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Testing of Bituminous Properties using Waste Polyethylene Terephthalate

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Abstract : Nowadays, Flexible pavements with bituminous surfaces are now widely used. The formation of various distresses such as rutting, bleeding, cracking, and potholing of bituminous surfacing is caused by increased traffic intensity on roads, overloading of commercial vehicles, and temperature variation of pavements due to climatic changes. Bitumen becomes very soft in the summer and brittle in the winter due to high temperatures. Several studies have revealed that the stability and strength of bitumen and bituminous mixes can be improved by the addition of certain additives, and the bitumen premixed with these additives is known as modified bitumen". The current research aims to use modified bitumen made from waste polyethylene terephthalate for road construction. A solution to this problem would be to use waste polyethylene terephthalate as a secondary material in construction projects.

Key Words: **Bitumen, Waste polyethylene terephthalate, Road construction**

I. INTRODUCTION

There is a noticeable increase in trash creation rates for many types of waste materials as a result of rapid industrial growth in various fields combined with population growth. The disposal of such massive amounts of garbage, particularly non-degradable waste materials, has become a major concern in both developed and developing countries. Every year, approximately 400 million tonnes of plastic are produced all over the world, with nearly 8 million tonnes of that plastic ending up in the ocean, where it harms marine animals. Damped plastic also has an impact on the environment. One of the most significant long-term solutions to this problem is the conversion of garbage into valuable goods. As a result, research into novel and creative uses for waste materials is strongly encouraged.

PET is the third most extensively used polymer in the packaging business, monopolizing the beverage bottle market and accounting for about 16% of European plastic usage in the packaging sector. Even though PET is primarily derived from fossil sources and is not biodegradable in the environment, recent advances in the field have highlighted the possibility of producing PET in a more sustainable manner (e.g., from biomasses) or of biodegrading this polyester via the enzymatic action of specific genetically modified/isolated bacteria/enzymes. When one considers PET's great recyclability and the prospect of possibly infinite reuse, one may conclude that the future of PET is yet to be written. As a result, all elements of industrial manufacturing (by traditional and sustainable chemical methods), intrinsic physicochemical/thermal/mechanical qualities, undesirable degradation events, chemical/mechanical recycling procedures, and PET processability are rigorously reviewed here.[9]

Plastic waste management is a significant barrier to meeting this goal. As a result, plastic pollution has received a lot of attention in recent years. [1], Plastic is a non-biodegradable substance, which means it does not degrade over time and, even when dumped in landfills, enters the environment via air and water.[2] This has serious environmental consequences, such as clogging sewer and drainage systems and being eaten by animals, causing disease and death.[2], can contaminate construction fill, and so on. Manufacturing various products, including some used in heavy construction, is the best way to dispose of waste plastic. [2]

Nowadays, waste management is a major concern. Waste products are dumped, reducing available living space, and plastic incineration emits toxic airborne fumes into the atmosphere, resulting in air pollution. As a result, recycling and reuse are the most efficient waste management methods. Many experts believe that the best way to manage waste is to use it in asphalt concrete and bitumen. [3]

Waste plastics have widespread use in bituminous construction.[2] Plastic is defined as a material that contains one or more organic polymers with a high molecular weight, is solid in its finished state, and can be shaped by its flow. Plastic has high durability and a very low degradation rate.[4] About 5-10% bitumen by weight improves the Marshall stability, strength, fatigue life, and other desired features of bituminous mix, resulting in increased lifetime and pavement performance. [2]

PET (polyethylene terephthalate) is a common thermoplastic polyester. PET is a type of polymer that is transparent. The mechanical and physical qualities of polyethylene terephthalate are excellent. It is also dimensionally stable under a variety of loading

circumstances. PET is most commonly utilized in the manufacture of plastic bottles, thermally stabilized films, electrical components, and textile fibres.[5] PET is formed by a polymerization process between an acid and alcohol. PET is lightweight, durable, and strong.[6] Globally, almost 20 million tonnes of PET bottles are manufactured. PET utilization can be solved by combining it with asphalt and bitumen, which are used in the construction of road pavement. [5]

II. MATERIALS AND METHODS

A.Physical properties of Aggregates

Aggregate has high compressive and shear strength, as well as enough permeability for interlocking. Aggregate is made up of coarse and fine aggregates ranging in size from (19mm to 2.36mm) and (2.36mm to 75µ). Both were used.
Different tests of aggregate were performed like aggregate impact, Aggregate crushing, Water absorption, Specific gravity test, etc. Test Results are shown in the table

Table 1: Physical properties of Aggregates

Sr. No	Type of Test	Test Method	Test Result	NORTH, 2013 Specification
1	Aggregate Impact	IS-2386 Part I	14.44%	< 27%
2	Los Angeles abrasion	IS -2386 Part I	29.36%	< 35%
3	Aggregate crushing	IS -2386 Part I	22.35%	< 30%
4	Water absorption	IS -2386 Part III	0.7%	< 2%
5	Specific gravity a. CA b. FA	IS -2386 Part III	 2.63 % 2.41 %	2-3%

