International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 09 | Sep 2020 www.irjet.net p-ISSN: 2395-0072

Construction of Bituminous Pavement by Using Plastic Waste

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Abstract - *Plastic was found to be an effective binder for bitumen mixes used in flexible pavements. This efficient method helps the pavements to resist higher temperature by minimizing the formation of cracks and reducing rainwater infiltration which otherwise leads to the development of potholes. These pavements have shown improved crushing and abrasion values and reduced water seepage. The use of Plastic bags & Plastic Bottles in Bituminous Road Construction to Enhance the Properties of Bituminous Road. In the Present situation disposal of plastic is major problem so that Government of India has banned use of Plastic. In this Present Investigation attempt has been made to study the safe disposal of Plastic waste in bituminous road construction so that cost of construction becomes economical. The waste plastic is shredded & coated over aggregate & mixed with hot bitumen and resulted mix is used for pavement construction. This will not only strengthen the pavement and also increases its durability. This innovative technology will be boon for Indian hot-humid climate. It's economical and Eco-friendly.*

***Key Words*: Plastic, Flexible Pavement, Strength, Bitumen, Aggregate.**

1. INTRODUCTION

A Government order in November 2015 has made it mandatory for all road developers in the country to use waste plastic, along with bituminous mixes, for road construction. This is to help overcome the growing problem of plastic waste disposal in India. Plastic is a huge threat to the environment. The plastic waste can have used in road construction and researches proved that the plastic wastes used after proper processing can enhance the life of the road also a solution to environmental problems. Plastic has slowly became an integral part of all human requirements. Plastic carry bags, packaging material, bottles, cups, and various other items have slowly replaced everything made of other material due to the advantages of plastic. Plastic is durable, easy to produce, lightweight, unbreakable, odourless, and chemical resistant. But plastic does not decompose. This is its biggest drawback.

Most of the paved roads in our country have granular sub base and base; bituminous base and wearing courses. Plastic is a very versatile material. Due to the industrial revolution, and its large scale production plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, electronics, electrical, building construction, communication sectors has been virtually revolutionized by the applications of plastics.

Plastics, a versatile material and a friend to common man become a problem to the environment after its use. Disposal of a variety of plastic wastes in an eco-friendly way is the thrust area of today's research. Looking forward the scenario of present lifestyle a complete ban on the use of waste plastic cannot be put, although the waste plastic taking the face of a devil for the present and the future generation. But the use of waste plastics in road construction is gaining importance these days because plastic roads perform better than ordinary ones and the plastic waste considered to be a pollution menace, can find its use. The use of waste plastic for coating the aggregates of the bituminous mix found to improve its performance characteristics. Recycled poly ethene carry bags were shredded into small sizes and is coated on aggregates of the mix at a specified temperature.

Bituminous mixes were prepared with 80/100 bitumen and plastic coated aggregates/ordinary aggregates with dust as a filler material. The uses of plastic waste help in substantially improving the abrasion and slip resistance of flexible pavement and also allows to obtain values of splitting tensile strength satisfied the specified limits while plastic waste content is beyond 30% by weight of mix. If the consistent mixing time and mixing temperature are not provided for bitumen– modifier mix, modified bitumen cannot exhibit good performance in situ, thus premature failures will occur. Therefore, there are certain recommended mixing time, mixing temperature and modifier content for all the polymers with a trademark. This all should be taken in mind while mixing and laying of roads is to be done using plastic waste. The plastic road would be a boon for India. In hot and extremely humid climate durable and eco-friendly plastic roads are of greatest advantages. This will also help in relieving the earth from all type of plastic waste.

1.1 Plastic

Plastic has slowly become an integral part of all human requirements. Plastic carry bag, packing materials, bottles,

cups and various other items have slowly replaced everything made of other materials due to advantages of plastic. Plastic easy to produce, lightweight, unbreakable, odourless & chemical resistant. But plastic does not decompose. This is biggest drawback .Disposal of plastic wastes in an eco-friendly way is the thrust area of today's research. On heating at 140 - 160°C, plastics such as carry bags, plastic cups, plastic packaging for potato chips, biscuits, chocolates, etc. Exhibit good binding properties.

1.2 Bitumen

Indian Standard Institutions defines bitumen as a black or dark brown non crystalline soil or viscous material having adhesive properties derived from petroleum crude either by natural or by refinery processes. In other words bitumen is any adhesive and solid mixture of hydrocarbons that are found naturally in tar, asphalt, mineral waxes, etc. used for constructing the road surface and roofing material. It is mainly used for Construction of roads, platforms, runways etc. Water proofing.

