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Utilization of Waste Plastic in Flexible Pavement-An Approach to Sustainable Development

V. M. Jadhav[1], K. V. Zanje[2], Prof. R. Y. Mane Deshmukh[3]

UG Student, Department of Civil Engineering, SMSMPITR, Akluj, Maharashtra, India[1-2]

Asst. Professor, Department of Civil Engineering, SMSMPITR, Akluj, Maharashtra, India [3]

Abstract: The debate on the use and abuse of plastics vis-à-vis environmental protection can go on, without yielding results until practical steps are initiated at the grassroots level by everyone who is in a position to do something about it. The plastic wastes could be used in road construction and the field tests withstood the stress and proved that plastic wastes used after proper processing as an additive would enhance the life of the roads and also solve environmental problems. The present write-up highlights the developments in using plastics waste to make plastic roads. The rapid rate of urbanization and development has led to increasing plastic waste generation. As plastic is non-biodegradable in nature, it remains in environment for several years and disposing plastic wastes at landfill are unsafe since toxic chemicals leach out into the soil, and under-ground water and pollute the water bodies. Due to littering habits, inadequate waste management system / infrastructure, plastic waste disposal continue to be a major problem for the civic authorities, especially in the urban areas. As stated above, plastic disposal is one of the major problems for developing countries like India, at a same time India needs a large network of roads for its smooth economic and social development. Scarcity of bitumen needs a deep thinking to ensure fast road construction.

Keywords: roads, grassroots level, practical steps, plastic wastes, road construction.

I. INTRODUCTION

A. General:

The growth of industries and population has led to an increase in waste production worldwide. Non-decaying materials like blast furnace slag, fly-ash, steel slag, scrap tires, and plastics pose challenges in both developed and developing countries. Numerous efforts have been made to dispose of these materials and utilize them, with published literature on various aspects. Organizations and researchers are working to find effective methods for utilizing these materials, with efforts in highway construction showing promising results. Thin plastic bags are widely used for packing and carrying household items, but their disposal in large quantities is a concern, especially in large cities. The mixing of these bags with bio-degradable organic waste in urban areas is the main cause. Some cities are attempting to limit or prohibit the use of thin plastic bags for packing and other common use to control this undesirable waste material from mixing with organic garbage.

B. Background of Proposed Work:

Plastic, a toxic waste material, accounts for almost 5% of municipal solid waste. It is often found in urban and rural areas, causing water stagnation and hygiene issues. Experiments have shown that waste plastic can be reused in road construction by adding it to hot aggregate, creating a fine coat. This aggregate, mixed with binder, provides higher strength, resistance to water, and better performance over time. Therefore, it is proposed to use waste plastic in rural road construction. Asphalt emulsions have been used in road construction since the early 20th century, with up to 10% of paving-grade asphalt now in emulsified form. Polymer modified asphalt technology, first patented in 1843, has been used by researchers and manufacturers to improve performance. The Texas Department of Highway and Public Transportation recorded the use of polymer modified asphalt emulsion in 1982 for a seal coat on State Highway 327 near Silsbee. As traffic increases and high-pressure radial tires become more common, roadway wear and deterioration

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accelerate. The growing population and industry growth have led to increased waste production worldwide. This work focuses on eco-friendly plastic disposal and strengthening of flexible pavement.

C. Necessity of proposed Work:

- Plastic mainly consists of low-density polyethylene and more durability than regular bitumen roads.
- Eco-friendly recycling of plastic wastes so plastic waste management will be done up to certain extent. And Eco-friendly process.
- This will provide more stable and durable mix for the flexible pavements. The serviceability and resistance to moisture will also be better when compared to the conventional method of construction.
- The polymer modified bitumen show better properties for road construction and plastics waste which otherwise are considered to be a pollution menace.
- Improvement in properties of bituminous mix provides the solution for disposal in a useful way.
- Poor locally available aggregates can make into use by coating them with waste plastic which will ultimately reduce the haulage cost& improves the physical properties of aggregates.
- Stone aggregate is coated with the molten plastic waste. The coating of plastics reduces the porosity, absorption of moisture & improves stripping value.
- Aggregate coated with plastic waste followed by bitumen shows nil stripping even after 72 hours resulting in No Pot Hole Formation.
- Hence the use of plastic waste for flexible pavement is one of the best methods for easy disposal of waste.

