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Utilization of Waste Plastic in Road Construction with Addition of Titanium Dioxide

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ABSTRACT- About 5% of municipal solid waste (MSW) has been discovered to include hazardous waste plastic. The disposal of discarded plastic is a major issue today. Due to the indestructibility of these plastic wastes, there are severe difficulties with public health and environmental damage. The results of several studies or tests conducted at various institutions showed that this plastic trash may be used to build bituminous roads.The use of this scrap plastic for building roads is determined by ecological, technological, and financial factors. Dispersal, dumping, and contamination issues may be greatly minimised or eliminated if this plastic trash could be used effectively for building roadways. The major goal of this study was to determine the ideal amount of waste plastic to incorporate into the asphaltic mixture in order to obtain the required strength. Simple plastic specimens without Tio2 and plastic specimens with Tio2 were made as two different types of plastic specimens (Tio2). On both types of specimens, the Marshall Stability Test and the (ITS) indirect tensile strength Test were conducted, and the results were then compared. It was discovered that adding titanium dioxide (TiO_2) as a chemical addition produced great results that showed higher values than the typical plastic specimen. The Marshall Stability and (ITS) Indirect Tensile Strength test was shown to be most effective when 16% of plastic garbage was added (Tio2).

KEYWORDS- Plastic waste, Marshall Stability, ITS, (Tio2) Titanium dioxide, admixture, construction.

I. INTRODUCTION

One of the materials that is being utilised the most frequently in daily life is plastic. Plastic is extremely cost-effective and has the qualities of being weightless, waterproof, and extensible. These characteristics of plastic increase our propensity toward it, resulting in regular usage of plastic. It has altered every aspect of life and has turned into a need. Plastic is used to make every item that has been created by humans. It has become everyone's friend because it is a versatile and useful element. Due to its extremely cost-effective nature, it may be applied to a wide range of industries, including agriculture, construction, products packing, protective covers, electronics, and more [1]. But despite its many benefits, plastic also has drawbacks, and because demand for it has grown, it has become a concern to get rid of it. Plastic is an eternal substance in nature, as we all know. It cannot be completely extinguished; they have a long lifespan [2]. Each person uses around 45 kg of plastic annually, which results in an average worldwide plastic production of 360 million tonnes [3]. The environments are suffering because of this exceptional waste plastic [4]. Researchers have started to investigate if this used plastic might have a place in construction.

In comparison to conventional roads, the marshal stability value is increased when waste plastic is used in the construction of the roads [5]. Normal roads' bitumen melts in hot weather and leads to crocodile cracks, bleeding, and other problems because it offers less resistance, whereas upgraded roads' bitumen offers more toughness, durability, and resistance as well as the ability to support big loads. The addition of plastic to bitumen not only proves to be cost-effective but also lengthens the life of the bitumen by preventing UV radiation from affecting plastic roads [6]. Our roads are kept from developing holes by the improved tackiness and viscosity of mixed bitumen, which interlocks the aggregates and aids in water resistance during severe downpours [7]. Therefore, utilising this plastic waste in place of bitumen during road construction lowers bitumen costs while also reducing the amount of plastic waste pollution[8]. It can also help to strengthen the roadways. However, it was discovered by the numerous 1 studies that waste plastic could only be utilised up to 15% of the weight of bitumen. Using titanium dioxide (TIO2) as an admixture to force the bitumen not decrease its rheological properties considerately even with the addition of further more amount of waste plastic, i.e. more than 15%, was an attempt to address the finding that using more than 15% of waste plastic causes the rheological properties of the roads to decrease rather than increase. It was discovered that titanium dioxide (TIO2) has the characteristics which can enhance properties of plumbum. The major goal of this research is to determine the ideal amount of waste plastic to incorporate into the asphaltic mix in order to obtain the necessary or required strength. The emphasis will be on how more plastic could be produced.