Advantage of bitumen

- Production of bitumen is economical.
- Archaeological and physical properties of bitumen bring versatility.
- Favourable melting point.
- Bitumen can go under recycling & adhesive in nature.

2. LITERATURE REVIEW

2.1 Fransis Hveem (1942)

"Optimum quantity of bitumen inroads" who was a project engineer of California Department of Highways, has developed the Hveem stabilometer in 1927. He did not have any previous experience on judging, the required mix of its colour, hence he decided to measure various mixture parameters to find the optimum quantity of bitumen. [Vallerga and Lovering 1985]. He had used the surface area calculation concept, (which was already in use, at that time for the cement concrete mix design), to estimate the quantity of bitumen actually required.

2.2 Dr. R. Vasudevan (2007)

He stated that the polymer bitumen blend is a better binder compared to plain bitumen. Blend has increased softening point and decreased Penetration value with a suitable ductility.

2.3 Zahra Niloofar Kalantar (2012)

Many researches on PMA mixture have been conducted for the past two decades. Although addition of virgin polymers to asphalt for the purpose of enhancing the properties of asphalt over a wide temperature range in paving applications was contemplated quite some time ago, recycled polymer added to asphalt have also shown almost the same result in improving the road pavement performance as compared to virgin polymers. In this study, a critical review on the history and benefits of using waste and virgin polymer in asphalt is presented followed by a review of general studies on using polymers in asphalt in order to improve the properties of pavement.

2.4 Amit P. Gawande (2012)

The quantum of plastic waste in municipal solid waste (MSW) is increasing due to increase in population, urbanization, development activities and changes in life style which leading widespread littering on the landscape. Thus disposal of waste plastic is a menace and become a serious problem globally due to their non-biodegradability and un aesthetic view. Since these are not disposed scientifically & possibility to create ground and water pollution. This waste plastic partially replaced the conventional material to improve desired mechanical characteristics for particular road mix. In conventional road making process bitumen is used as binder. This waste plastic modified bitumen mix show better binding property, stability, density and more resistant to water.

2.5 Rishi Singh Chhabra (2015)

In the highway infrastructure, a large number of originates materials and technologies have been invented to determine their suitability for the design, construction and maintenance of these pavements. Plastics and rubbers are one of them. Also considering the environmental approach, due to excessive use of polythene in day to day business, the pollution to the environment is enormous. The use of plastic materials such as carry bags, cups, etc. is constantly increasing day by day10. Since the polythene are not biodegradable, the need of the current hour is to use the waste polythene in some beneficial purposes. The use of these materials as a road construction proves eco-friendly, economical and use of plastic gives strength in the sub-base course of the pavement.

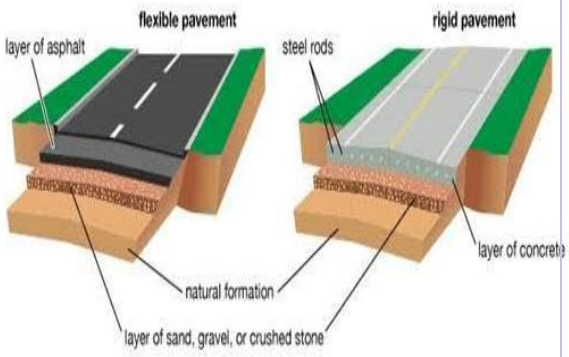
3. OBJECTIVE & SCOPE

- To compare the various properties of the bituminous road and plastic bituminous road.
- To identify the optimum proportion of waste plastic to be added in the bitumen mix for getting the required strength.
- To study the properties of Aggregate after coated with plastic.
- To convert solid waste into binder.

- To suggest safe disposal of Plastic.
- To decrease the bitumen content.
- To Increase the life of Pavement.

4. COMPARISON BETWEEN FLEXIBLE PAVEMENT (BITUMINOUS ROAD) AND RIGID PAVEMENT (CONCRETE ROAD)

Table -1: Comparison between flexible & Rigid Pavement

Sr No	Flexible Pavement	Rigid Pavement
1		
2	The Pavement which can change their shape to some extent without rupture.	The Pavement which cannot change their shape.
3	Less Durable.	More Durable.
4	Construction cost is less.	Construction cost is high.
5	Design Life 10 – 20 Years. (IRC 37-2001 & 58-2002)	Design Life 20 – 30 Years. (IRC 37-2001 & 58-2002)
6	High Maintenance Cost.	Low Maintenance Cost.
7	It undergoes the change its shape before failure.	It does not undergoes the change its shape before failure.
8	Eg. Bituminous Road, Earthen Road, Gravel Road, WBM Road etc.,	Eg. Concrete Road.