D. Scope of Work:

- To study the behaviour of Plastic Waste Bitumen Material in Road Construction.
- To study the strength related properties of Plastic Bituminous Road.
- To Design a Road with Maximum Durability By replacing The Aggregates by Using Plastic Waste Polymers.
- Sustainable Approach For pollution control of Plastic Waste. Study of waste plastic.
- Laboratory performances of plastic waste& bituminous mixes.
- Behaviour of plastic waste & bituminous mixes road.
- Comparison between normal bituminous road & plastic waste & bituminous mixes road.

E. Methodology

- Data collection from literatures.
- Preparation of Plastic bitumen film on the Aggregates.
- Select proper Proportions for road application.
- Casting of test samples and various tests on it.(Marshall Stability Test)
- Comparison of the results and solution to the proper mix proportion to achieve maximum strength with more amount of replacement of bitumen.

II. LITERATURE REVIEW

Fransis Hveem, a California Department of Highways project engineer, developed the Hveem stabilometer in 1927. He used surface area calculation to estimate the optimum quantity of bitumen needed for cement concrete mix design, without prior experience in judging mix color. Roberts et al. (2002) introduced bitumen in rural roads to prevent dust removal from Water Bound Macadam due to automobile growth. Heavy oils were initially used as dust palliative, and a pat test was used to estimate the required amounts of heavy oil in the mix. Roberts et al. (2002) introduced bitumen in rural roads to prevent dust removal from Water Bound Macadam due to automobile growth. Heavy oils were initially used as dust palliative, and a pat test was used to estimate the required amounts of heavy oil in the mix. Today the availability of the waste plastics is enormous, as the plastic materials have become part and parcel of daily life. They either get mixed with Municipal Solid Waste and or thrown over land area. Their present disposal is either by land filling or by incineration. Both the processes are not Ecofriendly. Under this circumstance, an alternate use for the waste plastics is also the need of the hour. Plastics are organic in nature and Bitumen is also a mixture of organic compounds. Hence the mixture of the two is possible.

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Rutting is a stress-controlled cyclic loading phenomenon causing permanent deformations in bituminous surfacing. The deformation process is accelerated by increased pavement temperature, reduced stiffness, and traffic loads. This paper investigates the use of waste polymeric packaging material (WPPM) in road construction to increase stiffness modulus and protect the environment. WPPM is used in bituminous mixes, such as milk bags and HDPE-based carry bags, to reduce rusting. The optimal dose of WPPM is 0.3 to 0.4% by weight of bituminous mix, with higher doses causing higher stiffness. Rutting of bituminous mix can be reduced to 3.6 mm after 20,000 cycles by adding the optimum quantity of WPPM. This study confirms the potential of WPPM in preventing moisture damage, improving pavement performance, and alleviating disposal problems for a clean and safe environment.

Bahia and Anderson (1984) studied bitumen, a thermo-visco-elastic material with significant behavior influenced by temperature and load application. They classified bitumen as rheological materials due to their viscosity stress and strain response, which is time and temperature dependent. The binder consistency and cementing mechanism of bitumen change depending on its viscosity. The study modified bitumen with penetration grade 60/70 with sasobit wax, obtained from coal gasification using the Fischer-Tropics process. Viscosity is a significant parameter in determining bitumen rheology and engineering properties, affecting workability and mix resistance. However, viscosity measurements have been used to classify bitumen, but due to its visco-elastic nature, the results lack uniformity due to variations in bitumen source and molecular content.

