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An Experimental Study on Utilization of Plastic waste and marble Aggregates in Flexible Pavement

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Abstract: All of us are aware of the environmental problems caused by discarded plastic. To deal with these difficulties, many researchers from different fields are always researching new ways to effectively reuse various types of plastic. Plastic roadways are bituminous roads that use trashed plastic as the wearing surface. They are currently widely used in India. Since the Indian Road Congress (IRC) developed a code of standards on plastic roads (IRC SP: 98–2013), a number of organizations have moved forward to bring about them in India because they are both a sustainable option and an essential one. The Indian Ministry of Road Transport and Highways is currently working on a program to make significant use of discarded plastic. India presently has over 100,000 kilometers of waste plastic-constructed highways. The road network in India has proven to be effective in offering a foundation for the development of the nation's economy. India is a multicultural nation, and its highways serve as a source of unity, providing the glue that brings people together, no matter where possible. The climate is hot and humid, plastic plaster is very useful. Prepared with the use of 13 mixing proportions in this study VG-30 bitumen may be used to bind materials together. By using, melted plastic from plastic bags, bitumen has been substituted with varied quantities of 0%, 6%, 12%, 18%, and 24% in this analytical study. A marble piece with a varied proportion of zero to thirty-six percent is used to replace the aggregates in the formula.

Keywords: Marble pieces, melted plastic, Inventive binder, Sustainable pavement material, Mechanical property, Functional pavement.

Introduction

Road transport is frequently the most expensive means of transportation with regard to maintenance and function. This has a major effect on our economy. Traffic is a mode of transport for a lot of people. Import traffic is decreasing. The use of vehicles has grown significantly as a result of the sharp growth in traffic.

Road transport is the transport of both individuals and goods across a network of roads. A road is a path that links two sites and has been built or renovated to allow both motorized and non-motorized vehicles. Road transport refers to moving people and goods along a road network. Road is a path that connects two points and has been paved or improved to allow travel in both motorized and non-motorized carriages. Comparing road transit to other modes of transport, there are many benefits. In comparison to other forms of transportation like trains and planes, road transportation requires a far smaller expenditure. Compared to railroads, highways are less expensive to build, operate, and maintain.

Road transport can be divided into two categories: passenger and goods/ resource transport. The main benefit of road transportation is that things may be moved from doorstep to doorstep, which is a very cost-effective method of moving, loading, and unloading goods. In rural locations lacking rail, sea, or air transport, road transit may

be the only way to get people and products from their homes to where they are going. Main roads are the only modes of transport that can move products between cities and small towns. However, while road transportation offers many benefits, it also has considerable drawbacks. For example, road traffic carries a high risk of incidents and injuries. As a result, motorized transportation is less safe than alternative modes of transportation. Road travel is also extremely chaotic when compared to other types of transportation. It's not expected and is irregular. Transporting massive items over miles is difficult and expensive. Today's road traffic has a huge negative environmental impact. The process of dissolving tar and creating cement for road construction can have a harmful influence on the environment.

Bitumen

Bitumen is a substance made by refining crude oil. Bitumen is frequently utilized in construction, notably for roads and highways, because of its moisture and adhesive features. The process of distillation separates lighter parts of crude oil, such as diesel and gasoline, and leaves only the heavier asphalt. Bitumen is a byproduct of crude oil. It includes calcium, iron, sulfur, and oxygen and is made up of complicated hydrocarbons. The type and origin of crude oil utilized to produce a substance impacts its quality and simplicity of manufacture. It is a viscoelastic and thermoplastic substance. This interdependence force to accurately assess the volume of traffic on the road so that the bitumen mix's qualities may be adjusted in accordance with the estimated stress levels. Depending on the road use, the adaptability of bitumen leads to a wide diversity of bitumen mixes.