5. METHODOLOGY

5.1 Materials used for the preparation of Plastic Bituminous mix

5.1.1 Aggregates

Aggregates can classify by their mineral, chemical and physical properties. The pavement industry typically relies on physical properties for performance characterization. An aggregate's physical properties are a direct result of its mineral and chemical properties.

Aggregates used in the surface course can be divide into two types according to their size: large aggregates and fine aggregates. Coarse aggregates are generally defined as those retained in the 10 mm sieve. Fine aggregates are those that pass through the 4.75 mm sieve and retained in the 0.075 mm sieve. Aggregates needed for the research work will be procure in the local market.

Fig-1 : Sieved Aggregates

5.1.2 Waste Plastic Modifiers

Modifiers generally used to enhance the properties of bituminous concrete mixes by reducing the air void present between the aggregates and to bind them together so that no bleeding of bitumen will occur. For the present study, we use plastic waste such as carry bags and hard polythene bags as a plastic modifier.

Fig-2: Shredded Plastic

5.1.3 Bitumen

Bitumen acts as binding agent for aggregates in bituminous mixes. Normally, in India we used mainly grade 60/70 or 80/100 bitumen in construction of flexible pavement. For the research, Grade 80/100 of bitumen was used confirming to ASTM standards.

Fig-3 : Bitumen

5.2 Preparation of Plastic coated Aggregates

5.2.1 Collection of Aggregates

Aggregates obtained from crusher plant have hard & tough rock having no skin. It should confirm to IS 383 – 1983. IRC recommends two sizes of aggregates size 12mm, 10mm & 6 mm.

5.2.2 Collection of Plastic

Plastic can be collected from various sources like domestic, commercial & Public Sources.
Segregation: Plastic waste collected from various sources is separated from other wastes.
Cleaning process: Plastic waste is cleaned and dried.
Shredding process: Plastics will be shredded or cut into small pieces.
Collection process: The plastic waste retaining on 2.36 mm IS sieve is collected.

5.2.3 Coating of Aggregates with Plastic

The aggregates are heated at specified temperature of 130 to 160o C & then Shredded plastic added after some time the plastic is coated to aggregate.

Fig-4 : Plastic coated Aggregates

6. EXPERIMENTAL INVESTIGATION

6.1 Quality control tests on Normal aggregates & Plastic Coated Aggregates

The comparative study is done by testing the normal aggregates & plastic coated aggregates by adding plastic 5%, 8% & 10 % to check the optimum proportion to suit the aggregate for Bituminous pavement The various tests that are carried out on aggregate are listed below

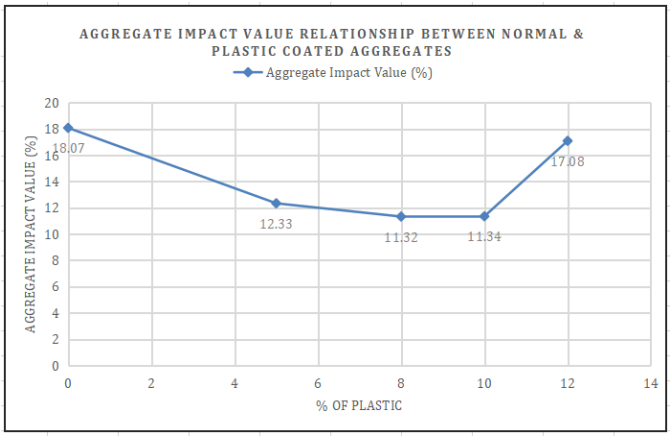
6.1.1 Aggregate Impact Test (as per IS 2386 Part IV - 1963)

The test is designed to evaluate the toughness of stone or the resistance of the aggregates to fracture under repeated impacts is called impact test. The aggregate impact test is commonly carried out to evaluate the resistance to impact of aggregates and has been standardized by ISI.

