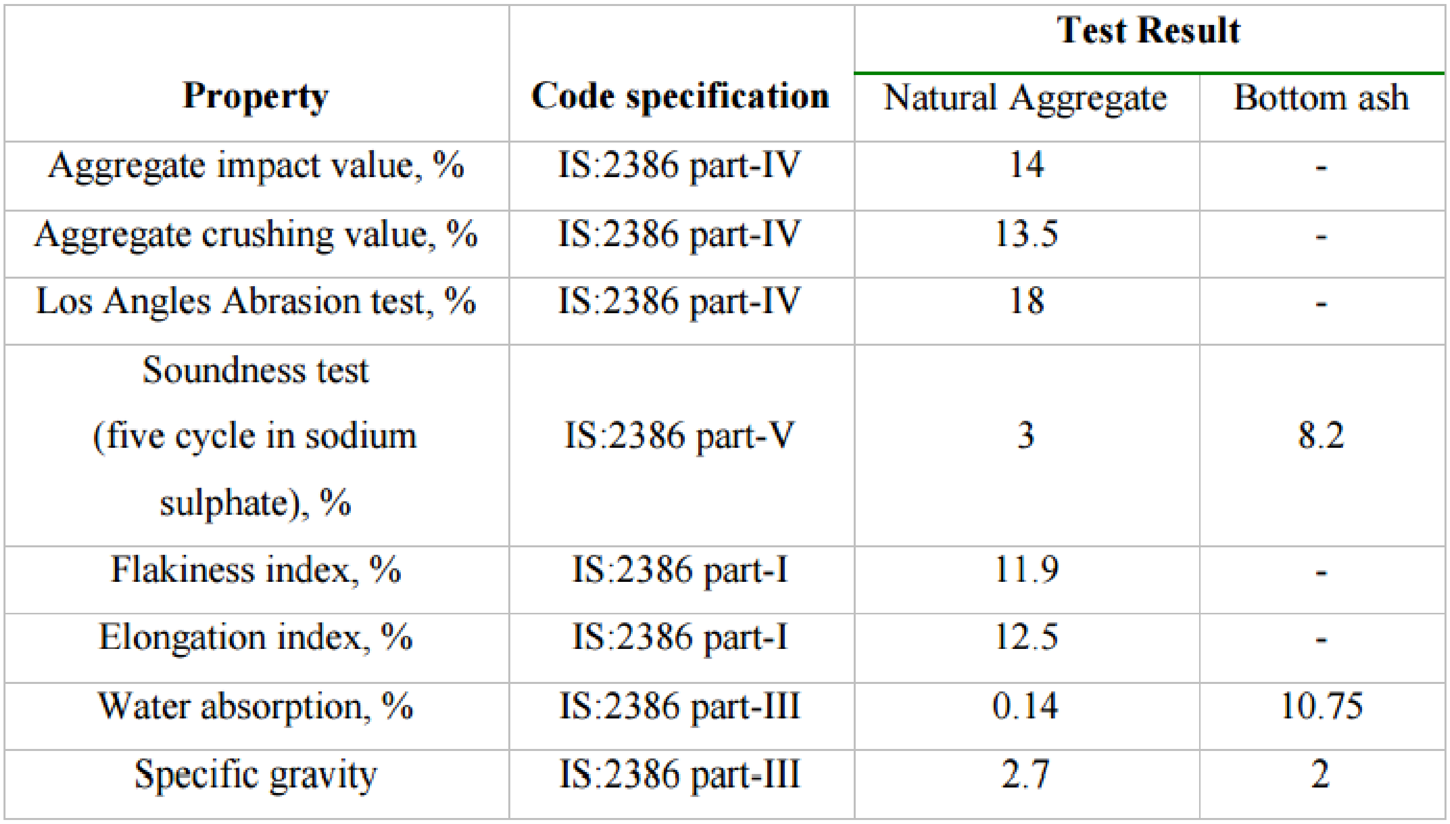
Diverse Mix Design Methodologies

Rather than a cohesive method, bituminous mix design is comprised of a number of distinct methodologies, each with its own advantages and disadvantages. The following actions describe some essential basic design strategies:

I. Recipe Method
II. Analytical Method
III. Performance Related Approach
IV. Mix Design Method
V. Empirical Mix Design Method
VI. Volumetric Method

The Bituminous Mix Design is chosen based on performance-related criteria. From time to time, the need for a decent Bituminous Mix Design varies.

Table 1: Physical property of coarse aggregate and fine aggregates



Property	Code specification	Test Result	
		Natural Aggregate	Bottom ash
Aggregate impact value, %	IS:2386 part-IV	14	-
Aggregate crushing value, %	IS:2386 part-IV	13.5	-
Los Angles Abrasion test, %	IS:2386 part-IV	18	-
Soundness test (five cycle in sodium sulphate), %	IS:2386 part-V	3	8.2
Flakiness index, %	IS:2386 part-I	11.9	-
Elongation index, %	IS:2386 part-I	12.5	-
Water absorption, %	IS:2386 part-III	0.14	10.75
Specific gravity	IS:2386 part-III	2.7	2

2.5 Coated Bituminous Mix:

A concerning amount of trash plastic is being produced at an alarmingly rapid rate. When they are molten, the three types of polymers that are most commonly encountered are polyethylene, polystyrene, and polypropylene. Each of these three forms of polymers possesses an adhesive quality. The accumulated bitumen mix that has been covered in plastic yields exceptional materials that can be used in the construction of flexible pavements. In addition to this, it exhibits better moral standards, which are generally attributed to Marshall Stability, and a Marshall Coefficient that is acceptable. As a result, the utilization of waste plastic in the production of flexible pavements is the solution that is not only the most appropriate but also the simplest to put into practice. Fig. 4 shows that the emulsion coating that was applied to the fiber as well as the oven-dried coating that was applied to the fiber. In many respects, the results obtained with polymer coated aggregates are superior to those obtained with polymer modified bitumen [23-24].

Research on the bitumen-plastic garbage mix and its qualities was prompted by the adhesive ability and thermal behavioral tests. The goal of the study was to determine whether or not the blend was suitable for use in the building of roads. The many steps that need to be taken in order to use waste plastic in the building of roads have already been carried out. After the aggregates had been heated, the necessary quantities of VG-30 bituminous mix and wrapped emulsion fiber pieces being added to the mixture, and it was thoroughly combined, as indicated in Figures 5 and 6.

2.5.1 Mixing Procedure at Hot Mix Plant:

As a component of the first step Utilizing a shredding machine, waste plastics such as plastic bags and bottles composed of PE and PP are chopped into sizes ranging from 2.36 mm to 4.75 mm. Before moving on to the next phase, it is important to ensure that any trash containing PVC has been removed.

In the second phase, the aggregate mixture is brought to a temperature of 165 degrees Celsius before being transported to the mixing chamber. In a similar manner, the bitumen should be heated to a max of 160 degrees Celsius. This is done in order to achieve a good connection and to avoid a weak bonding from occurring in the future. Keeping an eye on the temperature during this procedure is of the utmost importance. The shredded waste plastic is put on top of the heated aggregate later on in the third stage, which takes place in the mixing chamber. After 30 to 45 seconds, it will have covered the aggregate in a consistent manner all over. It gives the aggregate the appearance of being covered with oil. In the final stage, the aggregate that has been coated with waste plastic is combined with heated bitumen in the fourth process. After that, the finished mixture is put to use in the construction of roadways. The temperature for paving the road is between 110 and 120 degrees Celsius. The roller that is used ought to have a capability of 8 tonnes.

2.5.2 Mixing by Mini Hot Mix Plant

The initial step in the mixing stage is to use a shredding machine to cut waste plastic composed of PP, PE and PS into pieces ranging in size from 2.36mm to 4.75mm. These pieces will then be mixed together. During the second step, the bitumen should be heated to a temperature that is no lower than 160 degrees Celsius in order to achieve excellent binding and to avoid poor bonding. After this, the shredded waste plastic has to be mixed to the heated aggregate during the third step, which takes place in the mixing chamber. Within a period of thirty seconds, it covers the aggregate in a homogeneous coating, producing a plastic-coated aggregate that has the appearance of greasy. After that, the last step is to pour hot bitumen over the plastic-coated aggregate, and the resultant mixture is used for the building of roads. The temperature for paving the road is between 110 and 120 degrees Celsius. The roller that was used has a capacity of 8 tonnes.

2.5.3 Mixing by Central Mixing Plant (CMP)

A central mixing facility is also used for the dry processing method. On the conveyor belt, the chopped plastics are combined with aggregate in a mixing process. After that, this is placed into the heated cylinder. The bitumen is applied after the plastic has been applied to the aggregate. Plastic is applied first. Following this step, the mixer is put onto the dipper lorry, and it is driven to the location where the road will be laid. CMP enables much accurate temperature control and a more thorough mixing of this material, both of which contribute to the creation of a coating that is uniform. In order to properly investigate waste plastic material aggregate and bitumen, a variety of field testing and lab studies are required. This part provides information on the physical requirements of bituminous mix, the characteristics of plastic and the processing of plastic waste products for chopping up on aggregates [25-26].

Marshall Specimen preparations with complete bitumen non-modified index:

To ascertain the ideal binder concentration of controlled mix, Marshall Specimens were cast using 100% bitumen non-modified binder and aggregate blend. Approximately 1200 grams of aggregate were removed from the mixture that had been made and dried heated in an oven at temperatures ranging from 150 to 175 degrees Celsius. Concurrently, the binders are warmed at temperatures ranging from 150 to 160 degrees Celsius. Both the binder and the aggregate were thoroughly combined using a mixing jacket at a temperature of 165 degrees Celsius for a grade of bitumen measuring 60/70. After the binder layer had fully covered the aggregate, the mixture was ready to be compacted, at which point it was set in a mould that had been preheated to between 100 and 140 degrees Celsius. The specimen was subjected to impact loading with the use of a conventional hammering (75 blows). Following the completion of the chilling process, a specimen was taken from the mould using a sample extractor. Following demolding and chilling, samples were kept immersed under water in a thermostatic water bath that was sustained at 61°C for 30 to 40 minutes before to being put to the test. After that, samples were run through the Marshall Testing Machine to determine their stability and flow parameters. Both the penetration test and the stability test were carried out in the lab and the results are shown in Fig. 7.

Figure 7(a) depicts the penetration test and the softening point test, where the penetration test was conducted to evaluate the consistency of the binders and the softening point test was conducted to determine the temperature at which the binders would soften to a specific degree. Marshall Sample preparation and analysis utilizing modified binders: Upon completion of the Optimum Binder Content (OBC) calculation, the standard approach required the fabrication of Marshall Samples using an aggregate mix and a mix capable of construction. Determining the proper binder concentrations in a controlled mixture therefore the OBC of a mixture of bituminous concrete was determined by generating a Marshall Sample with a binder content varying from 5 to 7 percent and performing stabilization and volumetric analysis as recommended. This enabled the OBC to be computed. Fig. 8 represents the Marshall specimen after plastic or rubber components were added to the bitumen binder. These additives were utilized to improve the binder's characteristics. The term "Optimum Bitumen Content" refers to the value that corresponds to optimum stability, maximum bulk density, and 4% air voids in the BC mix. This number is computed based on the mean bitumen content. Both the flow value and the percentage of voids in the mineral aggregate must fall within the limits specified by MORTH, 2013 for the bituminous concrete mixture [27-28].