Bituminous Road Construction Benefits

- The no-joint design ensures a smooth rode. In addition, it generates fewer noises than concrete surfaces. The smooth texture of the bitumen road surface is preserved due to the reduced wear and tear.
- The process of bituminous paving deforming and failing gradually. Brittle failures may be seen in the concrete pavement.
- They have always had the choice of speedy repairs. They move quickly, so they don't take long to change the course for vehicles.
- Compared to concrete pavement, bituminous pavement is less expensive to install and maintain altogether.
- They really aren't impacted by de-icing agents and are resistant to melting at high temperatures.

Melted Plastic from Plastic Bags

The majority of the polyethylene used to build these roads is common post-consumer material, including product packaging. The most popular polymers for packaging include huge and little density polyethylene, polypropylene (PP), and polyethylene terephthalate (PET or PETE) (HDPE and LDPE).

Key advantages:

- Bitumen utilization reduces overall.
- While asphalt roadways only endure three years, plastic-surfaced roads last seven years.
- The Marshall Stability Value goes up.
- There are less potholes and striping because water cannot soak through.
- Because the road does not melt or break, the expense of road maintenance is reduced.
- enhanced capacity to bear loads (Withstanding increased load transport)
- There is no plastic leaching, and UV radiation has no impact.

Marble Pieces

Marble has been used as a building material since ancient times. The management of raw materials for the production of refined marble is today's most important eco-friendly concerns in the world. Marble dust can be used in various industries, including paper, agriculture, glass and construction, to help protect the environment. Marble dust is considered a by-product of the extraction and polishing of marble. Research has shown that marble can be used as a building material. Many developed countries have introduced construction waste management laws to reduce waste and ensure that waste is recycled. Marble dust is a solid waste from marble processing that can be used as a cement filler or fine aggregate in construction. Marble dust can be added to concrete to increase its strength.

Environmental Impacts of Plastic Bags

- Because of the high price and difficulty of recycling, most plastic bags end up in landfills, where they deteriorate over 300 years.
- When animals consume them, they breakdown into harmful particles that damage the ecosystem and enter the food chain. This leads to environmental deterioration, the death of animals, health hazards, and other negative consequences.
- Plastic bags cause approximately 100,000 animal deaths annually. Many animals, especially dolphins, whales, sea turtles, penguins, and dolphins, mistake plastic bags for food.
- This suggests that you will not live long enough to witness the breakdown of plastic.
- Research indicates that consuming or reheating food in bags of plastic can lead to health issues such as ulcers, asthma, obesity, and cancer. By the simple fact that plastic bags include components that, when heated, react with the food. Biphenyl-A (BPA) is one of them.
- Plastic bags are a common cause of drainage system clogging. This issue has a particularly strong influence on developing countries.

Literature Review

Most of the authors are using waste material as bitumen replacement.

Mr. M. Vikash, Sri Indira, et.al. (2022): Bitumen was used as a binder, covering aggregates while keeping them elastic throughout pavement construction. The goal was to identify the basic properties of aggregates, bitumen, reused plastics, and crumb rubber. Bitumen should have a perfect mixture of discarded plastic (pet) and rubber. Aggregates used with hydraulic cement media to make mortar or concrete include sand, gravel, crushed stone for hydraulic concrete made from cement, and iron slag from blast furnaces. It could be used as an alternative to 60/70 penetration bitumen. Vg30 is sensitive to heat and should not be used in hot environments.

M. Lalitha Pallavi, et.al. (2022): It helps achieve many goals, including reducing the cost and demand for non-renewable fuels. Lightweight materials are in high demand because their use can lead to energy savings. Plastics are classified as lightweight materials and are mass produced and used in a variety of applications due to their durability, affordability, and compatibility. Polyethylene waste is not biodegradable and should be used for various support purposes. The polymers used in making these materials include polyethylene, polypropylene and polystyrene.

