AN EXPERIMENTAL STUDY ON TYRE WASTE AND WASTE POLYTHENE USED IN WEARING SURFACE OF FLEXIBLE PAVEMENT

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Abstract
Due to the non-biodegradable nature of plastic and rubber tyres, their disposal has a significant negative impact on the environment. Utilizing plastic and tyre debris in bituminous mixtures improves their strength and characteristics while lowering the aggregate proportion. Waste plastics from diverse sources, such as milk jugs, polythene bags, and used tyres, are gathered, cleaned, and dried for processing. After that, a shredding (cutting) machine is used to process the used plastic and tyres. Tests including those for ductility, penetration, and softening points are used to determine bitumen's qualities. The shredded plastic and used tyres are combined with the aggregate and hot bitumen after the qualities of the aggregates are determined by abrasion, impact testing, etc. After preparing the aforementioned sample, we should check for stability by Marshall stability test. We accomplish this by varying the proportions of plastic and tyre waste. The test findings must to adhere to the IS criteria. The sample that was tested can then be used. Trash polythene and tyre waste can be used to modify bitumen, which can then be utilised as a surface for walking on (top layer). It is also known as flexible pavement's bituminous concrete mix. This modified bitumen made from scrap plastic performs better in terms of density and water resistance. Economical and environmentally friendly.

Keywords: Marshall Stability test, Tyre waste, Rubber tyres, waste plastics, milk covers, softening point
Penetration, ductility tests.

1.Introduction

1.1General:

The road network is one of the most popular forms of public transportation. Keeping the roads in good condition is crucial. The quality of the road is influenced by the materials utilised. The top layer of flexible pavement has the maximum stress strength, which is why it is primarily formed of bitumen from better material. For many years, bitumen has been utilised as a binding substance to construct pavements and roadways.

1.2 Flexible pavement:

Generally, all the hard surfaced pavement types are categorized into 2 groups:

i. Flexible Pavement: A pavement is referred to as "flexible" if the surface course is bitumen because the entire pavement structure is capable of bending or deflecting in response to traffic loads.

ii. Rigid Pavement: A pavement is referred to as "rigid" if its surface course is made of PCC and cannot flex or deflect under the weight of traffic. Due to the high elastic modulus of the plain cement concrete, these pavements are substantially stiffer than flexible pavements. Importantly, we may reduce or eliminate joints in stiff pavements by using reinforcing steel..

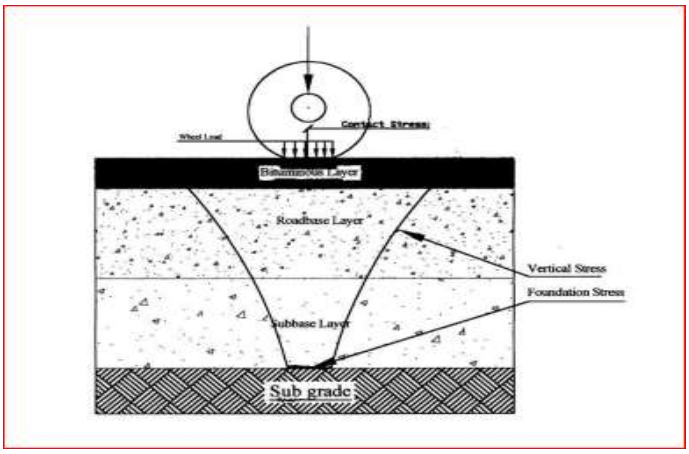


Fig 1: Stress distribution diagram in flexible pavement

1.3 There are different layers in flexible pavement:

1.Compacted Sub-grade (150 – 300 mm)
2. Sub-base Course (100 – 300 mm)
3. Base Course (100 – 300 mm)
4. Prime Coat
5. Binder Coat (50 -100 mm)
6. Tack Coat
7. Surface Course (25 – 50 mm)
8. Seal Coat

1.4 Wearing Surface:

In many regions of the world, bituminous concrete is also frequently referred to as asphalt. Despite its name, this substance differs significantly from regular concrete and doesn't contain cement. While the majority of surfaces made of cement are white or grey, bituminous concrete is distinguished by its characteristic black colour. It can also be poured over already-existing concrete to repair or fill in holes and irregularities. It is frequently laid directly over a gravel base layer to create new roadways and parking lots.