The production of samples and the testing of modified binders by Marshall: Following the completion of the optimum binder content calculation, the Marshall Samples were made using a customized binder and aggregate mix in accordance with the normal process. Fig. 9 demonstrates that the modified binders were used for casting the Marshall specimens. The *ductilimeter* that is used for the quantitative measurement of flexibility of others and non-modified materials.

The Digital Marshall Test Apparatus was used to examine the samples that had been prepared. After the specimens were inserted inside of the head assembly, the inspection head was moved into the appropriate location inside the loading machine. Whenever the loading unit was activated on the Digital Marshall Testing Machine, the bottom plate was lifted with the assistance of a mechanical jack. A consistent pace of 51 millimeters per minute was used to apply the load. The digital plate was used to record the maximum load value as well as the flow measurements that corresponded to it. Table 2 presents information on the aggregate's mechanical properties.

Table 2: Mechanical Properties of Aggregate

Type of Test	Test Method	Result	MORTH,2013 SPECIFICATIONS
Aggregate Impact Test	BS812: Part3	18.12%	<27%
Los Angeles Abrasion Test	ASTM: C131	26.7%	<35%
Aggregate Crushing Test	BS812: Part3	22.32%	<30%
Water Absorption Test	ASTM: C127	1.5%	<2%
Specific Gravity (Coarse aggregate)	ASTM: C127	2.47%	2-3%
Specific Gravity (Fine aggregate)	ASTM: C128	2.55%	

2.6 Characteristics of polymer modified bitumen

Another method for reusing waste plastic is now being investigated, in which the plastics are combined with bitumen and utilized for the preparation of the mix. The mixture was put to use in an investigation of the fundamental aspects of bitumen, including its softening point, penetration point, and ductility. Both the ductility and the penetration value have been brought down to extremely low levels. When more than 4% of waste plastics are added to the bitumen, the outcome is polymer modified bitumen that is very rigid and has very poor viscoelastic behavior.

3. Results And Discussion

On the basis of the methods described above, the following topics pertaining to polymer coated aggregates will now be examined in more detail:

3.1 Static indirect tensile test

In accordance with ASTM D 6931 (2007), a statically indirect tensile strength of bituminous mixtures was carried out in order to evaluate the resistance to heat cracking of a Marshall cylinder that was loaded in a vertical diametrical plane. The purpose of this evaluation was to determine whether or not the bituminous mixtures could withstand heat cracking. The reading that was taken from the dial gauge of the testing instrument was used to record the load at which tensile cracks first began to show in the specimen, which was then incorporated into a computation. Resistance to moisture damage (Tensile Strength Ratio (TSR). The ratio of tensile strength was used to determine how resistant bitumen mixtures were to the effects of being exposed to moisture. The test is quite similar to a static indirect tensile test; the main difference is that the specimens were processed in a gyratory crusher with 7% air space and specimen dimensions ranging from 151 mm in diameter to 63 mm in height. After preparing six samples with the same average air void, the data was split into two groups. Using a vacuum chamber and trying to apply a vacuum pressure of 70 kPa or 526 mm Hg for a short period of time such as five minutes, one subset was partially saturated so that it could be moisture influenced with distill water. After that, the partially saturated samples were cured so that they could be moisture compelled in filtered water at 61 + 1°C for 24 hours [29-30].

3.1.1 Static creep test

This kind of testing is used to examine how resistant bituminous mixes are to the occurrence of persistent deformation when subjected to a range of temperatures. Samples were created for the static creep test with the binder content, fiber content and fiber length optimized to achieve maximum performance. The evaluation was carried out in accordance with the Specification issued by the Texas Department of Transportation (2005).

3.1.2 Static indirect tensile test

The static indirect tensile test was conducted on the four sample types listed below.

I. Sample including biomass and coal ash
II. Sample containing coal ash
III. Sample devoid of cellulose and coal ash
IV. Sample containing fibre
V. Parameters used in the study

The value of each and every Marshall Property was determined by using the equation of concerns as well as any other applicable mathematical procedures. Fig. 10 depicts the pattern of crisscrossing that occurs in sisal fibers as they break under tensile stress. Plant fiber is used as fill along with the matrix in foamed concrete in order to enhance the foamed concrete's poor mechanical qualities, which are a direct consequence of the more number of pores [31-32].

3.2 Aggregate Impact Value:

The experiment found that the aggregate impact value is 18.13%, which is adequate for the paving of roads. The uses of a plastic coating raise the aggregate's impact value, which in turn increase the aggregate's overall quality. In addition, coating aggregate with polymers can make it useful, even if the aggregate itself is of low quality. It contributes to the enhancement of the quality of pavement structure and demonstrates that the aggregate's resistance to impacts and ranges should be lower than 10 percent. Table 3 represents that the results of measurements conducted to determine the tensile strength of fibers containing different amounts of DBM.

Table 3: Tensile strength measurement of various DBM contents fibers

Tensile strength ratio			**Design requirement**
Type of mixes	**Type of mixes**	**Type of mixes**	Minimum 80% (as per MORTH specification)
DBM With fiber	DBM With fiber	DBM With fiber	
DBM Without fiber	DBM Without fiber	DBM Without fiber	

3.2.1 Aggregate Crushing Value:

As a result of the experiment, the aggregate crushing value is 22.33 percent. The road would have a longer life span if it was constructed using aggregate that had a lower crushing value since this would suggest a lower crushed percentage under load. Less robust material would be crushed by the weight of the traffic. Table 4 makes it abundantly evident that plastic-coated aggregates exhibit a lower crushing value and are able to sustain traffic stress more effectively than plain aggregates. This information may be gleaned from the Table 4. According to ISS, the findings demonstrate that the aggregates fall within the acceptable range. Its range needs to be lower than 30 to 35%, at most. The long-term, continuous loading that is created by this static creep test is used to evaluate the level of permanent deformation. The deflection value for the DBM sample that was prepared with 0.5% fiber content, 10mm fiber length, 14% coal ash by weight of the mix and optimal binder content of 5.6 percent by weight of the mix significantly decreased when compared to other modified and unchanged DBM mix, as was observed from the deflection and time graph that was presented in Fig. 11. The change in the sample's deformation value as a function of time and temperature at 400 degrees Celsius is depicted in Figure 11.

Additionally, it has been demonstrated that the deformation value of a combination is reduced in contrast to the value of a regular mixture. This occurs when fiber or coal ash is added to the combination. The ability of DBM mixtures to retain water is compared in Table 4, both with and without the addition of fiber and coal ash concentrations [33–34].

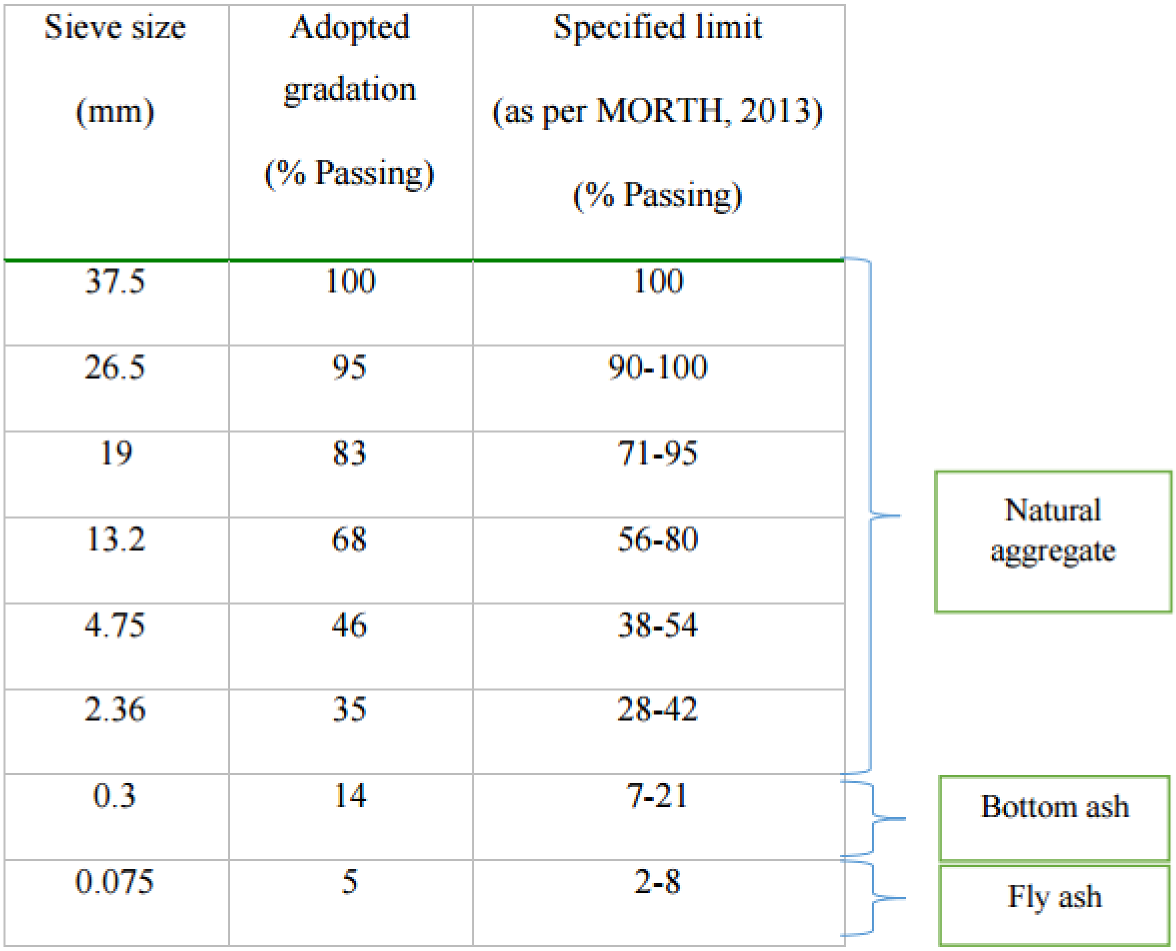
Table 4: Retained stability of DBM mixes with and without fiber and coal ash

Retained stability				
Type of mixture	**Avg. stability after half an hour in water at 60°C(kN)**	**Avg. stability after 24 hours in water at 60°C(kN)**	**Avg. retained Stability (%)**	**Design Requirement**
DBM with fiber and Coal ash	14.78	13.21	89.37	Minimum 75% (as per MORTH specification)
DBM with Coal ash	13.88	10.17	73.21	
DBM with fiber	12.63	10.10	79.94	
DBM without fiber and Coal ash	13.56	10.45	77.03	

3.3 Specific Gravity

A sample aggregate has a specific gravity of 2.56. An aggregate's strength may be estimated indirectly by looking at its specific gravity. The strength increases with increasing specific gravity. Comparing plain aggregate to aggregate with a plastic coating, the relative density of plain aggregate is lower. Since aggregates with low specific gravity values are often weaker than aggregates with relatively high specific gravitational values, the findings indicate that the raising of aggregates' strength increases their specific gravity. It should fall between 2.6 and 3.0%. Table 5 discusses the aggregate gradation in the concrete components.