Tabiya Hamdani, et.al. (2022): Flexibility and hardness were two categories that were used to classify types of hard-surface pavements. If the pavement surface was bituminous and the entire pavement structure bent or deformed because of

traffic pressure, the pavement was called flexible. The purpose of this research was to determine the Marshall properties of BC and DBM mixtures containing concentrations of 3, 4, 5 and 6% bitumen and 1, 1, 5, 2 and 3% polyethylene. Stone powder and copper slag were used as fine aggregates. Evaluation and comparison of mixed OPC using slag as fine aggregate

Nitin Dutt Anupam (2022): By using plastic waste, flexible pavement could achieve split tensile strength values that met the specified limits, even when the content of plastic waste was more than 30% of the mixture weightThe mixed aggregates were crushed into small pieces (4.75 mm and 2.36 mm) and covered with a recycled polyethylene carrier bag heated to a certain temperature. Bituminous mixtures were made using VG-30 bitumen, aggregates coated with plastic or conventional aggregates, and cement as filler.

Ankur Gajbhiye, et.al. (2022): Road infrastructure was deteriorating over time due to rising commercial traffic density, axle loads, and limited maintenance services. Higher axial loads and traffic degrade bituminous mixture performance, necessitating the application of new binders more frequently. To reduce pavement surface damage and increase the life of flexible pavements, traditional bitumen's must be enhanced in terms of performance attributes such as durability against lasting deformation (ruts) and fatigue cracks. The plastic content of grade 60/70 bitumen varies from 5% to 13%.

S. Geetha, et.al. (2021): Waste or industrial byproducts such as fly ash, slag, stone crusher dust, and floor ash, which were produced in vast amounts, were used as construction materials. After testing the systematic ratios of the two materials, we found that the performance of the recycled supplies was comparable to the original resources. An analysis of the associated costs was also carried out to additional benefits of using recycled materials. The RAP is 50% or 100%. Furthermore, author found that the Marshall Property values changed relatively little for different percentages of the RAP mix..

Ajay Hanumant Phale, et.al. (2021): Replacing part of the bitumen with foam ash. Bottom ash was included in the mix with ratios of 8, 10 and 12%, compared to cost-effective road construction methods using conventional bitumen and bitumen with bottom ash. Coal ash, which is a byproduct of thermal power plants, pollutes the environment but also has productive uses. Fly ash and bottom ash are also components of this coal ash. The bottom ash (BA) used that was collected from a coal-fired power plant (MH) located in Nashik. The collected local bitumen was mixed with BA, dried at 170 °C for 24 h and sieved. The first thing you can do is collect the bottom ash and then be crushed or finely chopped. Both bitumen and aggregate can be subjected to standard tests.

Sanjeet Kumar Mishra, et.al. (2021): Effects of recycled aggregates, plastic waste and sisal fibers on the properties of bituminous concrete. Shredded plastic waste was added to hot bitumen in different amounts (2, 4, 6, 8, 10 and 12% bitumen) and recycled aggregates in different amounts (10, 20, 30, 40, and 50%.). Bituminous concrete with a bitumen content of 5% (made with 40% M5 recycled aggregate, 60% natural aggregate, 8% plastic waste and 0.3% sisal fiber) is the most suitable concrete for bituminous concrete paving because it meets all the conditions. It turns out that there is IRC: Marshall Stability, flow rate and air void fraction according to IRC: 37 guidelines.

Methodology

We describe the study and begin the preparation of 13 mixed-measure research papers. VG-30 bitumen was used as a binder in this study. The research project replaced asphalt with 0%, 6%, 12%, 18% and 24% melted plastic from plastic bags. 0%, 9%, 18%, 27%, 36% are replaced by pieces of marble in different percentages.

Material used for prepare Sample

- Aggregate
- Bitumen
- Marble Piece
- Melted Plastic from Polybags

Source of Material

Table: Source of Material

Material	**Source**
Marble Pieces	Marble waste from construction site, Near Pratap nagar
Natural Aggregate	Prashant Material and Suppliers
Melted Plastic from Polybags	Available locally in Near Pratap nagar
Bitumen	Prashant Material and Suppliers

Composition of Mix Design for prepare sample

= Adhesives (asphalt) VG30: Type-1 19-13.2mm: Type-2 13.2-6.3mm: Type-3 <6.3mm

= (5.5: 14: 15: 63.5)

- Replace the type 1 collection with marbles pieces.
- Type-2 = Zero replacement
- Type-3 = Zero replacement

Percentage of asphalt replaced with liquid plastic bags = 0%, 6%, 12%, 18%, 24%.