Shukla and Jain (1984) found that adding EVA, aromatic resin, and SBS to waxy bitumen reduces its resistance to high temperatures, bleeding, and brittleness. Button and Little (1998) found that SBS modification significantly reduces rutting rate and exhibits superior fatigue properties compared to straight AC-5 bitumen. Justo C.E.G. and A. Veeraragavan (2002) found that adding 8% by weight of processed plastic to modified bitumen results in a 0.4 % bitumen savings, or about 9.6 kg bitumen per cubic meter of BC mix. This modification improves the stability, strength, life, and other desirable properties of bituminous concrete mix. The modified bitumen's properties decreased with the increase in plastic additive proportion, up to 12% by weight. The softening point increased with the addition of plastic additive, up to 8.0% by weight.

A.K. Choudhary (2010) emphasized the importance of maintaining and improving the performance of paved and unpaved roads after monsoons. A study aimed to demonstrate the potential of reclaimed high density polyethylene strips (HDPE) as soil reinforcement for improving engineering performance of sub-grade soil. HDPE strips obtained from waste plastic were mixed randomly with the soil, and California Bearing Ratio (CBR) tests showed that the inclusion of waste HDPE strips significantly improved strength and deformation behavior of sub-grade soils. This technique can be used in embankment/road construction.

Shankar et al (2009) used crumb rubber modified bitumen (CRMB 55) to improve characteristics compared to straight run bitumen and reduced modified binder content (5.67%). Rokade (2012) found that plastics are user-friendly but non-biodegradable, often disposed of through land filling or incineration. The better binding properties of plastics in their molten state have led to a method for safe waste disposal in road laying. Modified bitumen is an important construction material for flexible pavements. The use of waste plastic, Low Density Polyethylene (LDPE), and crumb rubber in flexible pavement construction is gaining importance.

This method not only collects modifier raw materials at low costs but also addresses the ecological threat posed by increased plastic use. The Marshal method of bituminous mix design was carried out for varying percentages of LDPE and Crumb Rubber to determine the different mix design characteristics.

III. SCENARIO

Roads have a long history, dating back to pre-historic humans who used narrow paths for hunting food. These paths were considered the first road marks and have evolved into various types of roads. India, with a road network of over 4.32 million kilometres, is the third largest in the world, with a road density of 0.66 km per square kilometre. India's roads are a mix of modern highways and narrow, unpaved roads, with 65% of commercial traffic and 80% of passenger traffic carried by roads.

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Roads are classified on the basis of behaviour of structure;

F. Flexible Pavement

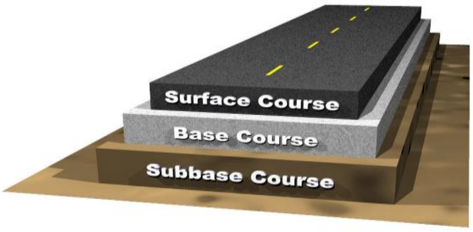

Figure 1: Flexible Pavement

Flexible pavement's load carrying capacity depends on the load distributing characteristics of the layered system. It consists of soil subgrade, sub-base course, base course, and surface course. The strength of flexible pavement depends on the construction of layers that distribute load over the subgrade, and the thickness of the pavement is significantly influenced by the strength of the subgrade.

G. Rigid Pavement

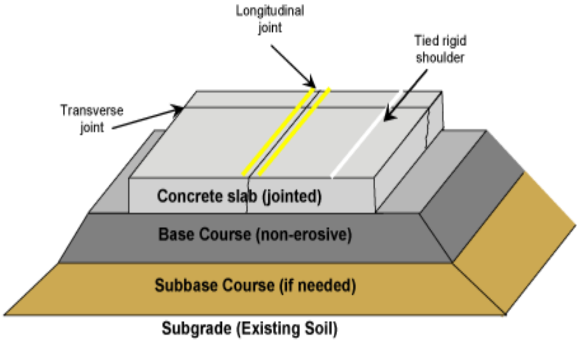

Figure 2: Rigid Pavement

The Rigid pavement can take up the tensile stresses & they consist of concrete slab which may serve as surfacing layer. The Rigid pavements are made of cement concrete which may either be plain, reinforced or prestressed. The Rigid pavement, because of its high modulus of elasticity for all ranges of temperatures, tends to distribute load over a relatively wide area.