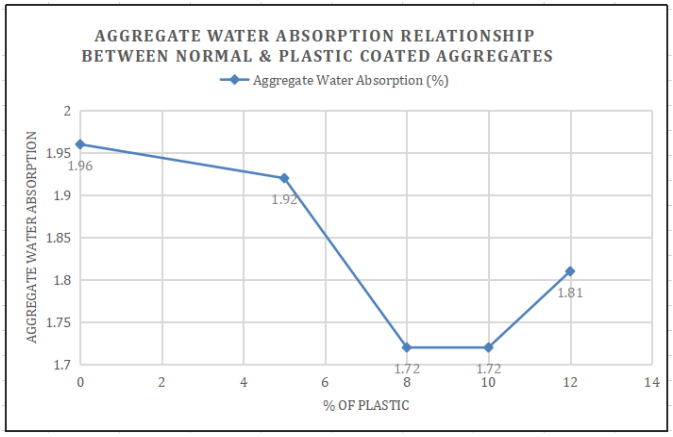
Aggregate Impact Value (AIV) = (W2/W1) X 100.
Where, W1 = Original Weight of Sample.
W2 = Weight of Sample passing through 2.36 mm IS Sieve.

Table - 2 : Result table of Aggregate Impact Value.

% of Plastic	W1	W2	AIV	Avg AIV
	gm	gm	%	%
0	370	60.20	16.27	18.07
	380	70.00	18.42	
	370	72.20	19.51	
5	330	38.00	11.52	12.33
	340	45.20	13.29	
	340	41.40	12.18	
8	340	35.70	10.50	11.32
	320	39.80	12.44	
	340	37.50	11.03	
10	330	37.20	11.27	11.34
	330	34.30	10.39	
	330	40.80	12.36	
12	365	64.40	17.64	17.08
	372	67.20	18.06	
	358	55.60	15.53	



Graph.1 Aggregate Impact Value Relation



Graph.2 Aggregate Water Absorption Relation

As per IRC Maximum Value of AIV = 30 % for Wearing Course.
As per IRC Lowest Aggregate impact Value is preferred to give good toughness.
From Above Table & Graph Optimum % of Plastic is added to aggregates is 8 % of Bitumen, to give good toughness.

6.1.2 Aggregate Water Absorption Test (as per IS 1124 – 1974)

The water absorption of coarse aggregate is measured by the percentage increase in weight of an oven dry sample after immersion in water for 24 hours. Water Absorption (WA) = (W1-W2/W2) X 100 Where, W1 = Weight of Saturated Aggregate. W2 = Wight of Oven Dried aggregate.

Table - 3 : Results table of Aggregate Impact Value.

% of Plastic	W1	W2	WA
	gm	gm	%
0	1020	1000.4	1.96
5	1019	999.8	1.92
8	1014.8	997.6	1.72
10	1015.65	998.4	1.73
12	1017.75	999.6	1.82

As Per IRC Water Absorption of Aggregate Should not exceed 2 %.

As Per IRC Lowest Water Absorption Value is preferred.

From Above Table & Graph Optimum % of Plastic is added to aggregates is 8 % of Bitumen, to give less water absorption.

6.1.3 Aggregate Abrasion Value (AAV) (Los Angel's Abrasion Test) (as per IS 2386 Part IV - 1963)

Due to the movements of traffic, the road stones used in the surface course are subjected to wearing action at the top. Hence road stones should be hard enough to resist the abrasion due to traffic. Abrasion tests are carried out to test the hardness property of stones and to decide whether they are suitable for the different road construction works.

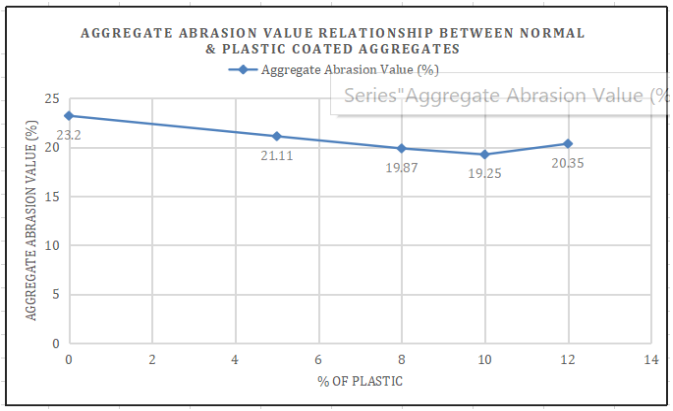
Abrasion Value = (W2/W1) X 100.

Where, W1 = Weight of oven dried sample before applying abrasive charge.