Percentage of total replacement with marble Chips = 0%, 9%, 18%, 27%, 36%.

Choose BC grade- 2nd as bitumen grade 5.5 % bitumen for maximum stability over the stability of the standard Marshall Mix.

Table: % Replacement of bitumen with Melted Plastic bags

Mix No.	Replacement of bitumen with Melted Plastic bags	Bitumen %	Melted Plastic bags%
1	0%	5.5	0
2	6%	5.17	0.33
3	12%	4.84	0.66
4	18%	4.51	0.99
5	24%	4.18	1.32

Table: Replacement of Aggregate with Marble piece

Mix No.	Aggregate Replacement with Marble Piece	Aggregate 19-13.2mm in %	Marble Pieces 19-13.2 mm in %	Aggregate 13.2-6.3 mm in %	Aggregate 6.3mm to less in %
1	0%	14	0	15	63.5
2	9%	12.74	1.26	15	63.5
3	18%	11.48	2.52	15	63.5
4	27%	10.22	3.78	15	63.5
5	36%	8.96	5.04	15	63.5

Table: Prepared Samples by Replacement of Bitumen by 6% of Melted Plastic bags

Name of Sample	Melted Plastic bags	Marble Piece
Standard	0%	0%
B-6-A-0	6%	0%
B-6-A-9	6%	9%
B-6-A-18	6%	18%
B-6-A-27	6%	27%
B-6-A-36	6%	36%

Table: Prepared Samples with Replacement of Bitumen by 12% of Melted Plastic bags

Name of Sample	Melted Plastic bags	Marble Piece
Standard	0%	0%
B-12-A-0	12%	0%
B-12-A-9	12%	9%
B-12-A-18	12%	18%
B-12-A-27	12%	27%
B-12-A-36	12%	36%

Table: Prepared Samples by Replacement of Bitumen by 18% of Melted Plastic bags

Name of Sample	Melted Plastic bags	Marble Piece
Standard	0%	0%
B-18-A-0	18%	0%
B-18-A-9	18%	9%
B-18-A-18	18%	18%
B-18-A-27	18%	27%
B-18-A-36	18%	36%

Table: Prepared Samples with Replacement of Bitumen by 24% of Melted Plastic bags

Name of Sample	Melted Plastic bags	Marble Piece
Standard	0%	0%
B-24-A-0	24%	0%
B-24-A-9	24%	9%
B-24-A-18	24%	18%
B-24-A-27	24%	27%
B-24-A-36	24%	36%

Here, B-Replacement of Bitumen; A= Replacement of Aggregate

Bitumen Penetration Test (IS 1203-1978)

An asphalt test of penetration determines the firmness or softness of an asphalt by determining the depth of an ordinary needle in 5 seconds at 25ºC. Bitumen samples with low permeability have higher softening points.

Bitumen Ductility Test (IS 1208-1978)

Asphalt ductility test is one of the major tests and requirements for asphalt before road construction. An asphalt ductility test is used to measure the ductility and ductility of each asphalt specimen.

Test of Flash and Fire point (IS 1209-1978)

This test is carried out to identify the flash point and flash point of asphalt, with flying asphalt functioning as the foundation for the result. The following are the tests conducted:

Flash point - The lowest possible air temperature that occurs when a material, when heated to a test lamp under certain material situations, rapidly produces light is known as the material's flash point.

Fire Point - The temperature that is the lowest at which an object will burn and ignite for an average of five seconds when ignition is applied is known as the fire point.