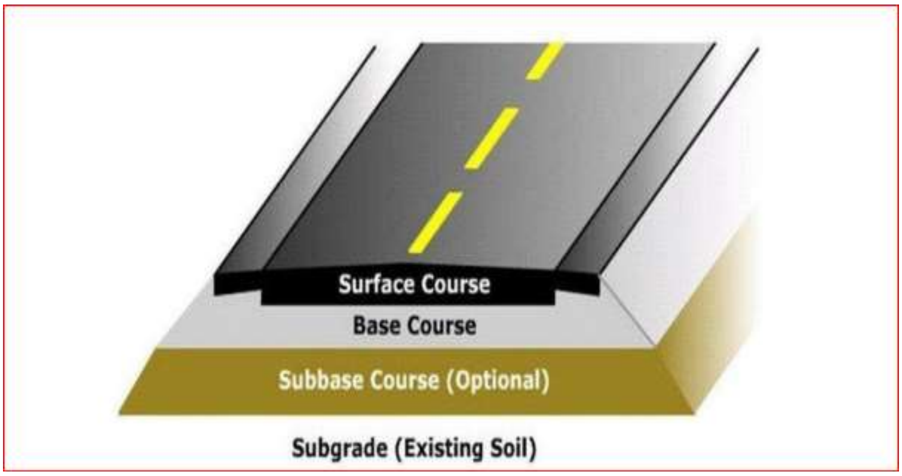


Fig 2: layers of flexible pavement

1.5 Literature review

1. A paper on the topic of "Use of waste plastic in construction of bituminous roads" was presented by Mrs. Vidula Swami from KIT'S College of Engineering in Kolhapur, Maharashtra, and it was published in the year 2012 issue of the International Journal of Engineering Science and Technology (IJEST).

2. A study on the issue of "Utilization of waste plastic in asphalting on roads" was given by Amit Gawande and G.S. zamre from the College of Engineering and Technology in Akola, Maharashtra, and it was published by "science research and chemical communication."

3. A presentation on the topic of "Utilization of waste plastic as a strength modifier in surface course of flexible and stiff pavement" was presented by Afro Sultana.S.K and K.B.S Prasad from the "GMR Institution of technology, Rajam Andhra Pradesh" and published in the "International journal of engineering research and applications" in July august 2010.

2. Materials

Bitumen is a material that is created by the distillation of crude oil and is renowned for its waterproofing and sticky characteristics. When bitumen is distillated, lighter crude oil constituents like gasoline and diesel are removed, leaving just the "heavier" bitumen. The maker also refines it numerous times in order to improve its grade. Naturally occurring bitumen deposits can be found in the bottom of ancient lakes, where extinct animals have decomposed and been subjected to heat and pressure. Bitumen can also be found in nature. In American English, bitumen means asphalt.

Fig 3: Bitumen

2.1Coarse aggregates:

For structural concrete, coarse aggregates are broken stones of hard rock, such as granite and limestone (angular aggregates), or river gravels. Coarse aggregates are irregular broken stones or naturally existing round gravels that are used to build concrete (round aggregates). Coarse aggregates are defined as those with a size greater than 4.75 mm. These aggregates, which range in size from 4.75 mm to 80 mm, are obtained from stone quarries and stone crushers. According to its code, coarse aggregate has a specific gravity of 2.5 to 3.