II. LITERATURE REVIEW

- Ruchi Bharti et al[9] The paper discusses many modern methods for utilising waste plastic in current circumstances and offers some ways to lessen these plastic wastes. Recycling, landfilling, reusing, hydrogenation, gasification, and incinerating are only a few of the several approaches. According to the study's findings, waste plastic can be managed using the same effective method. By using the measures indicated above, the environment could be protected from these dangerous waste plastics. Additionally, managing the waste plastic is made simple with these approaches, which are simple, environmentally friendly, and best.

- Sudheer Ponnada and Vamsi Krishna K[10]: This study has looked into the use of shredded plastic waste water bottles in asphalt to improve its rheological properties. The majority of the research in this experimental study focused on dry processes. In this investigation, bitumen was combined with heated plastic garbage. After that, other laboratory tests were performed, including those for ductility, penetration, flash and fire points, specific gravity, and elastic recovery. To determine the ideal proportion, the Marshall Stability test was also performed. When the results of modified and basic bitumen samples were compared, it was discovered that adding waste plastic to 7.5% and 5% of the asphalt improved the rheological qualities of the asphalt. It was discovered that adding 7.5% waste plastic to bitumen increases stability then replacing with 5%.

III. EXPERIMENTAL INVESTIGATION

A. Materials Used For Study

i. *Waste Plastic*

Plastic is a general term for any organic polymer-based synthetic or semi-synthetic material. These are derived from natural resources such as coal, plants, natural gas, oil, and minerals. Although the raw elements for today's plastics come from many different sources, the majority of plastics can be produced using hydrocarbons, which are easily accessible in natural gas, coal, and oil. The engineering department is passionate about recycling plastic wastes in light of the growing commitment to ecological biodiversity.The construction diligence sector is based on raw materials, so the interest for the implementation of waste plastic is the insinuation of the significant amounts of utilised. Instead of junking the environment, this waste plastic could be used in the civil engineering field. So one of the option for using the waste plastic in the engineering field is constructing plastic roads. Polyethylene with low density LDPE - Bins and bags for trash are an example.

ii. *Titanium Dioxide (TIO2)*

Titanium dioxide is an oxide that occurs naturally and is present in small amounts (0.6% of the earth's crust). The chemistry of titanium dioxide is (Tio2). It mostly consists of the crystal forms anatase, rutile, and brookite as shown in figure 1. To improve the characteristics of bitumen, white Tio2 powder that was purchased or obtained from industry was used. Titanium dioxide (TIO2) is a crucial substance with important properties including nanoparticles and titanium metal production. Rutile and anatase titanium dioxide are the two primary varieties of TIO2. The fundamental distinction between the two is how they appear; anatase titanium dioxide is colourless, but rutile titanium dioxide is typically found in dark red. Rutile has a positive optical property, whereas anatase has a negative one.

Figure 1: Titanium dioxide

B. Methodology

i. Collecting Of Waste Plastic

Plastic waste is gathered from sidewalks, composting facilities, garbage trucks, collecting programmes, or by purchasing it from rag-pickers or waste-buyers at a cost of Rs. 5-7/kg.

ii. Segregation of plastic waste

In a civilisation, the used materials are dumped outside in a specific location. To be reused, the plastic waste is being separated from the trash. Segregation is the process of separating plastic from other municipal garbage for use in road construction. It is one of the fundamental shapes utilised in plastic road paving. Additionally, it aids in the separation of various wastes that can be turned into manure to boost agricultural productivity.

iii. Cleaning of waste plastic

The plastic material separated out of civic junk is cleaned to remove soil dirt and dust with the help of water and other chemicals after wash the plastic waste is kept under sunlight or sometimes with the help of machines (both manual and mechanical process) for dry condition.

iv. Shredding of waste plastic

After being separated and cleaned, the plastic waste is either manually or with the aid of shredders, grinders, and agglomerates reduced to tiny particles between 2.36mm and 600 microns. Different polymers are combined after being shredded. Depending on the situation, plastic garbage may occasionally be washed again.