Test of Softening point (IS 1205-1978)

The temperature that occurs when the asphalt shrinks by a certain amount in accordance with test criteria is known as the softening point. For the test, a ring and ball instrument was utilized. The softening point is a helpful device for determining just how hot asphalt may get for different types of road applications.

Bitumen Specific Gravity (IS 1202-1978)

Bitumen blocks used in constructing roads can be divided using them. It may also be useful in determining the bitumen's glue position. Additionally, it can aid in the detection of mineral pollution found in bitumen. The density value increases with the number of mineral contaminants. Cleaning the bitumen binder of dirt is essential. Sometimes, asphalt volume is given instead of weight when bitumen mix solutions are introduced.

Standard Marshall Stability Test

The maximum load that the sample can carry at the specified test temperatures of 60 °C is referred to determine the Marshall stability of the mix. The deformation that the test specimen exhibits while

being loaded up to its maximum load is recognized as the flow value. 0.25mm units are used to measure flow.

Calculation of Specified parameters

Aggregate %=100-% Bitumen by Wt. of Mix**;** **Bulk Specific gravity of aggregate (Gsb)** = 2.755;

Effective Specific gravity of aggregate (Gse) = 2.844**; Specific gravity of Bitumen (GB)** = 1.02**;**

Proving Ring Correction Factor = 6.72**;** **Volume=** SSD weight **–** Weight (in water)**;**

Gmb (Density) =Weight (in air)/ Volume**; Gmm** = Total Wt. / [(% wt. of Agg. / SG of Agg.)+ (% wt. of Bitumen/ SG of Bitumen)]

VA = [(Gmm-Density)/Gmm]*100; **VMA**= 100-[(Density* Aggregate %) /Gsb]

VFB= [(VMA-Va)/VMA]*100; **Load**= PRR*PR Factor

Corrected Load =Load*Correction Factor; SSD= Saturated Surface Dry.

Figure: Sample making for Marshall Test

Figure: Marshall Stability testing

Tests on Aggregate (IS 2386-3 (1963)

Crushing Test

The combined strength of the bed is determined by preparing a cylindrical specimen with a diameter of 25 mm and a height of 25 mm. The cylinder is under pressure. Depending on the type of bed, the aggregate breaks down to different degrees and the compressive strength varies from a minimum of about 45 MPa to a maximum of 545 MPa. In fact, the compressive strength of the bed does not accurately reflect the strength of the aggregate in the concrete. For this reason, mass sampling is used correctly to determine the strength of a collection. The test was performed on aggregates that passed the 12.5 mm sieve and remained in the 10 mm sieve. A large sample is placed in a cylindrical shape and a 40 ton load is applied by pressing the test piston. Aggregate soil handling differs by less than 2.36mm and reverts to the model as a percentage of the original load.

Impact Test of Aggregate

Strength is the ability of a material to withstand a sudden impact. If we use the AC adapter on roads and roads where the car is running, a shock load can be applied to the AC adapter. This shock load can shatter the device into small pieces and damage roads and pavements. Therefore, the

synthesis used in the plan must be strong enough not to be affected.

Abrasion Test of Aggregate

Abrasion tests measure the strength and wear resistance of aggregates, such as B. their ability to crack, fracture and crack. AASHTO T 96 or ASTM C 131 recommends this test: Abrasion and fracture resistance of small and medium aggregates in LA steel. The aggregate is used for paving and road scraping. When driving on the freeway, dirt between the tires and the road surface can damage the equipment. The wheels of towed vehicles can be a traffic jam.

RESULT AND DISCUSSION

Test of aggregates and bitumen comparison made on strength, cost of construction.