B.Physical properties of Bitumen

Bitumen is a binding agent. At normal temperature they are in the form of semi-solid, it is heated until liquefied before blending them with the aggregates. Polymer Modified Bitumen PMB-70(SBS) is used as the binder in this study. All the basic fundamental tests and the thin film oven test was carried out at a specified temperature (153°C) on the bitumen sample as per the requirement. The test results were satisfying the requirements as per IRC-SP 53 2002. The results are presented in Table 2

Table 2: Physical properties of bitumen

Sr. No	Type of Test	Test Method	Test Result	BIS-73:2006 Specification
1	Penetration test in mm	IS: 1203-1978	67.8	60-70 mm
2	Softening point test ºC	IS: 1205-1978	49.9	40-55
3	Ductility test (25 ºC)	IS: 1208-1978	75.4	>75
4	Specific gravity test (27 ºC)	IS: 1202-1978	1.07	>0.99
5	Viscosity (135 ºC)	IS: 73-2013	176	>150

III. MARSHALL STABILITY TEST

During the stability test, the specimen is immersed in a bath of water at 60° 1° C for 30 minutes. It is then loaded into the Marshall stability testing machine and deformed at a continuous rate of 5 mm per minute till failure. The entire maximum in kN is defined as the Marshall Stability (that causes specimen failure). Volume correction is applied to the resulting stability value (Table 11.1). The Flow Value is the total amount of deformation in 0.25 mm that happens at maximum load. The total time between taking the specimen out of the bath and finishing the test should not be more than 30 seconds. [7]

A. Mix design procedure

After selecting the aggregate grading to be utilized, determine how much of each aggregate size is necessary to generate the design grade. Determine the specific gravity of the aggregate/asphalt cement mixture. Then Make test specimens out of various volumes of asphalt. Each compacted specimen's specific gravity is then determined. The specimens are next tested for stability. Then, for each specimen, compute the percentage of vacancies and the percentage of voids filled with bitumen. Choose the best binder content based on the data. Compare the design to the specifications now.[7]

B. Bitumen mix design

The aggregate and the appropriate binding content should be chosen so that the resulting mix meets these requirements. Like in creating a long-lasting pavement, it applies a waterproof coating to aggregate particles and binds them together with appropriate compaction. It is sufficiently stable to withstand deformation under repeated or prolonged stresses. The resistance of a mixture is generated from aggregate interlocking and cohesion, which are often developed as a result of binders. It is sufficiently flexible to endure deflection and bending without cracking. The right volume and grade of bitumen are required to provide the appropriate flexibility. There should be enough voids in the mix to allow for increased compaction when subjected to traffic loading. sufficient workability to ensure that the pavement mixture is efficiently laid during construction.

C.Preparation of sample

1200 grams of aggregate and filler are heated to temperatures ranging from 175 to 180 degrees Celsius. Bitumen is heated to 121 to 145 °C using the trial percentage (let's say 4% by weight of the mineral aggregates). At 154-170 °C, the bitumen and heated aggregates are entirely mixed. The mixture is placed in a heated mold and compressed using a 4.5 kg hammer, a free fall of 45.7 cm, and 75 blows on either side to make laboratory specimens with a compacted thickness of 63.53 mm. These experiments used three samples, each with a different amount of bitumen ranging from 4-6%. [7]

D.Marshall stability and flow

When the load is given at a constant deformation rate of 51 mm per minute, the load and deformation data are closely monitored. The greatest load reading and the specimen's matching deformation at failure load are shown. The specimen's "Marshall Stability" value is defined as the maximum load value in kg. The "Flow value" for the test specimen is the vertical deformation generated by the maximum load in mm units. The specimen is removed from the test head, and a new specimen is utilized for the test. It is referred to as the "Flow value" in millimeters. The specimen is removed from the test head, and a new specimen is utilized for the test.[8]

IV. RESULTS AND DISCUSSION

From the test results, it is found that for all combinations of sizes and proportions of waste PET the OBC value ranges between 5 to 5.5 %. The Marshall Mix properties are further analysed for all bitumen content i.e., 4% to 6% for all combinations which are shown below in the figure.

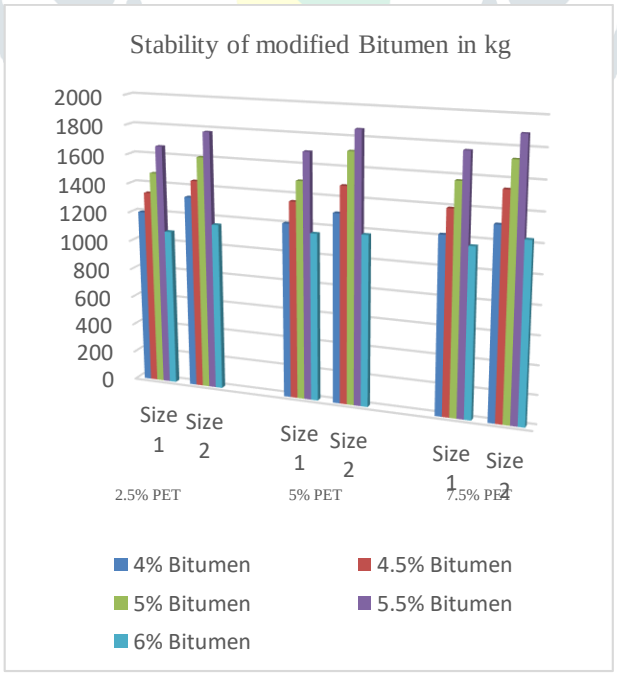

Fig. 1. Graph of stability of modified Bitumen for two sizes of PET

Fig.1 Shows the results of Marshall Stability for PET-modified mixes, it has been observed that between 4 to 5.5% of bitumen content stability increases and for 6% of bitumen content stability decreases. Also found that the stability is maximum for the 5.5 of bitumen content.