C. Tests Performed

- Specific gravity of bitumen test
- Penetration test
- Ductility test
- Specific gravity of aggregates
- Crushing test
- Abrasion test
- Impact test
- Marshall Stability Test
- Indirect Tensile Strength test
- Softening point test

i. ***Softening point test***

a) Procedure

- The specimen is heated to a fluid state at temperatures between 75 and 100 °C above its softening point.
- Next, heated rings maintained on the metal plate were poured in as shown in figure 2. Coating is carried out to stop the dextrin and glycerine solution from clinging to the metal plate.
- The extra bitumen is removed with a knife after the rings have cooled for 30 minutes in the air, and the rings are then retained in the support.
- The water's temperature is set at 5 °C at this specific moment. After maintaining it for 15 minutes, the balls are retained in place.
- A regulated heating unit is then used to maintain the water at a consistent temperature of 5 C/min.
- The softening point is the temperature that is measured when metal-softened asphalt comes into contact with a metal plate, which may be at the same distance away.

Figure 2: Softening point test apparatus

D. Gradation of Aggregates

Gradation of aggregates is the term used to describe the distribution of particle size inside an aggregate as measured by sieve analysis. Grading of aggregates, or the distribution of aggregate sizes, is a crucial attribute since it establishes the paste quantity needed for workable concrete. The factor regulating the price is this paste demand. One of the key elements in the design of the DBM mixture is the gradation of the aggregates.

IV. RESULTS AND DISCUSSIONS

A. Bitumen Test Results

The following experiments were carried out on asphalt as part of this study to determine the various physical characteristics of the bitumen as shown in table 1:

- Specific gravity
- Penetration
- Softening point
- Ductility

Table 1: Bitumen test results

Serial No.	Experiment	Test Results	Requirement as per IS:73:2013
1	Specific Gravity	1.01	0.97(min)
2	Penetration	64	60-70(mm)
3	Softening	48.2	40C(min)
4	Ductility	63.9	40cm(min)

B. Aggregate Test Results

The following tests were carried out on aggregates as part of this research to determine the various physical properties of the aggregates as show in table 2:

- Specific gravity
- Impact value
- Crushing value
- Abrasion value

Table 2: Aggregate test results

Serial NO.	Experiment	Test results	Requirement as per MORTH (Table 500-11)
1	Specific Gravity	2.61	2.5-3.0
2	Impact Value	23	Max 27%
3	Abrasion Value	29	Max 35%
4	Crushing Value	22.9	Max 30%

C. Marshall Mix Design

Bruce Marshal from the Mississippi highway department first devised the Marshall Mix design process in 1939. The fundamental goal of the Marshall Mix design process entails choosing a bitumen binder concentration with the proper density to compensate for the least amount of stability and range of flow usefulness. This technique is widely applied in regime test applications for paving operations and is utilised for developing and calculating asphalt surface mixtures.

i. Bitumen mix results

In this investigation, normal specimens containing varying percentages of bitumen, such as 4.5%, 5%, 5.5%, and 6%, were subjected to Marshall Stability tests. The test findings showed that 5% bitumen concentration was the ideal amount of bitumen to use for the experimental activity. The following table 3 displays the results:

Table 3: Test result for optimum bitumen content

S.NO	% of Bitumen	Stability (KN)	Flow (mm)	Density (g/cc)	VV %	VMA %	VFB %
1	5	19.03	3.2	2.33	3.8	15.69	72.18