Test Result of Bitumen

Table: Test on Bitumen Replaced with Melted plastic Bags

Replacement of Bitumen	Penetration (mm)	Ductility (Cm)	Flash Point (°C)	Fire Point (°C)	Softening Point (°C)	Specific Gravity
0%	70	46	176	245	55	1.05
6%	65	54	184	250	58	1.06
12%	60	68	188	258	62	1.08
18%	53	70	193	284	70	1.11
24%	51	72	195	287	74	1.13

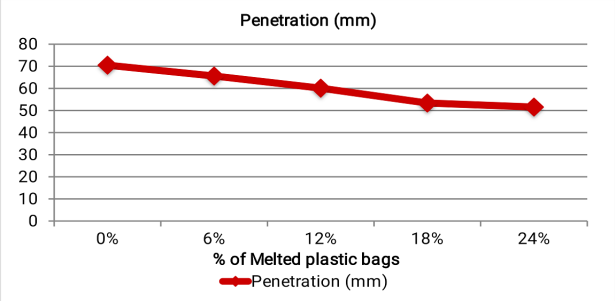

Figure: Penetration test of Bitumen Due to varying % of Bitumen Replaced with Melted plastic Bags

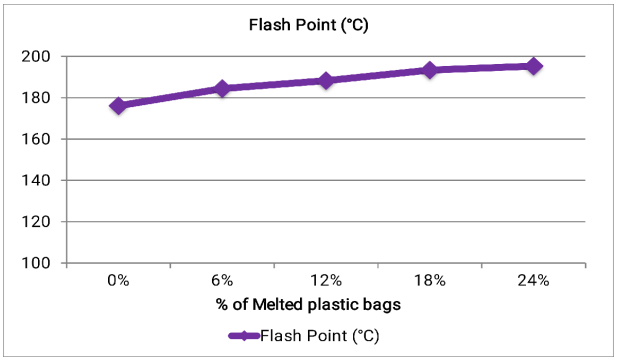

Figure: Flash Point test of Bitumen Due to varying % of Bitumen Replaced with Melted plastic Bags

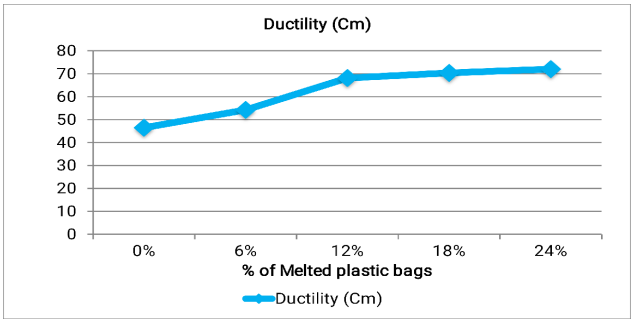

Figure: Ductility test of Bitumen Due to varying % of Bitumen Replaced with Melted plastic Bags

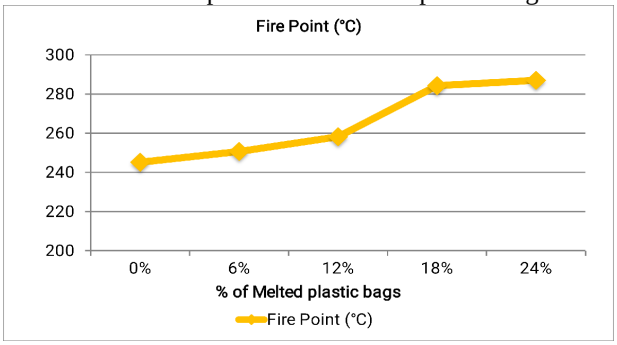

Figure: Fire Point test of Bitumen Due to varying % of Bitumen Replaced with Melted plastic Bags

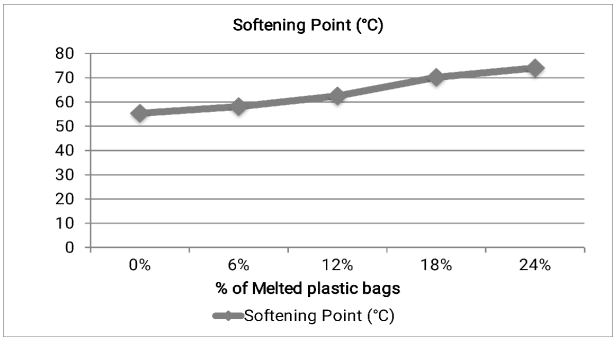

Figure: Softening Point test of Bitumen Due to varying % of Bitumen Replaced with Melted plastic Bags