Table 5: Gradation of aggregate in the concrete materials

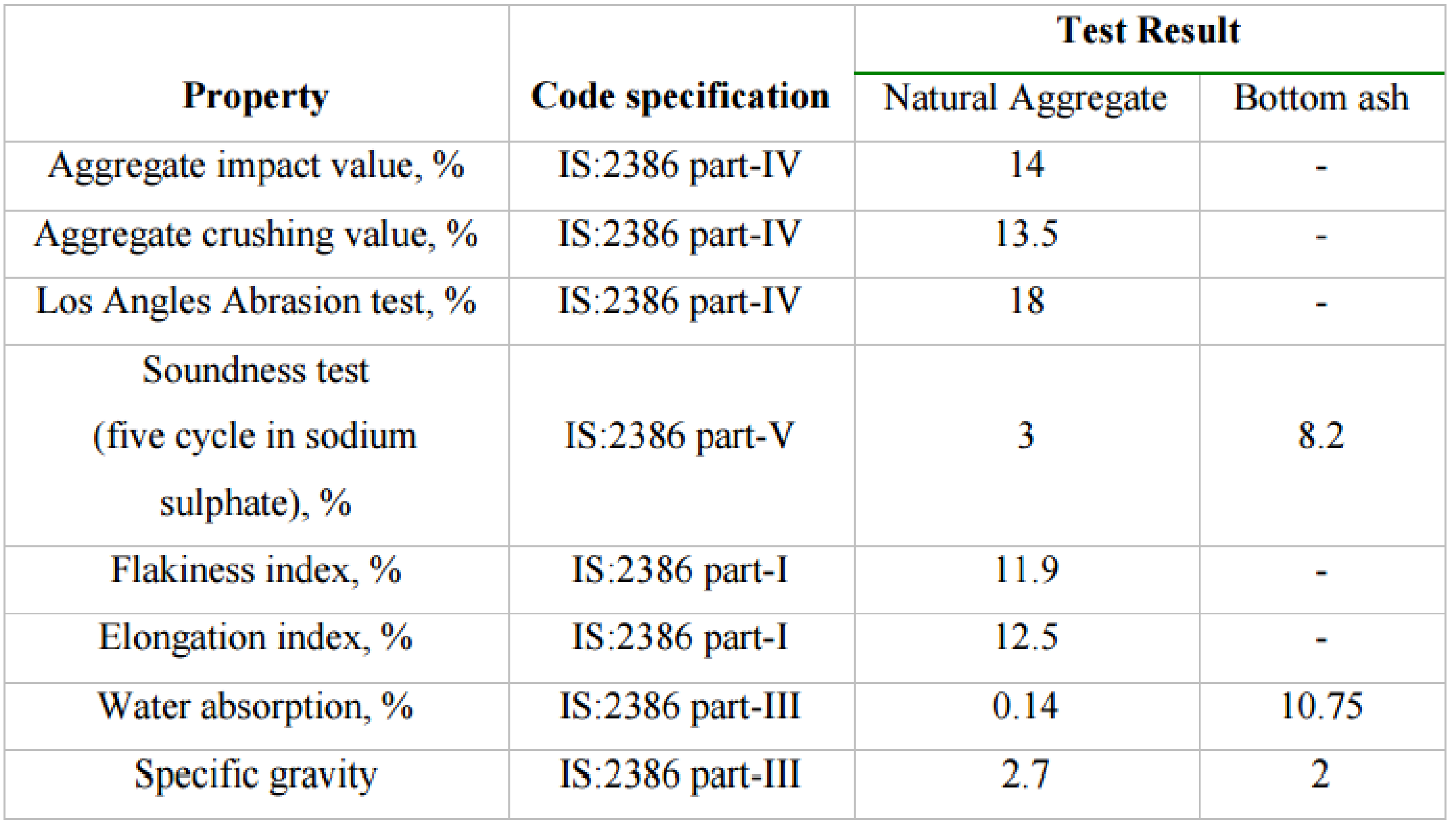


Sieve size (mm)	Adopted gradation (% Passing)	Specified limit (as per MORTH, 2013) (% Passing)	
37.5	100	100	Natural aggregate
26.5	95	90-100	
19	83	71-95	
13.2	68	56-80	
4.75	46	38-54	
2.36	35	28-42	
0.3	14	7-21	Bottom ash
0.075	5	2-8	Fly ash

3.3.1 Los Angeles Abrasion Value

Los Angeles abrasion value determined by the experiment is 26.7%. The pavement will experience some deterioration as a result of the vehicles' repetitive motions. This test provides percentages of wear and tear. According to this study, the proportions of wear and tear values of plastic coated aggregates decrease as the percentages of plastic increases. Table 6 discusses the physical properties of coarse aggregate and fine aggregate. When the abrasion value of plain aggregate in Los Angeles is compared to that of aggregates coated with plastics, coated aggregates have lower values. The acquire finding are within the rages, thus they can be used for construction [33-36]. It range should be less than 35%. Figure 6 depicts the aggregate graduation curve analysis for various types of particles included in the concrete ingredients.

Table 6: Physical property of coarse aggregate and fine aggregates



Property	Code specification	Test Result	
		Natural Aggregate	Bottom ash
Aggregate impact value, %	IS:2386 part-IV	14	-
Aggregate crushing value, %	IS:2386 part-IV	13.5	-
Los Angles Abrasion test, %	IS:2386 part-IV	18	-
Soundness test (five cycle in sodium sulphate), %	IS:2386 part-V	3	8.2
Flakiness index, %	IS:2386 part-I	11.9	-
Elongation index, %	IS:2386 part-I	12.5	-
Water absorption, %	IS:2386 part-III	0.14	10.75
Specific gravity	IS:2386 part-III	2.7	2

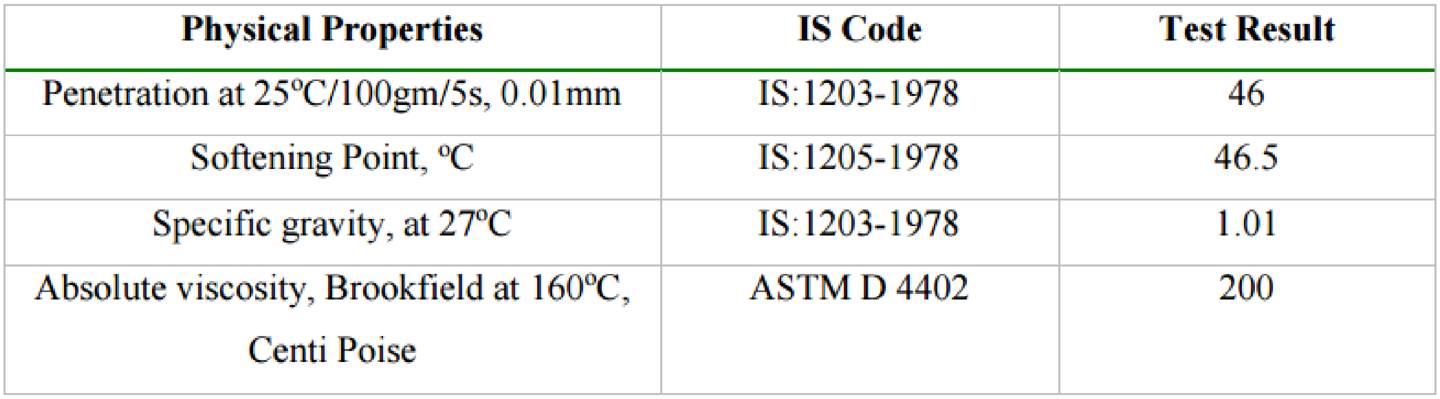
3.3.2 Marshall Stability value

The Marshall Stability was performed on both unmodified and changed mixtures. For each type of mixture, three samples were generated, and the average stability value was analyzed. Marshall Stability value of controlled mix (6% by weight of aggregate) is 9.06 kN, which meets the minimal BC mix stability standard. BM9 (84%B + 6%P + 10%R) of series C had the highest level of stability, followed by BM6 (90%B + 10%R) of series B and BM3 (92%B + 8%P) of Series A. The stability values of the tertiary mix, BM9 (53%), binary mix, BM6 (45%), and tertiary mix, BM3 (16%) are much greater than the stability value of the unmodified mix. The Marshall stability of bitumen is illustrated in Fig. 13. These results demonstrate that the modified binder mixture containing rubber and/or plastic wastes is more stable than regular bituminous mix. Almost all changed mixtures have higher stability ratings than unmodified mixtures [37-38].

3.4 Marshall flow value

The flow value of bituminous mixes was found to increase in each series along with an increase in the percentage of waste additives that were used in their replacement. The flow value of the non-modified mix is 3.8 millimeters, and the flow value of the tertiary optimum modified mix, BM9, is 3.9 millimeters. Both of these values fall within the specified range of 2–4 millimeters. Table 7 contains a discussion of the physical properties of binders that are relevant to the application of concrete. The flow value of the optimal binary modified mix, or BM3, which is 3.35 millimeters, and BM6, which is 3.7 millimeters, is likewise within the limit that has been given. Mixes that contain more than 10% rubber as replacements have flow values that are significantly higher than average [39-40]. The Marshall Flow studies of various percentages of fiber and bitumen content are shown in Fig. 14, as may be seen there.

Table 7: Physical Property of Binders apply in the concrete



Physical Properties	IS Code	Test Result
Penetration at 25°C/100gm/5s, 0.01mm	IS:1203-1978	46
Softening Point, °C	IS:1205-1978	46.5
Specific gravity, at 27°C	IS:1203-1978	1.01
Absolute viscosity, Brookfield at 160°C, Centi Poise	ASTM D 4402	200

3.5 Bulk density

The bulk density of the combination in its natural state is 2.320 g/cc. In binary series the maximum value of bulk density was obtained somewhere around 2.362 g/cc (BM3) for 8% replacement of bitumen by waste plastic. On the other hand, in series B the maximum value of bulk density was achieved somewhere around 2.328 g/cc (BM6) for 10% replacement of bitumen by waste rubber. Table 8 discuss about characteristics of bitumen that has been applied with polymers. Maximum density of 2.331 g/cc (BM9) was discovered to be achieved in series C of the tertiary mixes. This was accomplished by replacing 16% of the bitumen with a combination of waste plastic (6% of the total) and rubber (10%). It was exposed that each of these number is more than the density of the mix that has not been adjusted. The different amounts of fibers are present in the bitumen contents, together with their effects of the flow value depending on their length are depicted in Fig. 15.