2.2 Types of Coarse Aggregate

I. Classification based on Shape
- Elongated Aggregate
- Flaky Aggregate

II. Classification based on Geological Origin
- Natural Coarse Aggregate
- Artificial Aggregate

III. Classification Based on Size
- All-in-Aggregate

Fig 4: coarse aggregate

Table 1 :Sizes of coarse aggregate

Coarse aggregate	size
Fine gravel	4mm-8mm
Medium gravel	8mm-16mm
Coarse gravel	16mm-64mm
Cobbles	64mm-256mm
Boulders	>256mm

2.3 Waste polythene:

It is made via the free-radical polymerization of ethane and ranges in density from 0.910 to 0.940 g/cm3. The reaction is conducted in the presence of a catalyst, dioxygen (in traces), or a peroxide initiator at a temperature between 350 K and 570 K under a pressure between 1000 and 2000 atmospheres.

Fig 5: polythene bag

Table 2: properties of LDPE

Melting point	105-115°C
Density	0.910-0.940 gm/cm*3
Chemical resistance	Alcohols and acids
Water absorption	Very low
Temperature resistance	Up to 80°C

2.4 High-density polythene: It has a modest degree of branching and a density of more than or equal to 0.941 g/cm3. It is produced when ethene addition polymerizes in a hydrocarbon solvent. The reaction is conducted with Ziegler-Natta catalysts or metallocene catalysts under a pressure of 6 to 7 atmospheres and at a temperature of 333 K to 343 K. Additionally chemically inert, HDPs are employed in the production of bottles, butter tubs, milk jugs, water pipes, and garbage cans.

Fig 6: HDPE bottles

Table3: Properties of HDPE

Melting point	120-140°C
Density	0.93-0.97 gm/cm*3
Chemical resistance	Alcohols and acids
Water absorption	Very low
Temperature resistance	Low

3. Methodology

Types of Tests on Aggregates

In the case of aggregates, 9 key tests have been identified that define aggregate quality. These tests on aggregates are listed below -

- Aggregate Crushing Test
- Aggregate Impact Test
- Aggregate Abrasion Test
- Flakiness Index Test
- Elongation Index Test
- Specific Gravity and Water Absorption Test

3.1 Aggregate Crushing Test

Aggregate strength is described as the aggregate's resistance to gradual loading. The Crushing Value Test on aggregates determines the strength of the aggregate. The aggregates retained on a 10 mm IS sieve after passing through a 12.5 mm IS sieve are collected. With the aid of a plunger, these aggregates are gradually loaded with 40 tonnes. Then a 2.36 mm sieve is used to filter the crushed aggregates. Aggregate Crushing Value is the weight of the aggregates that pass through the 2.36 mm screen, represented as a percentage of the total weight of aggregates (ACV). The strength of the aggregate will increase as the ACV decreases. ACV less than 10 denotes an exceedingly strong overall composition, while ACV greater than 35 indicates weak aggregate.

Aggregate Crushing Value (ACV) =weight of material passing through 2.36 mm sieve/ weight of total aggregate

3.2 Aggregate Impact Test

The capacity to withstand impact loading is referred as as the aggregate's toughness. Impact Value Test on aggregates determines the aggregate's toughness. The aggregates retained on a 10 mm IS sieve after passing through a 12.5 mm IS sieve are collected. A metallic hammer with a mass of 13.5–14.0 kg is used to deliver 15 blows to this sample of aggregate as it falls freely from a height of 38 cm.

After impact, the aggregates are run through a 2.36 mm sieve. Aggregate Impact Value is the weight of aggregates passing through the 2.36 mm sieve, represented as a percentage of the total weight of aggregates (AIV). The toughness will increase when the AIV decreases. For bituminous macadam, the AIV should not be more than 35%, and for water-bound macadam, it should not be more than 40%.

Weight of material passing through a 2.36 mm sieve/weight of the total aggregate is the aggregate impact value (AIV).