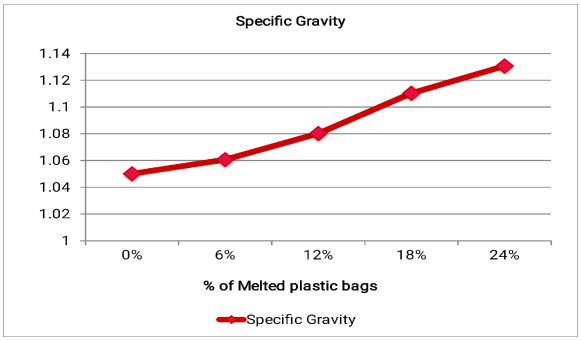

Figure: Specific Gravity test of Bitumen Due to varying % of Bitumen Replaced with Melted plastic Bags

Test Result of Aggregate

Table :Tests on Aggregate Replaced With Marble Piece

Replacement of Aggregate	Crushing Value %	Impact Value %	Abrasion Value %
0%	31.66	24.32	32.57
9%	29.38	26.6	34.30
18%	27.51	28.69	37.02
27%	26.63	30.62	40.28
36%	24.56	32.81	42.83

Test Results of Standard Marshall Stability

Table: Standard Marshall Stability Test Result for Optimum Bitumen

Bitumen Content (%)	Density	% Air Void	% VMA	% VFB	Stability (Kg)	Flow
4.50	2.575	6.927	15.088	54.53	1020.91	2.22
5.00	2.597	5.301	14.764	64.63	1081.48	2.55
5.50	2.610	4.118	14.854	72.87	1116.43	3.4
6.00	2.607	3.291	15.265	79.07	1055.86	3.66
6.50	2.624	2.886	15.148	82.24	1103.62	4.25

Table: Percentage Replacement of Bitumen from Melted plastic Bags

Replacement of Melted plastic Bags	Density	% Air Void	% VMA	% VFB	Stability (Kg)	Flow
0%	2.608	4.15	16.97	76.05	1111.44	3.47
6%	2.492	3.81	12.96	71.22	1116.26	3.38
12%	2.494	3.62	11.29	66.37	1123.27	3.33
18%	2.497	3.34	10.72	62.91	1128.62	3.29
24%	2.502	3.28	10.39	58.04	1130.72	3.26

Table: Standard Marshall Stability Test Result for 18% Optimum Bitumen and Varying Percentage of Aggregate

Name of Sample	Density	% Air Void	% VMA	% VFB	Stability (Kg)	Flow
B-18-A-0	2.610	4.118	14.854	72.870	1116.430	3.400
B-18-A-9	2.688	4.242	15.300	75.056	1149.923	3.502
B-18-A-18	2.741	4.324	15.597	76.514	1172.252	3.570
B-18-A-27	2.793	4.406	15.894	77.971	1194.580	3.638
B-18-A-36	2.714	4.283	15.448	75.785	1161.087	3.536

CONCLUSION

Result Conclusion of Test of Bitumen

- Maximum penetration of bitumen when replaced with melted plastic bags is up to 70 mm at 0% replacement, while lowest penetration is down to 51 mm at 24% replacement.
- Maximum ductility of bitumen when replaced with melted plastic bags is up to 72 cm at 24% replacement, while lowest ductility is down to 46 cm at 0% replacement.
- Maximum flash point of bitumen when replaced with melted plastic bags is up to 195 °C at 24% replacement, while lowest flash point is down to 176 °C at 0% replacement.
- Maximum fire point of bitumen when replaced with melted plastic bags is up to 287 °C at 24% replacement, while lowest fire point is down to 245 °C at 0% replacement.
- Maximum softening point of bitumen when replaced with melted plastic bags is up to 74 °C at 24% replacement, while lowest softening point is down to 55 °C at 0% replacement.
- Maximum specific gravity of bitumen when replaced with melted plastic bags is up to 1.05 at 0% replacement, while lowest specific gravity is down to 1.13 at 24% replacement.