Table 8: Properties of Polymer Modified Bitumen

Percentages of plastics	Ductility (cm)	Penetration (mm)	Softening point (°C)
1%	66	93	56
2%	56	89	51
3%	23	80	50
5%	16	60	78

3.6 Air voids:

Air voids in the unmodified BC mix were determined to be 3.72%, which is well within the permissible limits according to MORTH (2013). In all changed mixtures, the percentage of overall air spaces increases as the amount of waste materials replaced with bitumen increases. This is because the density of waste additives integrated in BC design varies. Figure 16 depicts the variations in unit weight and bitumen contents caused by the applications of different fiber percentages.

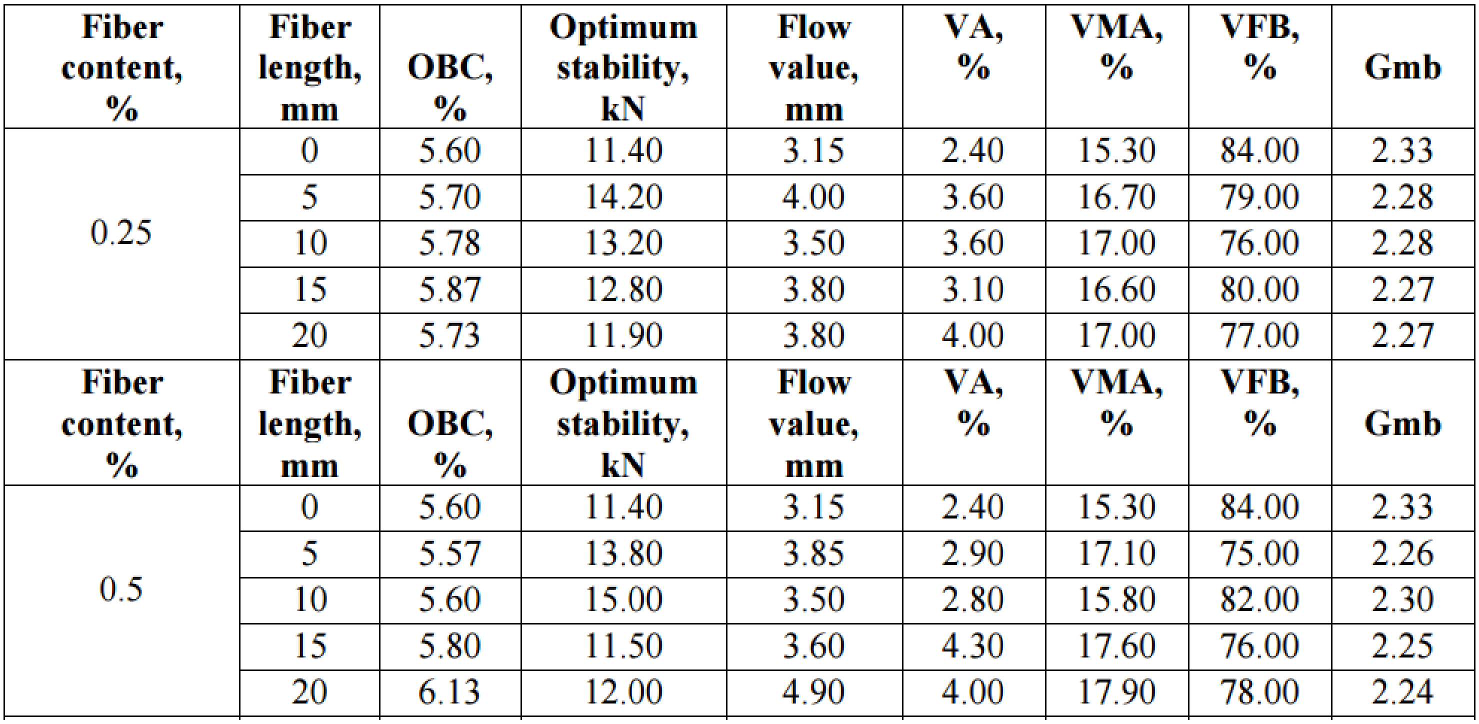
3.7 Voids in mineral aggregate:

Voids in mineral aggregate is found to be 12.07% in non-modified mix, which is well within the specified limits that depend upon nominal maximum size of aggregate and design air voids. Overall voids in mineral aggregate increase with increased in the partial replacement percentage of waste additives in all three modified mixes. The various percentages of fiber length at VMA vs Bitumen contents are shown in the Fig. 18.

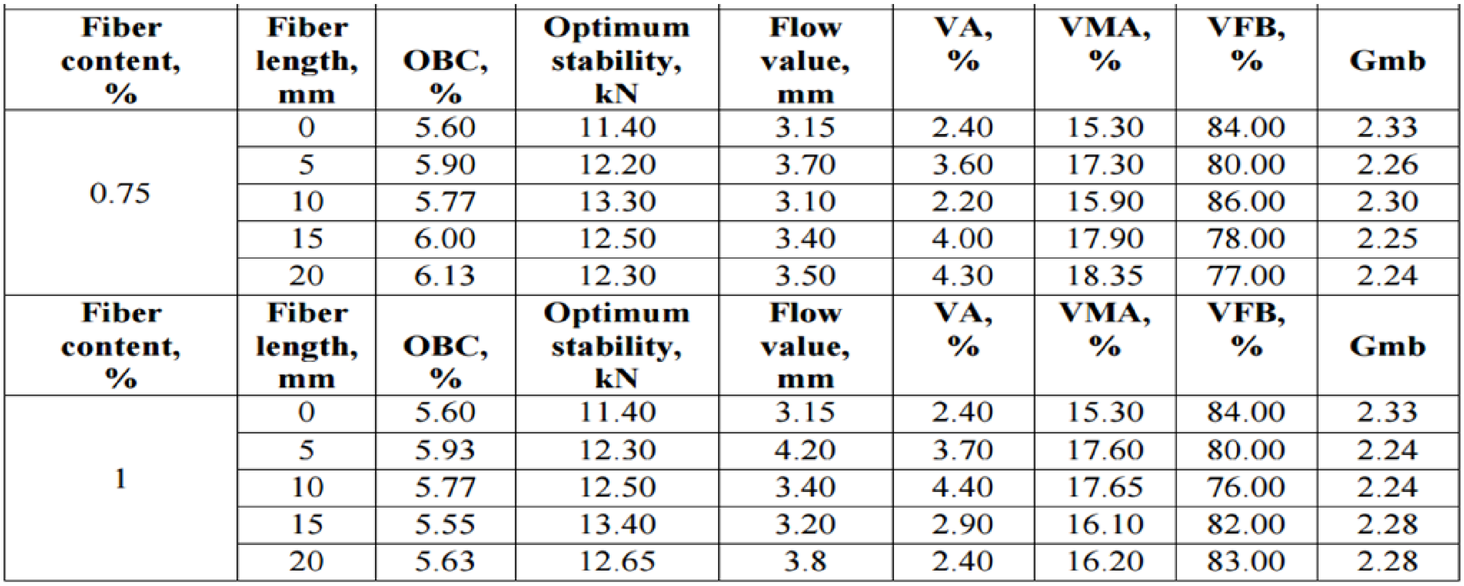
In this study, several features of mixtures of SMA, BC, and DBM were explored. These parameters included Marshall Properties, drainage characteristics, static tensile strength and static flow characteristics. Bitumen and carbon were the only two components of the mixtures used. Polyethylene with penetration degree of VG 30 nevertheless, certain of the features, such as tear resistance, dynamic characteristics of indirect tensile strength, and dynamic creep behavior, needed to be researched further. These include fatigue properties, tear resistance, and dynamic characteristics. During the dry mix process, the polyethylene is included into the mix. In addition to this, polyethylene can be utilized in the process of wet mixing bitumen in order to get the desired modifications. To measure the degree of homogeneity of the modified bituminous mixture, it is necessary to observe the microstructure of the mixture using the approach that is most appropriate [41-42].

The combination of soil mixtures formed with other types of widely available plastic wastes, wastes to replace conventional fine aggregates, and loads of different types of binders, including modified binders, should be attempted to explore the sufficient scope research of materials. It suitable for soil mixes in today's demanding situations. The various percentages of fiber length VFB vs fiber contents of the materials is shown in the Fig. 19. Thus, using a higher rate of polyethylene waste is not ideal [43-44]. The different percentages of fiber contents effects on the stability, flow value and VA%, VMA% and VFB% are discussed in the Table 9. Although there is discussion of ecological contamination due to this waste of non-biodegradable plastics in which the transfer of such materials has become a difficult problem, its use in the development of adaptive asphalt will give a higher place to its coverage and, thereafter it will take care of the question of its transfer on the other hand and give a superior adaptive asphalt with an improved finish on the other hand [45-46].

Table 9: Various percentages of fiber contents effects on the stability, flow-value and VA%, VMA% and VFB%



Fiber content, %	Fiber length, mm	OBC, %	Optimum stability, kN	Flow value, mm	VA, %	VMA, %	VFB, %	Gmb
0.25	0	5.60	11.40	3.15	2.40	15.30	84.00	2.33
	5	5.70	14.20	4.00	3.60	16.70	79.00	2.28
	10	5.78	13.20	3.50	3.60	17.00	76.00	2.28
	15	5.87	12.80	3.80	3.10	16.60	80.00	2.27
	20	5.73	11.90	3.80	4.00	17.00	77.00	2.27
Fiber content, %	**Fiber length, mm**	**OBC, %**	**Optimum stability, kN**	**Flow value, mm**	**VA, %**	**VMA, %**	**VFB, %**	**Gmb**
0.5	0	5.60	11.40	3.15	2.40	15.30	84.00	2.33
	5	5.57	13.80	3.85	2.90	17.10	75.00	2.26
	10	5.60	15.00	3.50	2.80	15.80	82.00	2.30
	15	5.80	11.50	3.60	4.30	17.60	76.00	2.25
	20	6.13	12.00	4.90	4.00	17.90	78.00	2.24