Roads can be classify on the basis of material used for construction in following manner

Earthen Roads:

The road having its foundation and wearing surface consisting of 1 or 3 compacted layers of an ordinary or stabilized soil is known as earth road or Kutch road. These roads are lowest form of low cost roads.

Gravel Roads:

The road having its wearing surface consisting of 1 or 2 compacted layers of gravels mixed with sand and clay is known as gravel roads. These roads are considered as low cost roads.

WBM Roads:

The road having its wearing surface consisting of clean, crushed aggregates, mechanically interlocked by rolling and bound together with filler material and water laid on a prepared base course is called as Water Bound Macadam (WBM) roads. These are superior type of low cost roads.

Bituminous Roads:

The roads having their wearing surface consists of bituminous material are known as bituminous roads. Types of bituminous materials used are as follows:

- Asphalt
- Tar

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- Cut-backs
- Emulsion

Generally these roads are used now-a-days.

Cement Concrete Roads:
The roads having their wearing surface consisting of cement concrete slab are called as Cement Concrete Roads. Due to their high initial cost and inadaptability to stage construction, concrete roads are not popular in India.
In addition to these roads, the roads are constructed by using materials like agricultural waste, industrial waste, culets, tyres, incinerator ash, etc.

National Scenario:
India is advancing the use of LDPE, EVA copolymer, and SBS as bitumen modifiers. The optimal concentrations for 2% PE in asphalt include 2% LDPE 2% SBS, 5% EVA, and (2% LDPE + 5% EVA). Reclaimed PE material can be blended with bitumen using a 1/8 HP high-speed stirrer. Plastics waste is also being used to blend with bitumen, with the government of Tamil Nadu and Pondicherry and corporations like Mumbai and Cochin implementing this technology. The use of virgin polymers to improve the characteristics of polymer-modified bitumen is growing, but the main obstacle to widespread use is their tendency towards gross phase separation under quiescent conditions.

H. International Scenario
Bituminous mixes used in the surface course of the bituminous pavements are being improved in their performance by incorporating various types of additions to bitumen, such as rubber latex, crumb rubber, virgin polymers, recycled plastics etc. Additions of polymers like Styrene Butadiene Styrene (SBS), styrene-ethylene-butylenes-styrene (SEBS) and styrene-butadiene-rubber (SBR) were found to increase the quality of bitumen. Shuler et. Al carried out investigations on indirect tensile test using AC-5 and SBS polymer system as one of the modifiers. SBS modified AC-5 exhibited superior fatigue properties. Use of recycled polypropylene and lo-density polyethylene as modifiers for plain bitumen resulted in increased durability that asphalt concrete with polyethylene modifier is more resistant to rutting during elevated temperature. The use of ethylene vinyl acetate (EVA) as a binder additive produced highest fatigue life improvement. The resistance to deformation of asphalt concrete modified with 5% low-density polyethylene is significantly better than that of unmodified mix. There is improvement in the recycled polyolefin. The use of styrene-butadiene elastomers decreased the penetration value; polyethylene increased softening point and viscosity.