3.3 Aggregate Abrasion Test

Aggregate's ability to withstand wear and tear is due to its hardness (abrasion). The Deval Abrasion Test, Dorry's Abrasion Test, and Los Angeles Abrasion Test can all be used to gauge an aggregate's hardness. The standardised test for measuring the hardness of aggregates in India is the Los Angeles Abrasion Test. In this test, aggregates that are retained on a 10 mm sieve after passing through a 12.5 mm screen are put in a cylinder with steel balls. The sample is abrasively damaged by spinning the cylinder 500 times at a speed between 30 and 33 rpm.

3.4 Specific Gravity and Water Absorption Test

Two crucial tests on aggregate are the Specific Gravity and Water Absorption Tests since these factors are crucial for designing concrete and bituminous mix designs. Specific gravity is defined as the mass of an aggregate divided by the mass of an equivalent volume of distilled water at a certain temperature. Two different types of particular gravity exist. Both apparent specific gravity, in which only the volume of the aggregate is taken into account without taking into account the volume of voids, and bulk specific gravity take into account both the aggregate's entire volume and the volume filled by voids.specific gravity of the bulk Gbulk is defined as the dry mass of aggregate, aggregate volume, or water density.

The proportion of a substance's mass to its apparent specific gravity The terms "dry mass of aggregate" or "volume of aggregate without voids" and "water density" are all referred to as "Gapp." The typical range of aggregate specific gravity for paving projects is between 2.6 and 2.9. A water absorption rating of more than 0.6% is considered inadequate. For road paving, water absorption ranging from 0.1% to 2% is typically employed.

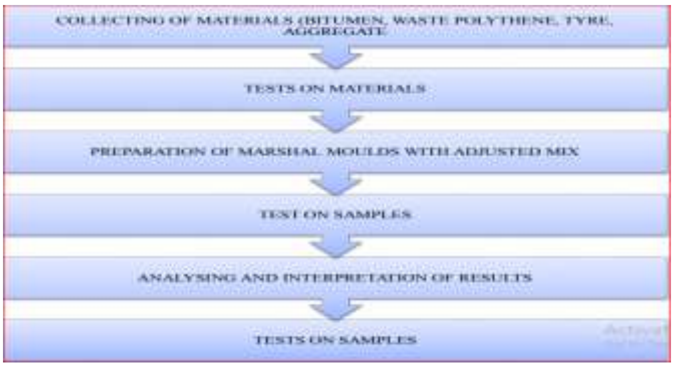


Fig 7: Heating of aggregates

After heating of the aggregates we should prepare the sample by mixing aggregates, filler, bitumen , polythene, rubber in the bitumen mixer.

Fig 8: mixing of sample

Fig 9 : Marshal moulds

Fig 10: Marshall stability test for moulds

4.Results & Discussion

4.1Test results of properties of bitumen:

Detailed Tests results performed on bitumen:(IS 1201-1220)

Table 4: detail results of tests performed on bitumen

s.no	Test performed	Obtained value
1	Penetration value	40
2	Softening point	74.5 °c
3	Fire point	104 °c
4	Flash point	95 °c
5	Ductility value	60cm

Table 5:Test results of properties of coarse aggregates:

s.no	Test performed	Value obtained	Permissble value
1	Specific gravity	2.58	2.5-3
2	Aggregate impact test	21.95%	20-35%
3	Aggregate crushing value test	24.48%	Max 30%
4	Los angels abrasion tset	30%	Max 30%