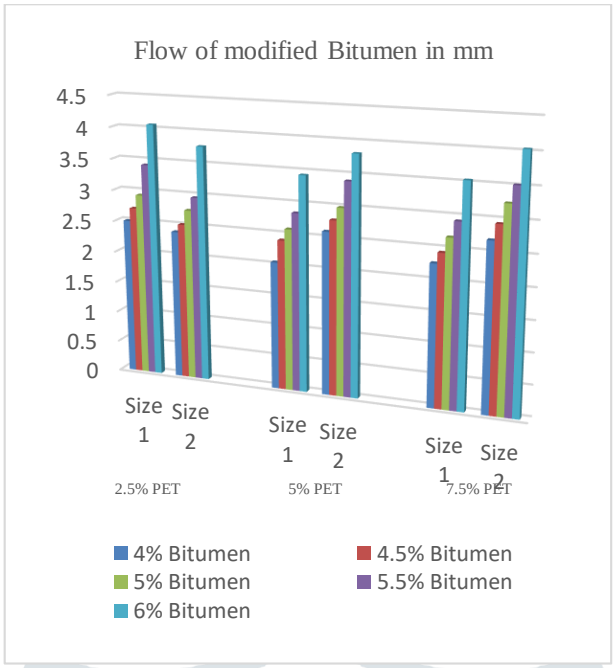

Fig. 2. Graph of the flow of modified Bitumen for two sizes of PET

Fig.2 shows the results of flow for PET-modified mixes, it has been observed that the flow value comes within the limit (2 to 4 mm). For 6% bitumen, the flow value exceeds the limit. Air void is an important volumetric parameter controlling the selection of OBC. Low air voids in the mix may make the mix susceptible to rutting and bleeding, while excess air voids may cause cracking and accelerated aging of the binder. Flow value increase with increasing modified bitumen contents. Flow of the sample is the flexibility of the mix greater flow value indicate more flexibility of the mix. PET flow value gradually increase compared to PP and conventional bitumen. Overall result indicate that both of material is suitable for road payment as a modifier at percentage of 9.0% by weight of the bitumen sustain flow and reduce deformation of the pavement surface.

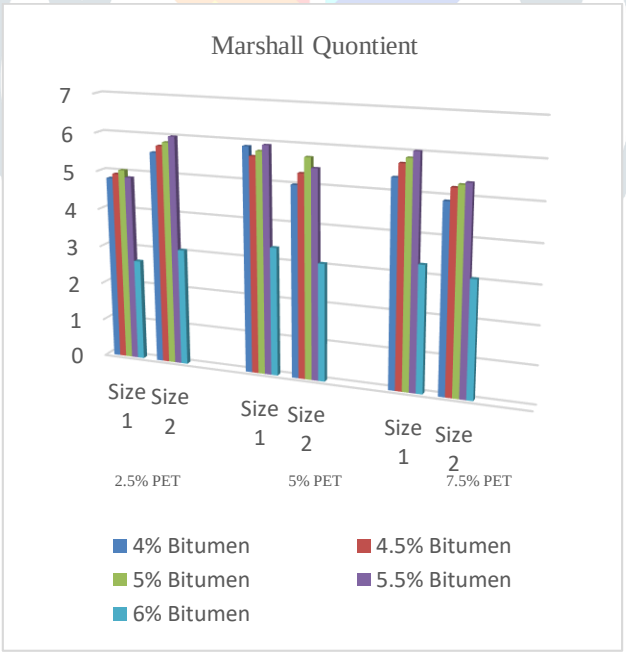

Fig. 3. Graph of Marshall quotient for two sizes of PET

Fig.3 shows the results of the Math Marshall quotient for PET-modified mixes more than the conventional mixes. Marshall quotient is the ratio of stability to flow of bitumen.

V. CONCLUSION

Polyethylene terephthalate (PET) is the polymer used in the manufacture of plastic bottles. Plastic is non-biodegradable material which will remain in the environment for hundreds of years leading to waste disposal crisis as well as environmental concerns. Therefore, this study is focuses on the use of waste PET in bituminous mix. PET waste used is in the form of chips or granules. The IRC: SP: 98-2013 guideline for bituminous mix using waste plastic has been considered for reference criteria.

The study was performed with three content of waste PET (2.5%, 5.0%, and 7.5% by weight of binder) and four different sizes varying from 236mm-3.25mm for modified mix by dry process. From the observations, results and analyses, the following conclusions are deduced

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