Fiber content, %	Fiber length, mm	OBC, %	Optimum stability, kN	Flow value, mm	VA, %	VMA, %	VFB, %	Gmb
0.75	0	5.60	11.40	3.15	2.40	15.30	84.00	2.33
	5	5.90	12.20	3.70	3.60	17.30	80.00	2.26
	10	5.77	13.30	3.10	2.20	15.90	86.00	2.30
	15	6.00	12.50	3.40	4.00	17.90	78.00	2.25
	20	6.13	12.30	3.50	4.30	18.35	77.00	2.24
Fiber content, %	**Fiber length, mm**	**OBC, %**	**Optimum stability, kN**	**Flow value, mm**	**VA, %**	**VMA, %**	**VFB, %**	**Gmb**
1	0	5.60	11.40	3.15	2.40	15.30	84.00	2.33
	5	5.93	12.30	4.20	3.70	17.60	80.00	2.24
	10	5.77	12.50	3.40	4.40	17.65	76.00	2.24
	15	5.55	13.40	3.20	2.90	16.10	82.00	2.28
	20	5.63	12.65	3.8	2.40	16.20	83.00	2.28

4. Findings From Above Investigation

Plastic garbage and its disposal is an environmental problem that contributes to pollution and global warming. The incorporation of plastic waste into BM can enhance the material’s mechanical strength and chemical stability. Nonetheless, this strategy will undoubtedly be effective for addressing plastic waste disposal and enhancing the quality of flexible pavements. For instances PE, PS and PP based plastic waste can be used as an alternative to bitumen. To employ plastic waste as a modifier of the BM is feasible as only a few researchers reported that the addition of plastic waste degraded the properties, while the majority of researchers found that the addition of plastic waste improved the properties of BM, bitumen and aggregates air voids percentage is the sole metric that increases with plastic addition; this problem can be solved by incorporating an optimal amount of plastic into BM so that its qualities are enhanced and air voids percentages within an acceptable range and does not pose a problem. In certain instances, plastic addition lowered the cost of flexible pavement maintenance. Therefore the concept of using waste plastic materials in flexible pavement in worth implements [49-52]. Figure 20 depicts the adaptability of plastic waste uses in pavements based on several parameters analysis.

4.1 Processing Techniques

Research on incorporating plastic into pavement can be subdivided in a number of ways, such as by the kind of plastic waste treatment, types of plastic utilized, layer of a flexible pavement modified, etc. In this study, the research is split based on the processing techniques of modification. There are two traditional procedures: the wet process and the dry process. However, some researchers have modified these conventional techniques in order to improve the performance of pavement.

4.2 Wet process

The wet method is one of the modification processes in which a modifier is added to bitumen and mechanically mixed until a homogenous solution is obtained at a temperature of 170^{o}C. The modified bitumen is then added to heated aggregates (170^{o}C) and stirred for some time to achieve homogeneity. At 120^{o}C, the mixture is compacted over the pavement. Figure 21 depicts a diagram of the wet process.

In order for researchers to evaluate the effects of wet process modifications, they used one of two methodologies:

(i) They used the full wet process to create modified BM and then carried out qualifying tests such as the Marshall stability and flow test or other performance tests such as the wheel tracking test in order to evaluate whether or not a modifier caused an improvement or deterioration in the material.

(ii) The second approach is to simply change the binder, which is bitumen, by mixing it with a modifier. This is done in place of the entire wet process. After this, qualification tests on the modified binder are carried out. These tests include the penetration test, the softening point test, and others. There were a limited number of researchers who used both techniques to analyze the impact of alterations in more depth. The initial process that was employed for the modification was the wet process, and the rest of the ways were developed at a next time. It has only been reported by a small number of studies that the wet process represents better performance when compared to the dry method, and that this approach is capable of adding more than 10 weight percent of the optimal binder content (%wt) in plastic. Second, because the wet process is used more frequently than the dry process, more study is done on the wet process [55-56].

4.3 Dry process

The dry process is a modification technique in which a modifier is applied to preheated (170°C) aggregates and stirred to coat the aggregates uniformly with modifiers. Then, 160°C-hot bitumen is added to the mixer and blended for a period of time to achieve uniformity in the modified BM. At a temperature of 120°C, the mix is compacted. Similar to the wet process, two methodologies were used by the researchers to observe the changes brought about by the dry process modification. The first methodology was to use the complete dry process to form modified BM and conduct qualifying tests or other performance tests to observe the impact of a modifier. Some studies even employed both approaches to change aggregates by mixing them with a modifier and not adding a binder, and then performing qualifying tests on aggregates such as crushing value test [57-58]. Fig. 22 represents the schematic application of the dry manufacturing technique in pavements.

Researchers have chosen to employ the dry processing methodology because it allows for the addition of a greater quantity of plastic, it is inexpensive, it does not involve the purchase of any new equipment, and this method of modification may be quickly adopted by the industry. Second, there is no emission of fumes during the modification process, in contrast to the wet procedure, which emits fumes during the modification of bitumen [59-60].

The many benefits that comes to utilizing the plastic materials in bituminous roads

Increase the percentage of plastic garbage used

Reduce the demand for bitumen by approximately 10%

Enhance the durability and functionality of the road

Reduce the cost of a single-lane road to roughly Rs 5,000 per kilometer

Create employment for rag pickers

Develop an eco-friendly technology

Improvements to the fatigue life of roads

Absorption of traffic-related gases by smoke absorbent

Negative aspects of using plastic in bituminous roads

During the cleaning process, the toxin-containing plastic trash would begin to leach.

During the road-building process, the presence of chlorine will cause the emission of poisonous HCL gas.

5. Conclusions

Following are some more important conclusions drawn from the above experimental studies of modified and non-modified BC mixes:

I. The results indicated that the partial substitution of bitumen with rubber and plastic waste contributions to the improvement of Marshall Stability values. This contributed to the overall improvement of the mix’s strength qualities and also increases the mix’s density.
II. Mixture having a high density performs well in road construction. In addition, the anticipated mix cost study demonstrates that the use of various waste additives in BC mix aids in road construction and makes it more cost-effective than non-modified mix.
III. Various materials that become waste after their service life, such as rubber tyres and plastic bottles can be used as a partial replacement in bitumen concrete mix to assist meet the rising demand for bitumen in road building.
IV. The study’s finding indicates that the addition of waste rubber tyres and plastic bottles improves the strength and overall longevity of the BC mix by double its overall performance. With the application of these waste materials in the specified quantities, it is possible to produce the desired features of BC.
V. Utilizing waste materials such as rubber tyres and plastic bottles in bituminous concrete mix may help reduce the cost of road construction. In addition, it may aid in preventing the environmental contamination caused by the disposal of such waste materials in the ground.
VI. Residual fibers improve the quantities of bitumen, such as its point of penetration and softening. There is a substantial decrease in the penetration values for the changed mixtures, indicating an improvement in their resistance to temperature.
VII. Due to the increased viscosity of the bitumen, the softening point rises as the fraction of fibers increases. The results indicate that modified bitumen containing less than 0.7% fibers can be used satisfactorily in road construction, whereas modified bitumen containing more than 0.7% fibers can be utilized satisfactorily in both road building and as roofing materials.
VIII. As the percentages modifier grows, the ductility value declines, although the rate of loss slows when more than 0.5% fiber is added. Less than 50cm of ductility should not be utilized in road construction, although it can be used as filler for cracks and joints. With the addition of polythene, the Marshall flux value is observed to drop, hence increasing the resistance to deformation under heavy wheel loads.
IX. The plastic road would be advantageous for India's hot and extremely humid climate, where ecological and sustainable paths will rid the land of all types of plastic garbage.

Declarations

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There are no conflicts of interest declared by the authors.

Data Availability Statement

The paper's claims are appropriately cited in the publication, and no extra information is accessible.

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Figures

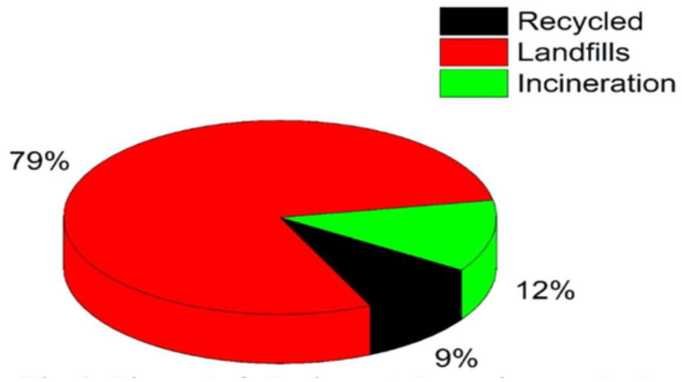

Figure 1

Disposal of plastic waste by various methods

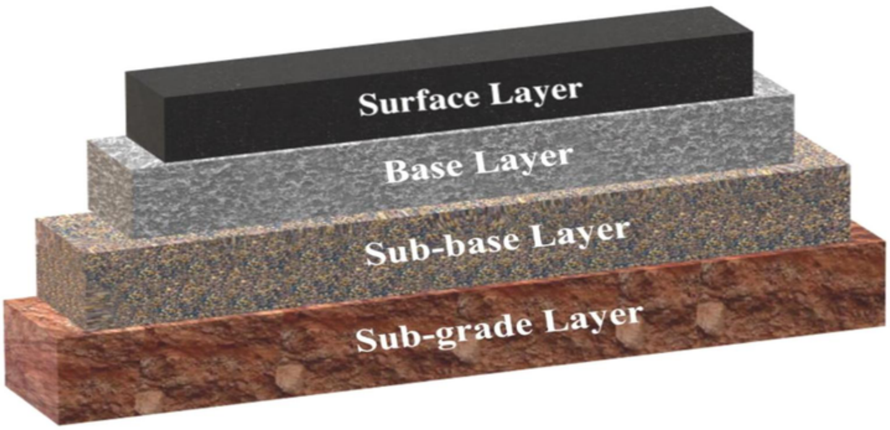

Figure 2

Layer in flexible pavement

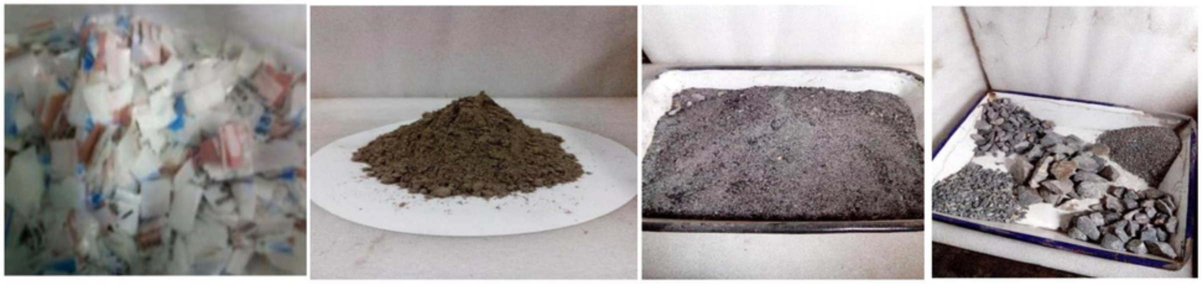

Figure 3

Collections of various waste materials plastic waste, fly ash, bottom ash and dry stone ash