IV. PRELIMINARY STUDIES OF PLASTIC WASTE

I. Plastic Waste Management Techniques

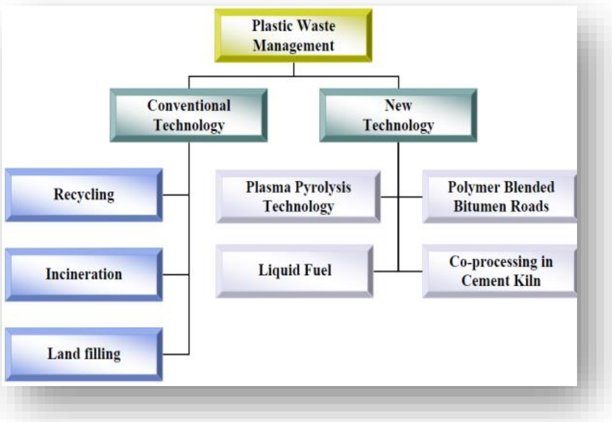

Figure 3: Plastic Waste Management Techniques

Disposal of plastic waste is a serious concern in India. New technologies have been developed to minimize their adverse effect on the environment. Currently worldwide accepted technology used for the plastic disposal is

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incineration. However, the incinerators designed poorly, releases extremely toxic compounds (chlorinated dioxins and furans) therefore, facing strong opposition from various non-government organizations.

J. Comparison between Other Roads and Bituminous Roads

Table 1: Comparison between Other Roads and Bituminous Roads

Sr. No.	Other Roads	Bituminous Plastic Mix Roads
1	Strength is less.	Strength is more compared to other roads.
2	Resistance towards water stagnation is less i.e. pot holes may occur.	Resistance towards water stagnation is more i.e. no pot holes are found.
3	Blending takes place at 45ºC for bituminous roads without plastic.	Blending plastic roads remains stable even at 55ºC.
4	Durability is less.	Durability is more.
5	Maintenance cost is low.	Maintenance cost is more.

K. Availability of Waste Plastic

Municipal solid waste typically contains a mixture of plastic waste, including materials made from PE, PP, PET, PVC, and PS. The majority of plastic waste is composed of these materials, with PET and PVC accounting for 5 to 8% and 1%, respectively. These materials are separated and segregated using chemical analysis, and their thermal and chemical properties are tested. The plastics industries supply certified PE, PP, and PS waste, which are tested for thermal and chemical properties before being used. The consumption of plastics has increased from 4000 tons/annum in 1990 to 4 million tons/annum in 2001, and is expected to rise to 7.5 million tons/annum by 2007. Nearly 50-60% of the total plastics are used for packing, and these materials are either landfilled or incinerated, which are not eco-friendly processes and pollute land and air. Any method that can use these plastic waste, consisting of polymers like PE, PP, and PS, for construction purposes is welcome.

V. SUSTAINABLE DEVELOPMENT

Since the construction revolution, the world has experienced significant technological advancements and population growth, leading to increased resource use. However, these activities have led to pollution, waste generation, landfills at capacity, toxic waste, global warming, resource depletion, and deforestation. These issues strain Earth's carrying capacity, limiting its ability to sustain life while preserving regeneration. Implementing resource-efficient measures is crucial as the world's population grows.

L. Objectives of the Sustainable Development

- Social progress, recognizing the needs of everyone.
- Effective protection of an environment
- Prudent use of natural resources.
- Maintenance of high and stable levels of economic growth and employment.

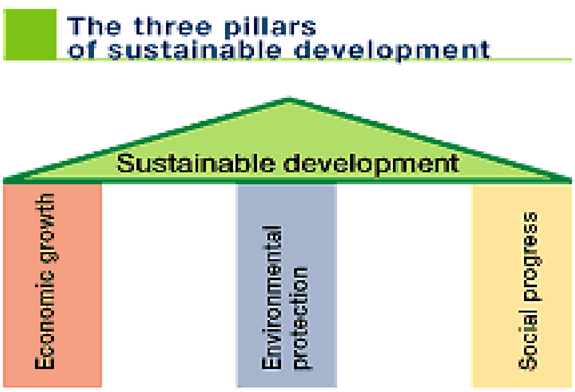

Figure 4: Three Pillars of Sustainable Development

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Table 2: Aspects of Sustainable Development

Economic	Environmental	Social
Creation of new markets and opportunities for growth of sales.	Reduced wastes, effluent generation, and emission to environment.	Worker health and safety.
Cost reduction through efficiency improvements and reduced energy and raw materials inputs.	Reduced impact on human health.	Impacts on local communities, quality of life.
Creation of additional added value.	Use renewable raw materials. Elimination of toxic substances.	Benefits to disadvantaged groups (such as the disabled).