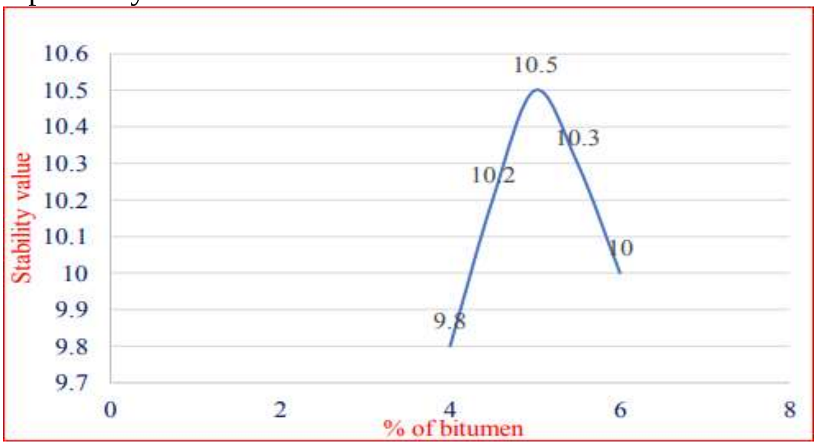
4.2 Marshal stability test

Table 6: detailed results of optimum bitumen content

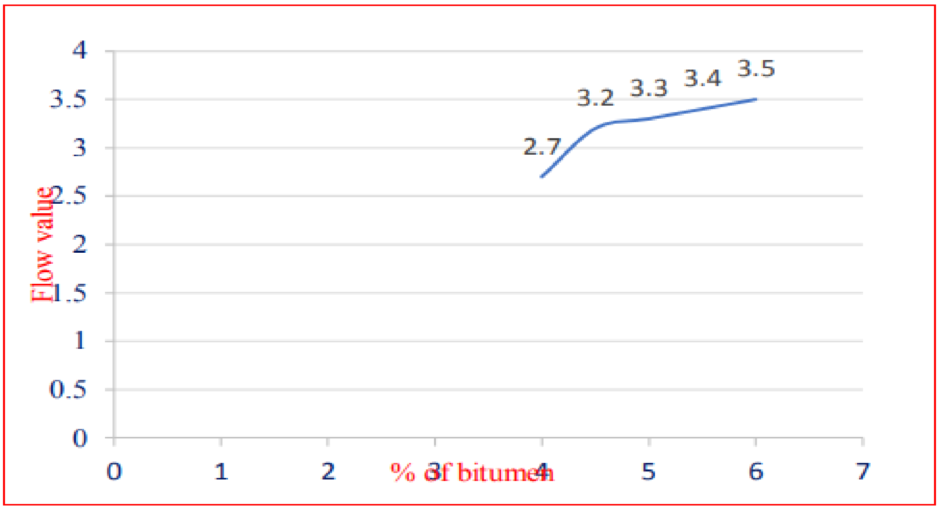
To find optimum bitumen content:

s.no	% of bitumen	Stability (kN)	Flow value(mm)	Bulk density (Gm) g/cc	Air voids %	VMA %	VFB %
1	4	9.8	3	2.25	2.17	10.89	80.09
2	4.5	10.2	3.2	2.15	2.71	12.06	77.52
3	5	10.5	3.3	2.25	2.74	13.6	79.85
4	5.5	10	3.4	2.14	2.05	13.31	81.95
5	6	9.6	3.5	2.17	1.76	14.33	88.13