Figure 4

Coating of emulsion on fiber and Oven dry coated fiber

Figure 5

Cutting of coated fiber and addition and mixing of fiber

Figure 6

(a) Pouring of mixture in mould, (b) Compaction of mixture in progress, (c) DBM samples and (d) Marshall test in progress

Figure 7

(a) Penetration test and (b) Marshall stability test

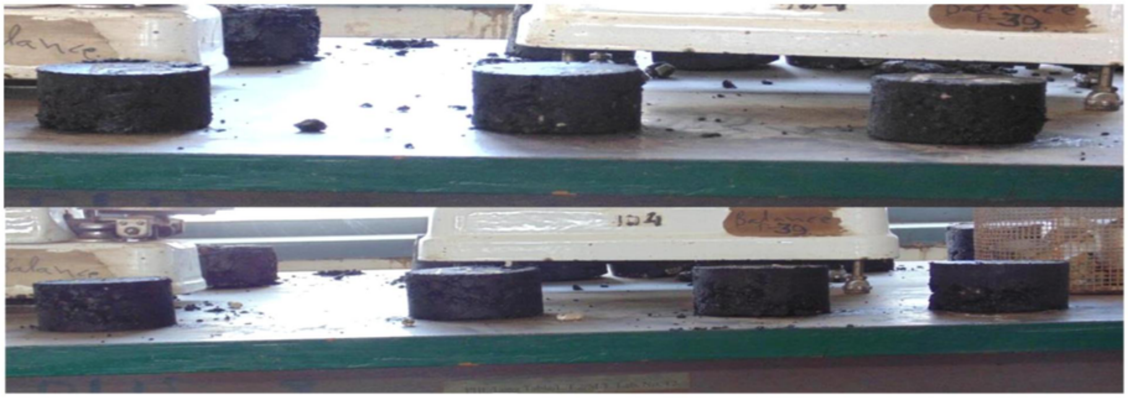

Figure 8

Marshall Specimen with plastic/rubber and bitumen binder (binary mix)

Figure 9

Marshall Specimen with plastic and rubber and bitumen binder (tertiary mix)

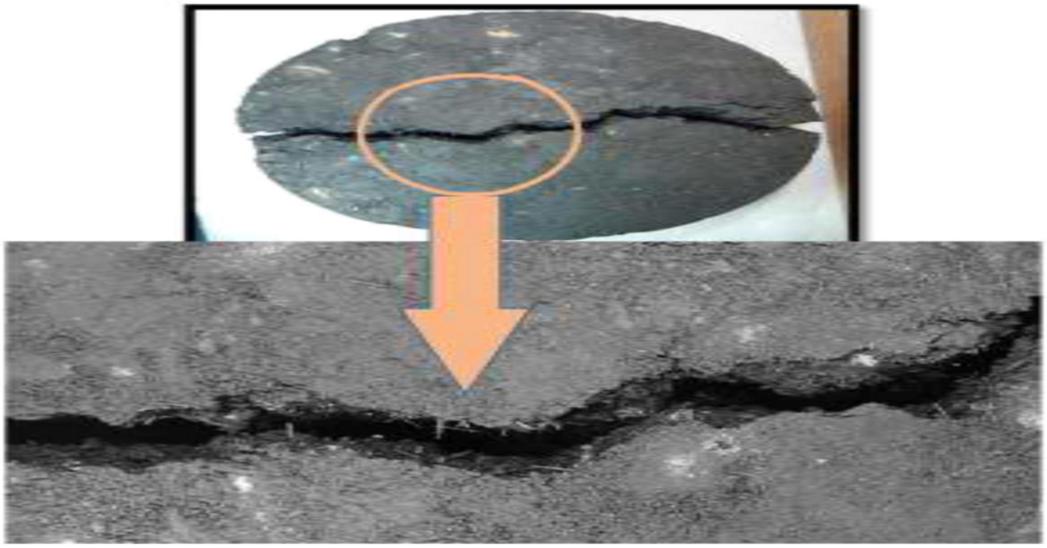

Figure 10

Criss-cross pattern of sisal fiber at tensile failure crack

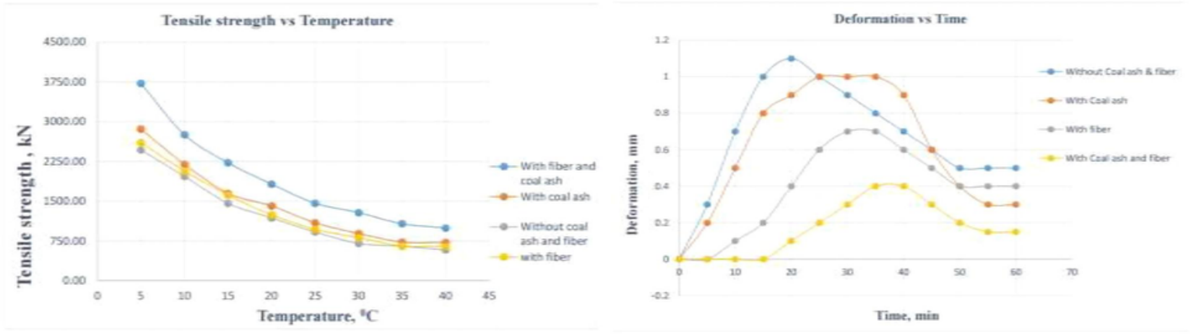

Figure 11

Variation of deformation value at 400oC for DBM sample with respect to time

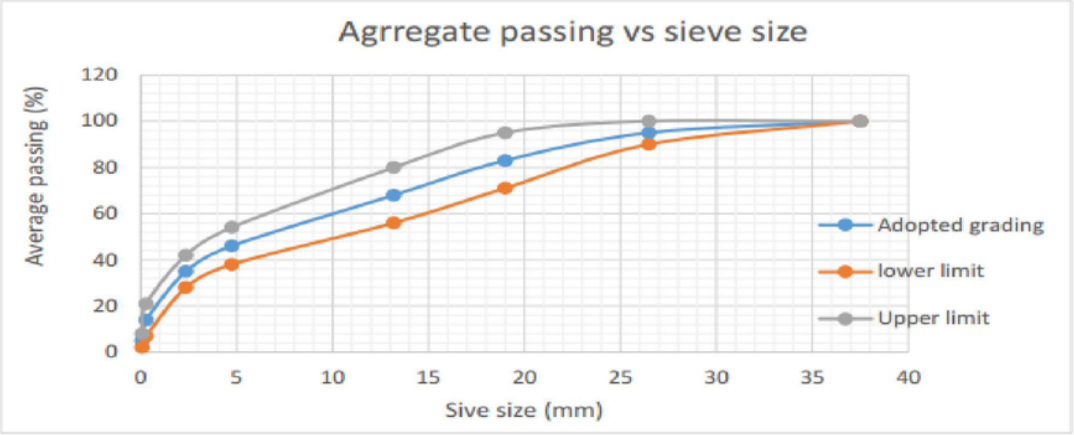

Figure 12

Aggregate gradation curve analysis for various types of particles present in the concrete materials

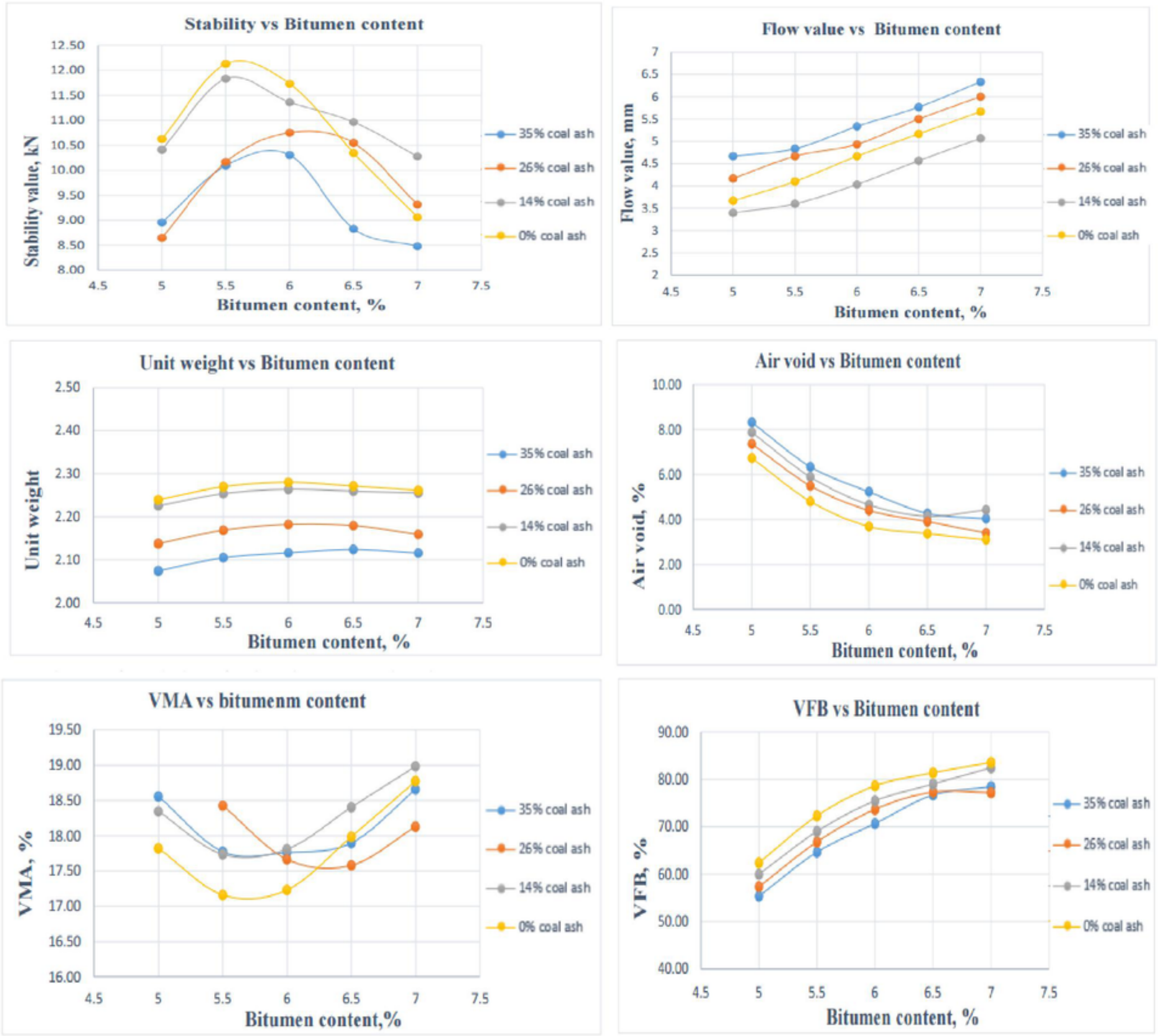

Figure 13

Marshall Stability of bitumen at the flow rate, stability, unit weight and air-void ration