M. Benefits of Sustainable Development

a) Lower construction and maintenance costs overall reduction in cost of project.
b) New aspect of waste management in a sustainable manner.
c) No emission of foul gases which are harmful to human health as well as Environments.
d) The economical method to overcome the problem with new approach with environmental benefits.
e) Less material usage and less wastage proper management.
f) Longer carriageway life to sustain heavy loads for a longer period of life.

VI. RESULT AND DISCUSSION

N. Sieve Analysis

Sieve Size	Percent by Passing Weight		
	Type I Base course	Type II Binder or leveling course	Type III Wearing course
37.5	100	--	--
26.5	72-100	100	--
19	60-89	82-100	100
13.2	46-76	60-84	66-95
9.5	40-67	49-74	54-88
4.75	30-54	32-58	37-70
2.36	22-43	23-45	26-52
1.18	15-36	16-34	18-40
0.6	10-28	12-25	13-30
0.3	6-22	8-20	8-23
0.15	4-14	5-13	6-16
0.075	2-8	4-7	4-10
Asphalt cement (% by weight of total aggregate)	3.5 – 5.0	4.0 – 6.5	4.5 – 6.5

O. Sample Preparation

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Figure 5: Sample Preparation

P. Results For 0% plastic waste in mix

Sr. No.	% of bitumen	Weight of sample (gm)	Height (cm)	Bulk density (gm/cc)	% Air Voids	% V.M.A.	Stability (KN)	Flow (mm)
1	2.5	1372	7.5	1985	5.55	28.75	15.19	2.19
2	3	1360	7.5	2010	5.32	28.94	15.54	2.56
3	3.5	1345	7.4	2030	4.86	29.45	15.92	3.32
4	4	1296	7.3	2039	4.56	29.7	16.45	3.54
5	4.5	1307	7.3	2024	4.27	29.85	16.78	4.12
6	5	1297.5	7.3	2041	4.07	30.23	17.01	4.45
7	5.5	1357.5	7.5	1990	4.10	30.45	16.87	4.65
8	6	1372	7.5	1945	4.12	30.76	16.54	4.87
9	6.5	1331.5	7.4	1910	4.12	30.96	15.99	5.12

Q. Results For 5% plastic waste in mix

Sr. No.	% of bitumen	Weight of sample (gm)	Height (cm)	Bulk density (gm/cc)	% Air Voids	% V.M.A.	Stability (KN)	Flow (mm)
1	3	1338	7.4	1954	5.74	31.02	17.98	2.54
2	3.5	1294	7.3	2020	5.53	31.29	18.34	2.92
3	4	1297	7.3	2041	5.39	31.5	19.03	3.45
4	4.5	1308	7.3	2056	5.13	32.1	19.54	3.78
5	5	1295.5	7.3	2030	4.91	32.51	19.91	4.1
6	5.5	1374	7.5	1992	4.96	33.21	19.74	4.51
7	6	1332	7.4	1950	5.02	33.65	19.45	4.73
8	6.5	1326	7.4	1881	5.07	33.85	18.87	4.96

R. Result for 10% plastic waste in mix

Sr. No.	% of bitumen	Weight of sample (gm)	Height (cm)	Bulk density (gm/cc)	% Air Voids	% V.M.A.	Stability (KN)	Flow (mm)
1	3	1310	7.4	1900	5.85	40.05	19.32	2.89
2	3.5	1312	7.4	1956	5.65	40.5	19.64	3.12
3	4	1308	7.4	2042	5.43	41.21	20.32	3.56
4	4.5	1330	7.5	2084	5.12	41.83	20.81	3.7
5	5	1295	7.3	2104	5.02	42.12	21.03	4.1
6	5.5	1332	7.5	2075	5.14	42.65	20.87	4.62
7	6	1374	7.5	1995	5.21	42.94	20.45	4.86
8	6.5	1378	7.5	1925	5.28	43.12	19.83	5.13