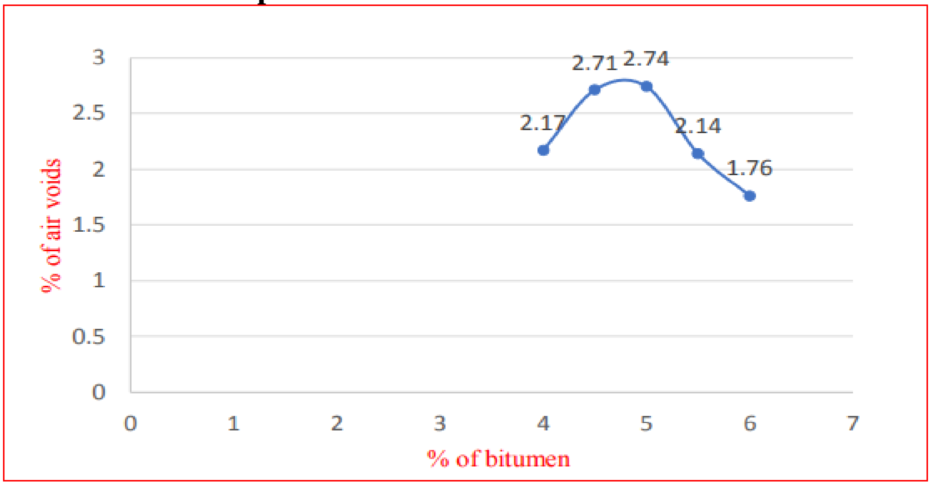
To regulate the durability of asphalt mixes, the road authorities typically set restrictions for voids in the total mix (VTM), voids in mineral aggregates (VMAs), and voids filled with bitumen (VFB). The VFA measures how much asphalt cement is used to fill voids in the compacted aggregate mass. It and the asphalt-void ratio are interchangeable terms. The VFA property is crucial since it is a good indicator of relative durability and has a strong relationship with percent density. If the VFA is too low, there won't be enough asphalt to offer durability, which will lead to over-density under traffic and bleeding. The VFA is a crucial design characteristic as a result. After the test results, the course aggregate was combined with 5% bitumen, which generated ideal values for stability, flow, bulk density, air voids, voids in the mineral aggregate, and voids filled with asphalt, which were 13.6 and 79.85%, respectively.



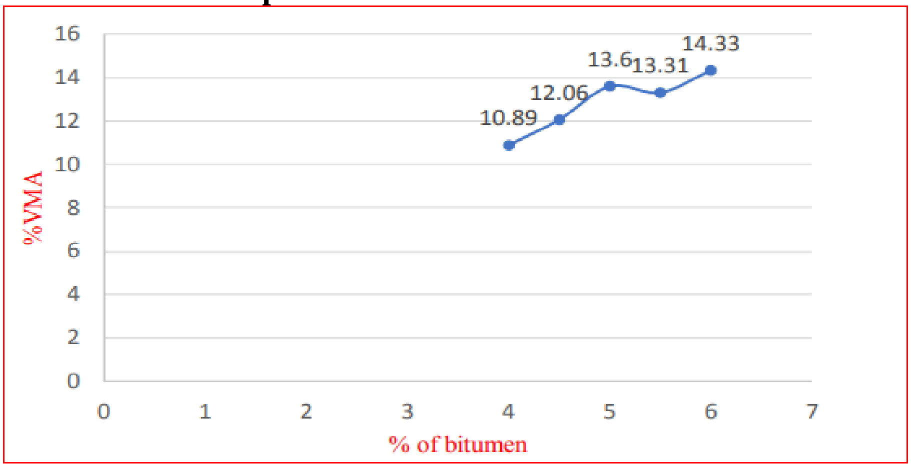
Graph 1: % of bitumen vs stability



Graph 2 : % of bitumen vs flow value



Graph 3 : % of bitumen vs air voids



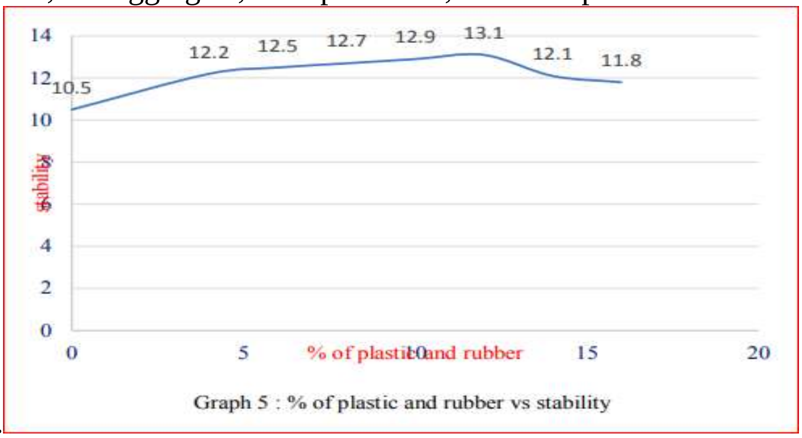
Graph 4 : % of bitumen vs VMA

Marshall test by replacing aggregates by polythene and rubber:

Table 7 Observation table by replacing aggregates by polythene and rubber

Sample no	% of rubber and plastic	Stability (kN)	Flow value(mm)	Bulk density (Gm) g/cc	Air voids %	VMA %	VFB %
1	sample without adding rubber and polythene	10.5	3.3	2.25	2.74	13.6	79.85
2	87%A+5%B+4%P+4%R	12.2	3.3	2.12	2.75	13.02	78.87
3	83%A+5%B+6%P+6%R	12.5	3.1	2.13	3.04	13.28	77.1
4	79%A+5%B+8%P+8%R	12.7	3.4	3.4	3.09	13.35	76.85
5	75%A+5%B+10%P+10%R	12.9	3.7	3.7	3.47	14.08	78.35
6	71%A+5%B+12%P+12%R	13.1	3.9	3.9	3.5	14.3	81.2
7	67%A+5%B+14%P+14%R	12.1	3.6	3.6	3.15	13.47	77.61
8	63%A+5%B+16%P+16%R	11.8	3.2	3.2	2.76	12.9	77.12

The term "voids in the mineral aggregate" (VMA) refers to the air-void gaps, including spaces filled with asphalt, that exist between the aggregate particles in a compacted paving mixture. VMA is a measurement of the volume of air voids required in the mixture as well as the space available to hold the asphalt. The more VMA there is in the dry aggregate, the more room there is for the asphalt layer. Most specifications include explicit minimum requirements for VMA because the more asphalt layer there is on the aggregate particles, the more durable the mix will be. The optimal parameters, such as stability value 13.1kN, flow value 3.9, bulk density 3.9 g/cc, air voids 3.5%, voids in the mineral aggregate 14.3, and voids filled with asphalt 81.2%, were generated by the mixture of 71% asphalt, 5% aggregate, 12% polethene, and 12% plastic.