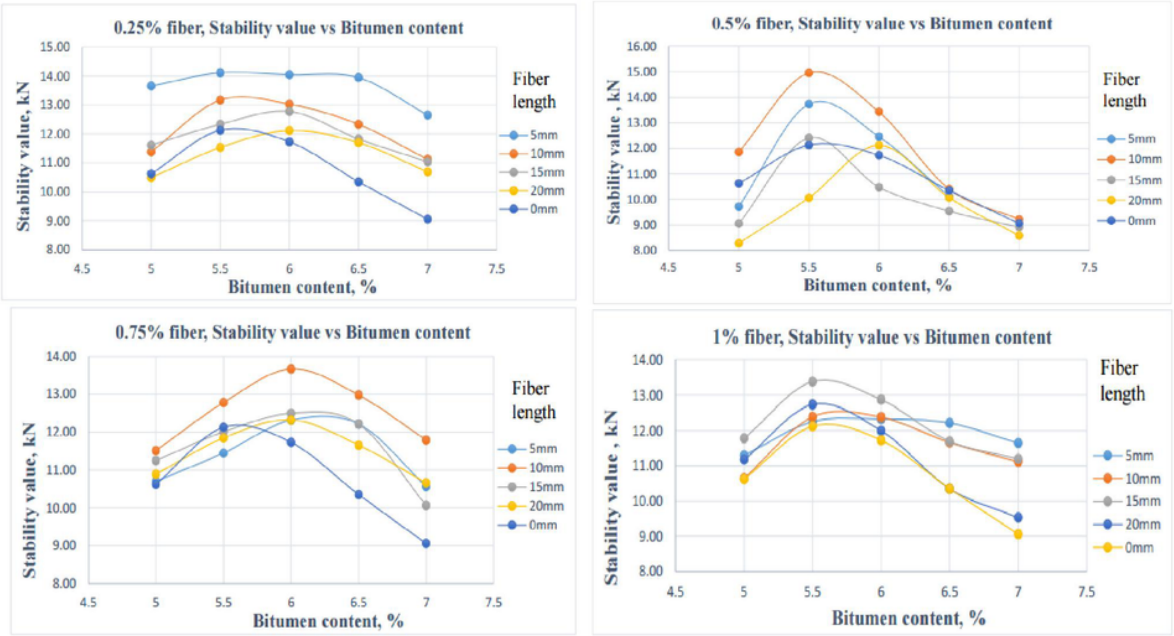

Figure 14

Marshall Flow value analysis at different percentages fiber contents and bitumen contents

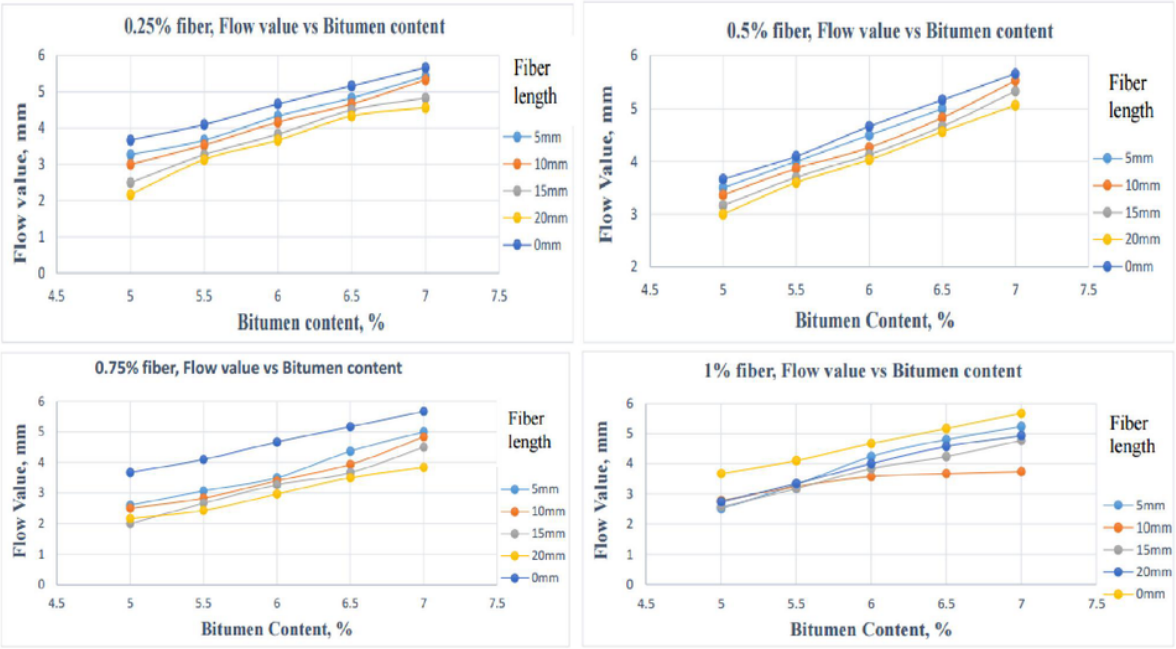

Figure 15

Various amount of fibers present effect on the flow value and bitumen content according to length

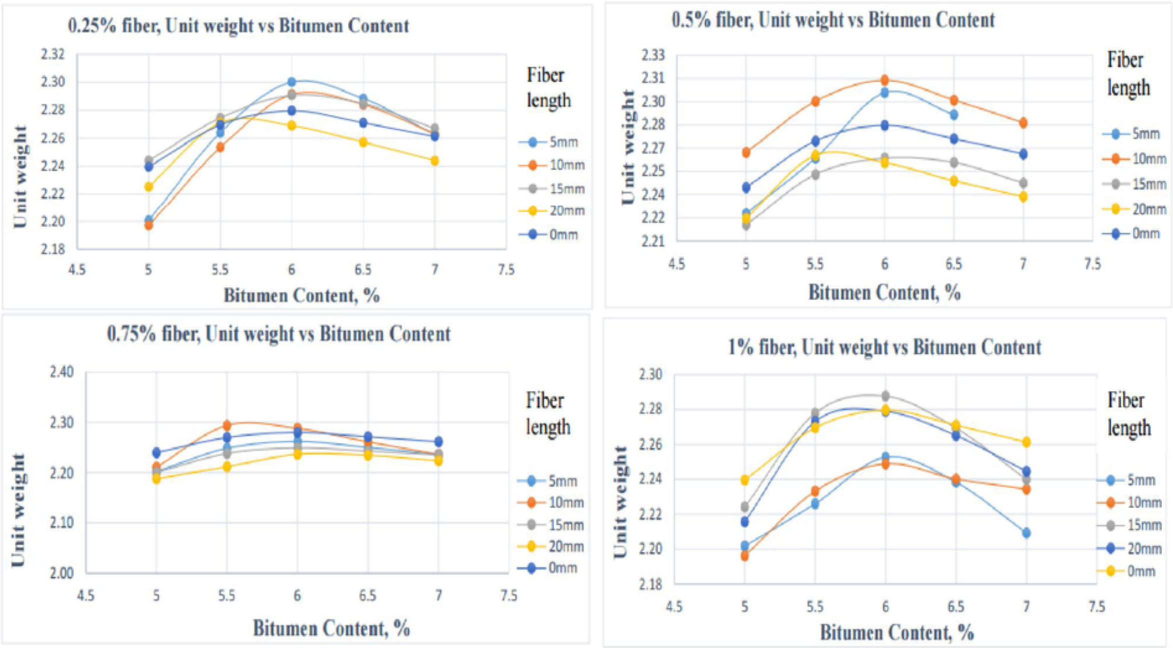

Figure 16

Changes the unit weight vs bitumen contents by different percentages of fibers

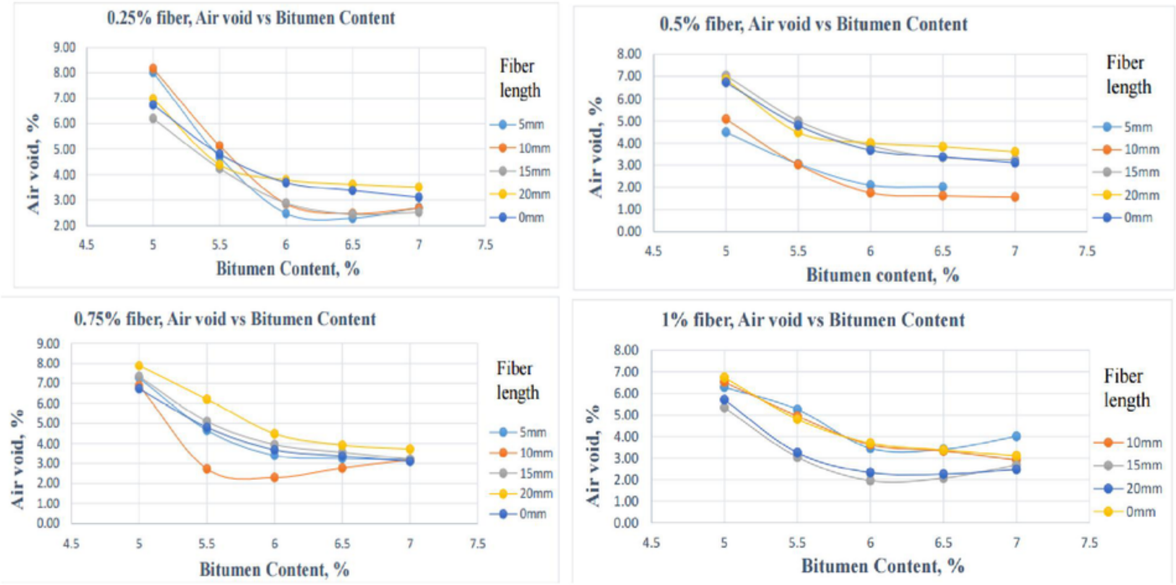

Figure 17

Percentages of air voids by different percentages of fibers at the bitumen contents