Result Conclusion of Test on Aggregate

- When marble fragments are used to replace aggregate, the maximum crushing value increases to 31.66 % at 0% replacement and the lowest crushing value decreases to 24.56% at 36% replacement.
- When marble fragments are used to replace aggregate, the maximum impact value increases to 32.81 % at 36% replacement and the lowest crushing value decreases to 24.32 % at 0% replacement.
- When marble fragments are used to replace aggregate, the maximum abrasion value increases to 42.83 % at 36% replacement and the lowest abrasion value decreases to 32.57 % at 0% replacement.

Marshall Stability Test

As more melted plastic bags are included in the bitumen mixture, the density result rises. As more of the plastic bags are melted and added to the bitumen mixture, the amount of air spaces decreases. Plastic bags in the bitumen mix melt, the percentage VMA outcome declines.

Future scope of work

- Lignin was also used in this study to a larger amount than 20%.
- Bitumen percentages in the marsh stability test can potentially be the subject of additional research.
- To examine various marble chunk content ratios in the sample concrete.
- In this study, palm kernel shells were also suggested as a Partial Replacement for Coarse Aggregate.

REFERENCE

[1] Indira, Mr M. Vikash Vnvl Sri, Et Al. "Enactment of Utilization of Waste Plastic and Rubber in Flexible Pavements." Journal of Engineering Sciences 13.7 (2022).

[2] Pallavi, M. Lalitha, Subhashish Dey, and G. T. N. Veerendra. "Applications of plastic waste materials in bituminous mixes pavement for increasing the strength of pavement materials." (2022).

[3] Hamdani, Tabiya, et al. "A Detailed Study on the Utilization of Waste Polythene in Bituminous Mixes."2022

[4] Anupam, Nitin Dutt. "Utilization of Waste Plastics in Flexible Pavement." Journal of

Progress in Civil Engineering ISSN 2322: 0856.2022

[5] Gajbhiye, Ankur, et al. "Potential of Plastic Used in Bituminous Road."2022

[6] Geetha, S., M. Selvakumar, and S. Muthulakshmi. "Characteristics of Polymer Modified Reclaimed Bitumen and Aggregate as a Sustainable Pavement Material." IOP Conference Series: Materials Science and Engineering. Vol. 1055. No. 1. IOP Publishing, 2021.

[7] Phale, Ajay Hanumant, and Sumit R. Thakur. "Comparative Analysis of Modified Bitumen with Bottom Ash for Indian Road Construction." (2021).

[8] Mishra, Sanjeet Kumar, and Subrat Roy. "A Study on the Effect of Recycled Aggregate, Waste Plastic & Sisal Fiber on the Properties of Bituminous Concrete." (2021).

[9] Pawar, A. V., et al. "Review Paper on Experimental Study on Use of Plastic in Flexible Pavement." (2021).

[10] Mahajan, Shubham, and Ajay K. Duggal. "Review on Comparison between the Performances of Plant Produced Plastic Modified Asphalt with Laboratory Prepared Mix for DBM and BC Layers." (2021)

[11] Panda, Bhagyashree, Nazia T. Imran, and Kundan Samal. "A Study on Replacement of Coarse Aggregate with Recycled Concrete Aggregate (RCA) in Road Construction." Recent Developments in Sustainable Infrastructure. Springer, Singapore, 2021. 1097-1106.

[12] Biswas, Arjita, Amit Goel, and Sandeep Potnis. "Performance comparison of waste plastic modified versus conventional bituminous roads in Pune city: A case study." Case Studies in Construction Materials 13 (2020): e00411.

[13] Zhang, Junhui, et al. "Marble Piece from construction and demolition wastes as alternative filling materials for highway subgrades in China." Journal of Cleaner Production 255 (2020): 120223.