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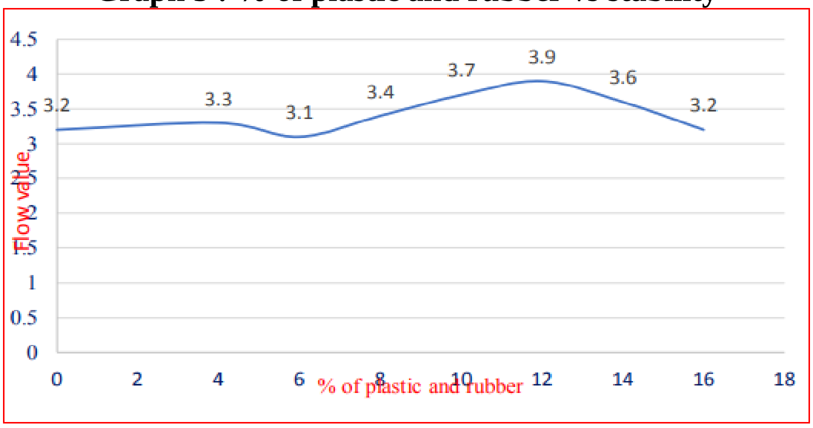
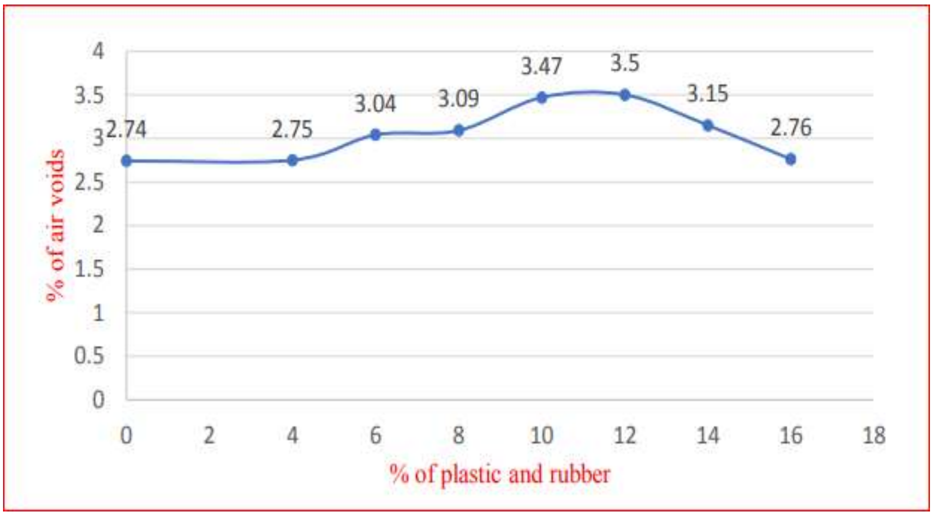
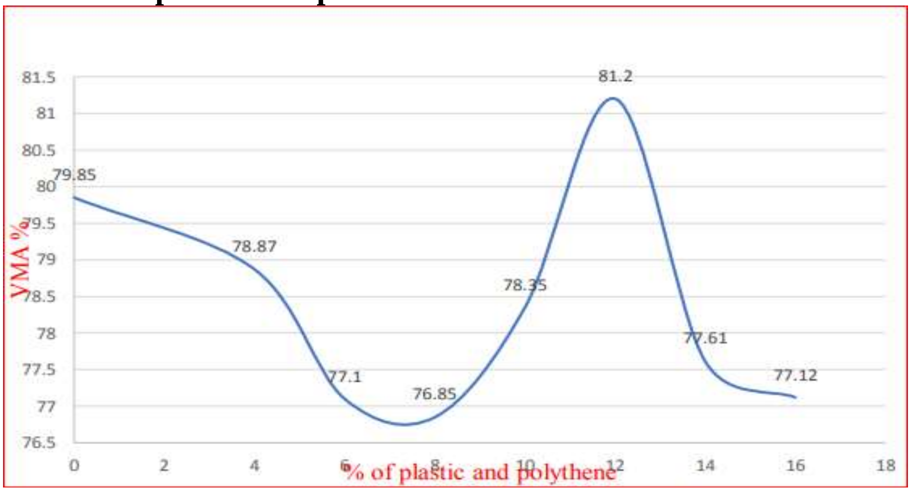
Graph 5 : % of plastic and rubber vs stability



Graph 6 : % of plastic and rubber vs flow value



Graph 7 : % of plastic and rubber vs % of air voids



Graph 8 : % of plastic and rubber vs % of VMA

5. Conclusion

In an experimental test of the Marshall stability test, which was initially conducted to determine the ideal bitumen content, a wearing surface of flexible pavement made of polythene (plastic) and waste tyre rubber performed well. After 5% bitumen content, the stability value starts to decline. The bitumen percentages used are 4, 4.5, 5, 5.5, and 6. It was discovered that 5% bitumen content produced the highest stability value.

For the roads to operate better, plastic is combined with bitumen and aggregates. The aggregates' polymer coating decreases voids and moisture absorption. As a result, there are fewer ruts and no potholes are created. Plastic pavement is more durable than flexible pavement and can resist heavy traffic. Utilizing plastic blends will reduce the bitumen content by 12% and increases the strength and performance of the road. This new technology is eco-friendly

In the case of crumb rubber modified bitumen, the values of various parameters, including softening point, penetration, elastic recovery, and marshall stability, have been found to be within specified requirements. The Marshal Stability value, which is the strength parameter of bituminous concrete, has showed an improving trend, and the maximum values have increased by around 12% by the inclusion of tyre waste, according to crumb rubber modified bitumen.

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