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S. Result for 15% of Plastic

Sr. No.	% of Bitumen	Weight of sample (gm)	Height (cm)	Bulk density (gm/cc	% Air Voids	% V.M.A.	Stability (KN)	Flow(mm)
1	3	1312	7.4	2120	6.56	44.54	17.98	3.01
2	3.5	1324	7.4	2170	6.32	45.01	18.34	3.34
3	4	1328	7.5	2231	5.98	45.32	19.03	3.76
4	4.5	1335	7.5	2275	5.76	45.64	19.54	4.09
5	5	1364.5	7.5	2305	5.45	45.81	19.91	4.56
6	5.5	1362	7.5	2285	5.5	46.15	19.74	4.97
7	6	1308	7.4	2258	5.57	46.42	19.45	5.43
8	6.5	1334	7.5	2204	5.65	46.75	18.87	5.87

T. Interpretation of Result

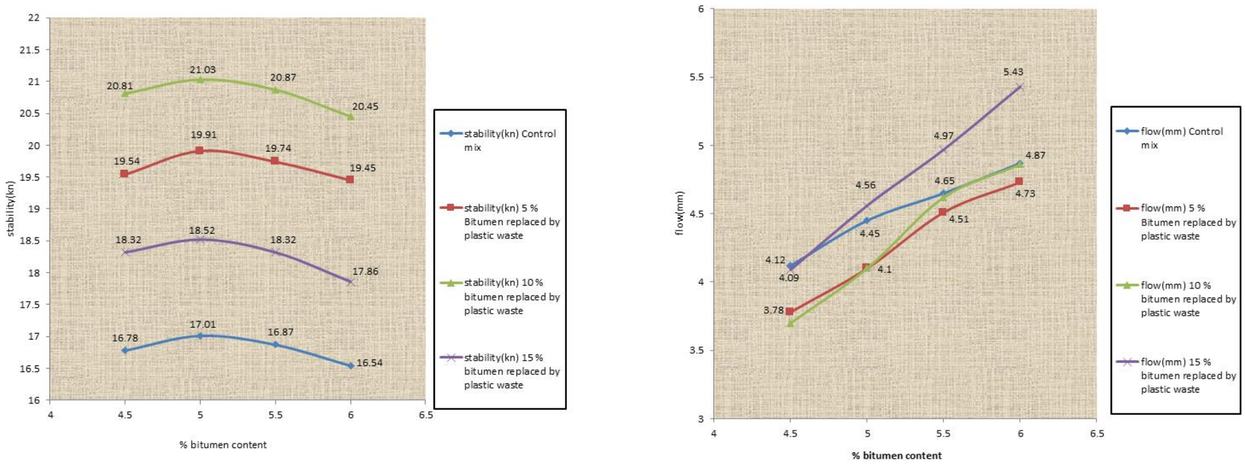

Figure 6: (a) Stability (KN) Vs Bitumen content (percent) for all cases (b) Flow (mm) Vs Bitumen content (percent) for all cases

VII. CONCLUSION

Following are some conclusions drawn during testing of specimen and interpretation of results:

- The addition of waste plastic modifies the properties (like, ductility, penetration etc.) of bitumen.
- The modified bitumen shows good result when compared to unmodified bitumen mixes.
- It is found that 10%replacement of bitumen by polymer gives satisfactory performance.
- Plastic has property of absorbing sound, which also help in reducing sound pollution of heavy traffic
- The waste plastic thus can be put to use and it ultimately improves the quality and performance of BC.
- From the experimental work it is clear that the properties (i.e. stability, flow) of Modified bituminous mix are increase 1.5% to those of the control mixes (ordinary bitumen).
- The comparison of results by analysing the strength criteria for particular stability measures of pavement can be improved by polymer addition to bitumen blend

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