ii. Waste plastic mix results

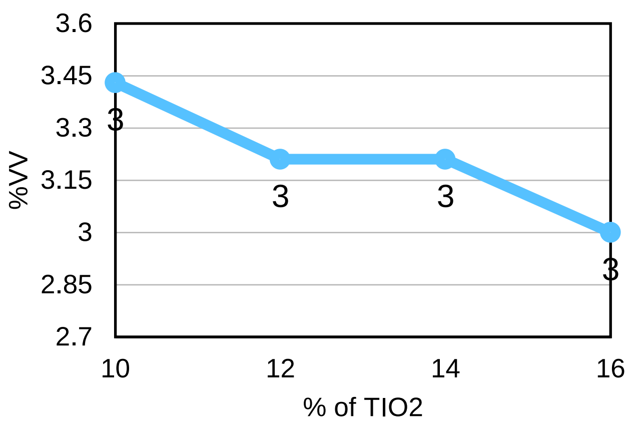
The results of stability and flow value in wearying percentages of plastic wastes are shown in Figure 1. For stability, the value rises as the amount of waste plastic increases up to 14%, and then it falls when waste plastic amounts to 16%. However, as the percentage of waste plastic grows, the flow value rises.

iii. Waste plastic with TIO2 mix results

Following the selection of the plastic content, the specimens containing Tio2 were made by Marshall Mix Design using 16% plastic waste and varied amounts of Tio2 such as 10%, 12%, 14%, & 16%. Following that, these specimens underwent a variety of tests, the results of which are displayed in the following table 4:

Table 4: Test results of varying % of titanium dioxide (TIO2)

S.NO	% of plastic	% of TIO2	Stability (KN)	Flow (mm)	Density (g/cc)	VV %	VMA %	VFB %
1	16	10	25.8	1.54	2.21	3.43	14.4	74.68
2	16	12	28	1.9	2.22	3.21	14	74.87
3	16	14	29.7	2.06	2.22	3.21	13.6	75.6
4	16	16	35.7	2.69	2.24	3	13.14	75.82



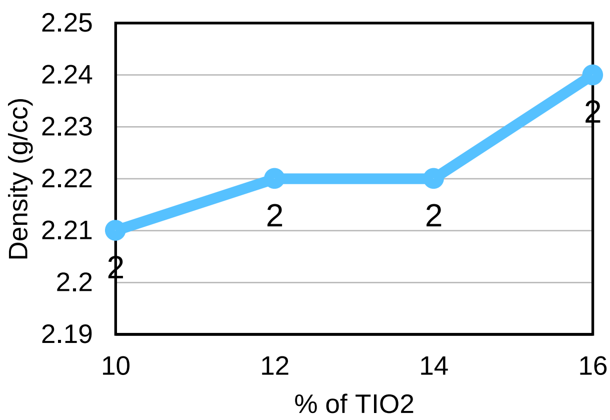


Figure 3: % of titanium dioxide (TIO2) vs. density and air voids

Figure 3 shows the results of the density and air void measurements at 16% waste plastic with the addition of a Tio2 wear percentage. When compared to the typical plastic waste specimen, the result demonstrates that density values rise while air void values fall. It is abundantly obvious from the aforementioned findings that employing TiO2 as a chemical additive has produced great results, showing higher values when compared to the typical plastic specimen. With the addition of 10, 12, 14, and 16 percent of TiO2, the Marshall stability was found to be at its greatest at 16%.

iv. Indirect Tensile Strength Test Results

For this method, the Marshall Sample's vertical diameter is loaded at 50 mm per minute while deforming between two antipodal loading strips. For a sample with a diameter of 101.6mm, loading strips with a thickness of 12.7. 0.3mm are employed to provide a consistent loading, which in turn produces the constant arrangement as shown in table 5.

Table 5: Test results of indirect tensile strength (ITS) test.

% of waste of plastic	Type of plastic	Type of admixture	Unconditioned	
			ITS (MPa)	
			Normal waste plastic specimen results	Plastic waste with 16% TIO2 specimen results
9	PET	TIO2	0.88	1.07
11	PET	TIO2	0.91	1.16
14	PET	TIO2	1.08	1.27
16	PET	TIO2	1.01	1.35