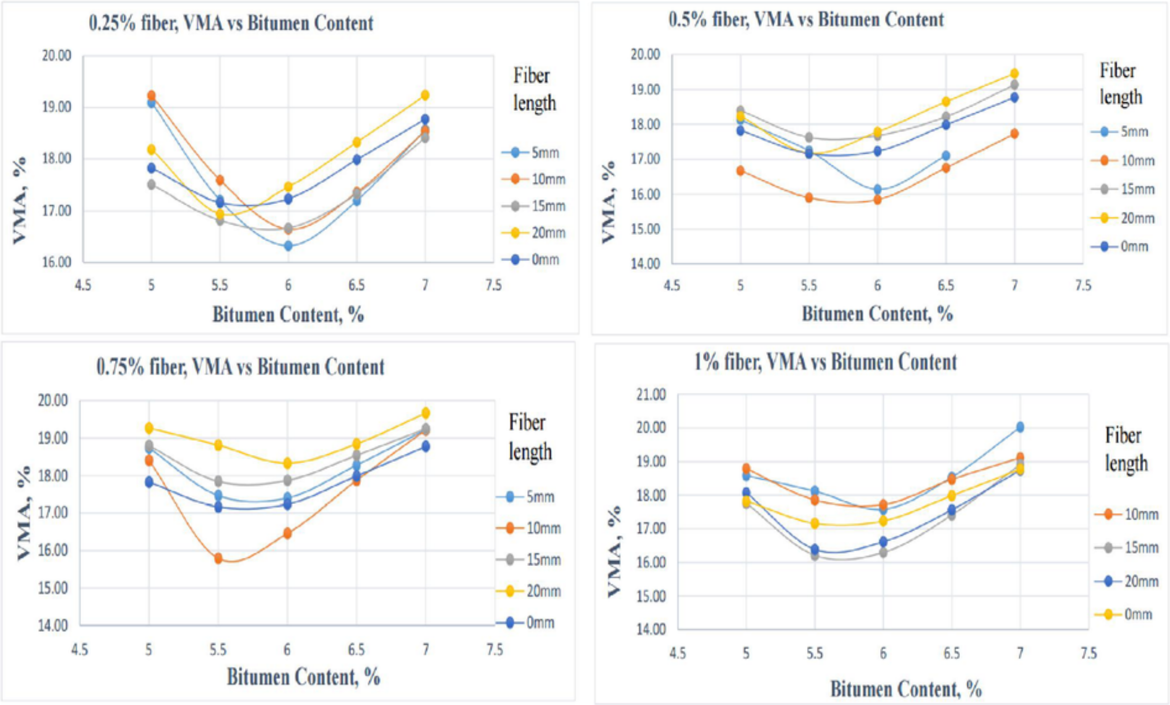

Figure 18

Different percentages of fibers length at VMA vs Bitumen contents

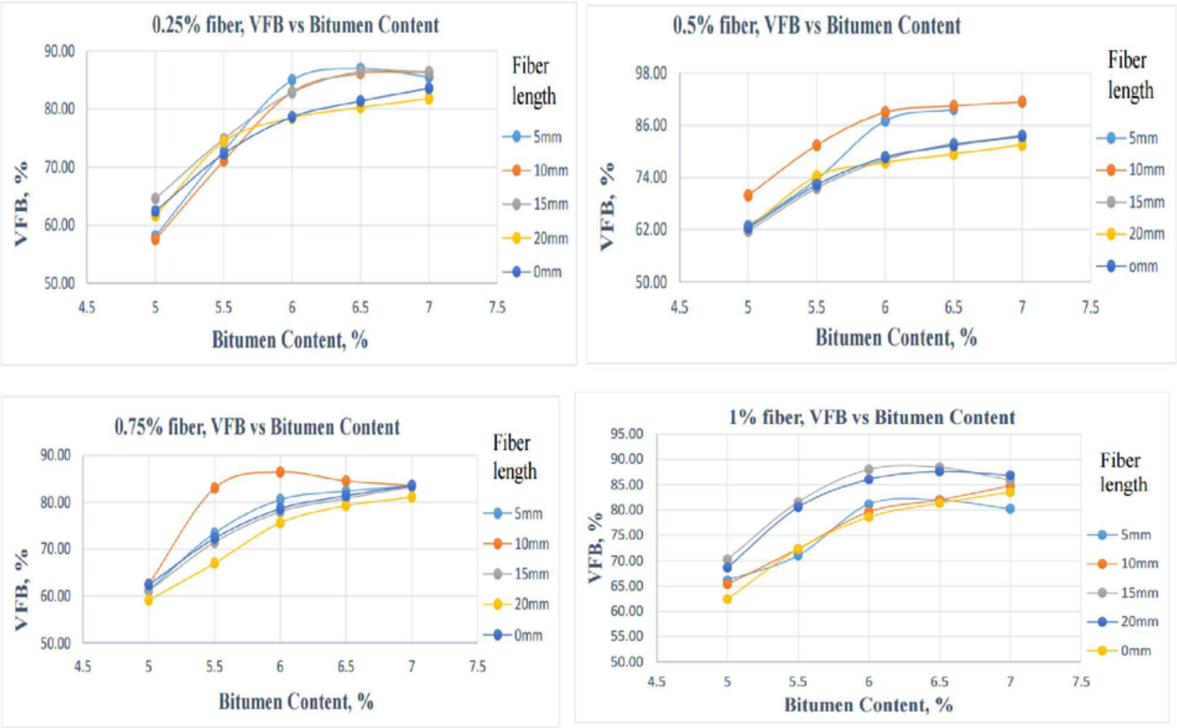

Figure 19

Different percentages fiber length VFB vs fiber contents of the materials

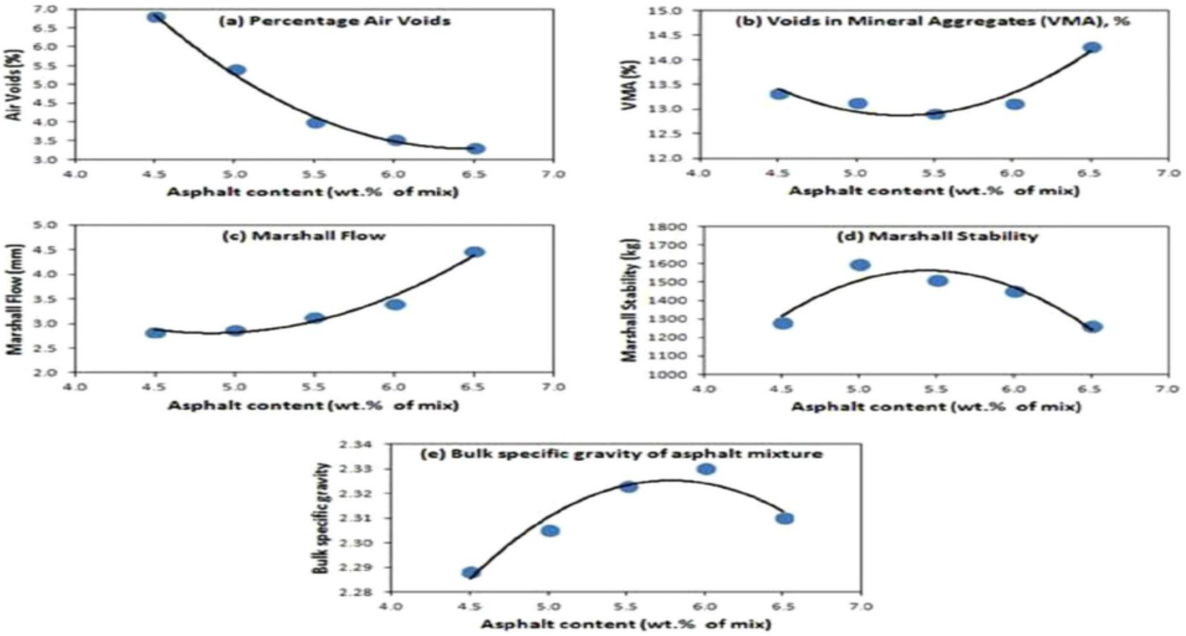

Figure 20

Flexibility of plastic waste materials application in pavement at the different parameters analysis

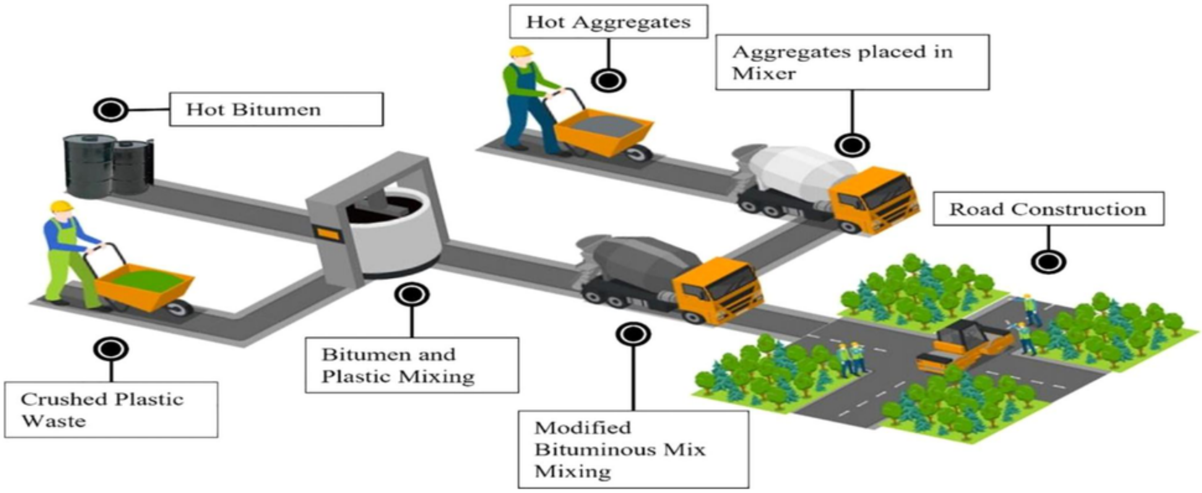

Figure 21

Manufacturing process of wet mix application in pavements

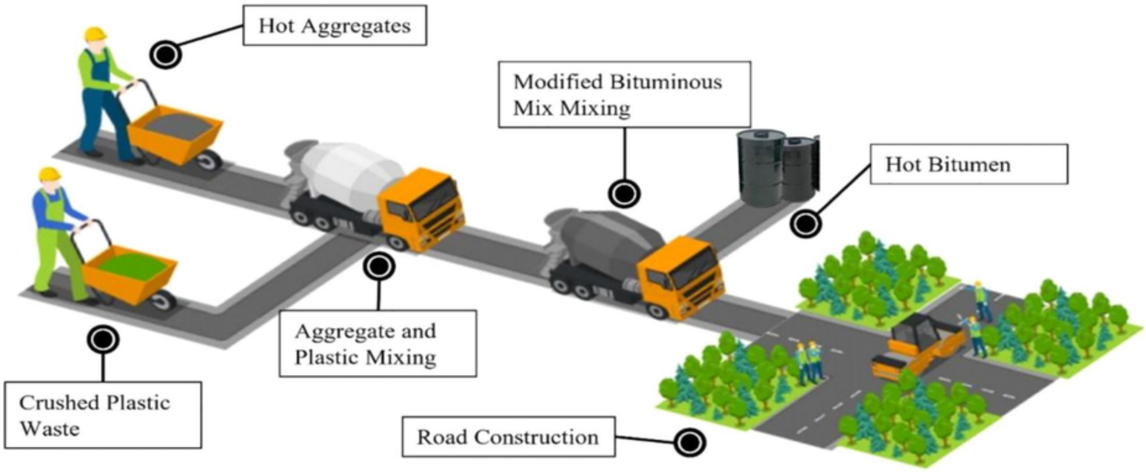

Figure 22

Manufacturing process of dry mix application in pavements

Supplementary Files

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