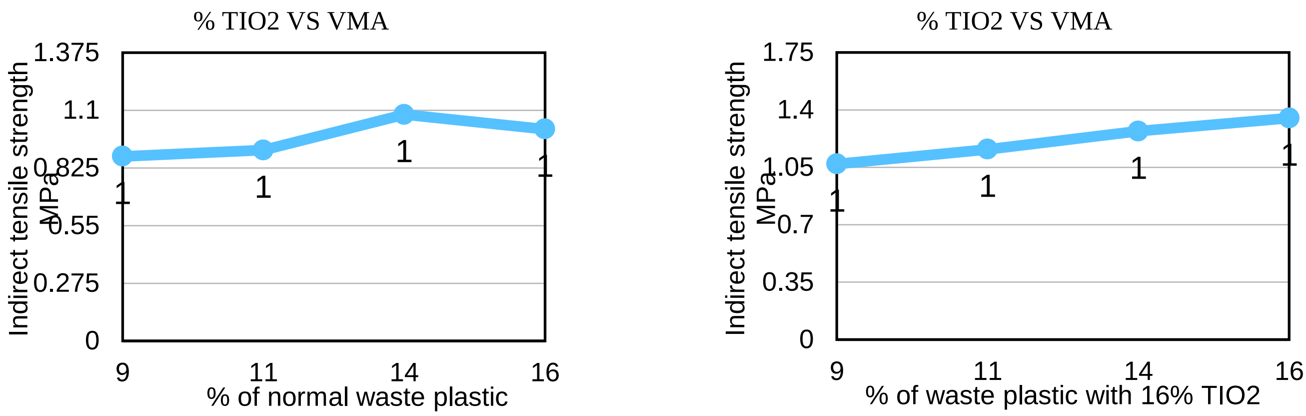


Figure 4: % of normal plastic waste vs. % of plastic waste with 16% of TIO2

The values are computed using the following equation below:

St. =2000×P/πtD
Where,
St. = IDT Strength
P = Peak load
T = sample height before testing in mm
D = Diameter of the Specimen in mm

For indirect tensile strength two types of plastic specimens were made, normal plastic waste samples and plastic waste samples blended with titanium dioxide having variant percentage of plastic waste like 9%, 11%, 14%, and 16% and for titanium dioxide samples 16% of titanium dioxide is used.
The test results shown in the graphs in figure 4 and tables 5 as well as the graphs and tables clearly show that using the optimum percentage of 16% of titanium dioxide (TIO2), the indirect tensile strength (IDT) of plastic waste mixed with titanium dioxide mixture significantly increased when compared to the simple waste plastic samples. Increasing the resistance of roads to wear, deformation, and cracking will be made possible as a result.

V. CONCLUSION

The use of waste plastic in the field of civil engineering has a significant potential to lessen biological and environmental contamination on a global scale. When compared to synthetically manufactured materials, the behaviour of waste plastic in construction elements or other items is inherently different. However, building materials made from waste plastic might perform better than traditional building materials. Utilising waste plastic will help to some extent slow down the use of conventional building materials.

- Comparing the results of the (ITS) indirect tensile test to the typical waste plastic mix, they show a significant improvement.

The major goal of this research was to determine the ideal amount of waste plastic to incorporate into the asphaltic mix in order to obtain the necessary or required strength. The following conclusions came from this research:

- One creative piece of technology is the use of discarded plastic in road construction. In addition to stabilising the road, it also extends the life of the pavement. The strength, cost, and durability are shown by the examination in this study.
- This study reveals that due to the use of plastic with the addition of Tio2, Marshall stability value, a strength parameter for DBM, has proven to be a huge increase and the maximum values have increased by around 35% by addition of PET and Tio2.
- The inclusion of TiO2 significantly increases the density and rheological parameters of the plastic specimens when compared to the standard plastic specimens.

- The mixtures that are unable to withstand strain are anticipated to allow breaking since the greatest value of tensile strength corresponds to strong cracking resistance.
- Also the residue such as fly ash generated in thermal plants is very difficult to dispose off, so using this fly ash as a filler material may not only support in disposing it off, but may also supporting increasing the characteristics of asphaltic mixture.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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