W2 = Wight of Sample passing through 1.7 mm IS Sieve, after applying abrasive charge.

Table - 4 : Results table of Aggregate Abrasion Value.

% of Plastic	W1	W2	AAV
	gm	gm	%
0	2500	580	23.2
5	2502	528.4	21.12
8	2503	497.3	19.87
10	2500	481.2	19.25
12	2501	508.9	20.35



Graph.3 Aggregate Abrasion Value Relation

As Per IRC Maximum Abrasion Value = 30 % for wearing course.

A Per IRC Lowest Aggregate Abrasion Value is preferred.

From Above Table & Graph Optimum % of Plastic is added to aggregate is 8 %, & 10 % of Bitumen, to give good hardness.

6.1.4 Aggregate Crushing Value (ACV) (as per IS 2386 Part IV - 1963)

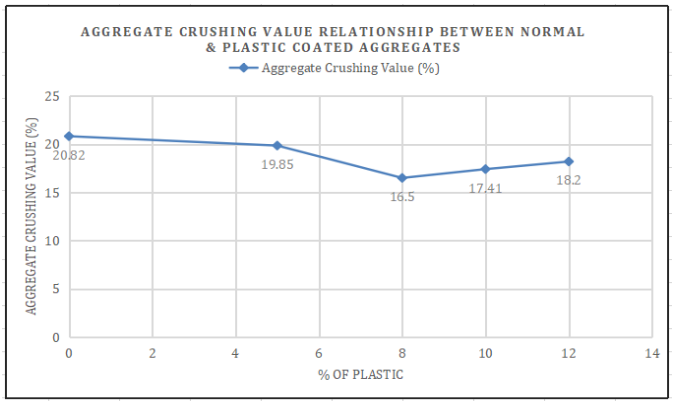
The strength of the coarse aggregate may be assessed by aggregate crushing test. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied compressive load. To achieve a high quality of pavement, aggregates possessing high resistance to crushing or low aggregate crushing value re preferred.

Aggregate Crushing Value = (W2/W1) X 100. Where W1 = Weight of oven dried sample = 3860 gm.

W2 = After applying compressive load Weight of sample passing through 2.36 mm IS Sieve.

Table - 5 : Results table of Aggregate Crushing Value.

% of Plastic	W1	W2	ACV
	gm	gm	%
0	3860	804	20.83
5	3950	784	19.85
8	3795	626	16.5
10	3894	678	17.41
12	3984	725	18.2



Graph.4 Aggregate Crushing Value Relation

6.2 Quality control tests on Bitumen

A Hydrocarbon material of either natural or pyrogenous origin, found in liquid, semi-solid or solid in state and completely soluble in carbon-disulphide is called as bitumen.

Properties of bitumen.

It is usually solid or semi-solid in state.
It melts and gives distinctive odor when heated.
It possesses adhesive properties when softened by heat.

6.2.1 Penetration Test (as per IS 1203 – 1978) It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure

Table - 6 : Results table of Bitumen Penetration Value

Penetration Value		
96	78	102
Avg Penetration Value = 92		

Bitumen Confirms to the grade 80 / 100 grade.

6.2.2 Softening Point Test (as per IS 1205 – 1978).

The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.

Softening Point of Bitumen = 47.50 0 C.

As per IRC Softening Point of Bitumen varies from 35 ^{0} C to 70 ^{0} C.

From All above Experimental Investigations on Aggregate & Bitumen, the optimum Plastic is to be added in bituminous carpet is 8 % of bitumen replaced

by plastic, to achieve better properties of pavement & Increase the Life of Pavement

7. BITUMINOUS MIX PREPARATION.

7.1 Bituminous Carpet Mix Preparation.

The model was prepared by casting the Open Graded Carpet (OGC) used as a wearing course of bituminous pavement.

7.1.1 Calculation of quantities of materials required for 1 m² of surface area (20 mm Thk) as per IRC

- Thickness of Pavement = 20 mm.
- Aggregate Size 12.5mm Passing & Retained on 10mm IS Sieve.
- Qty of Aggregate for 1 Sqm Area.
  Volume of Aggregate = 0.027 Cum.
  Density of Aggregate = 1780 kg / m³.
  Weight of Aggregate = 48.06 Kg.
  Bitumen content = 5 % of weight of aggregate.
  Bitumen = 2.4 Kg.

Table - 7: Qty of Materials required for 1 Sqm

% of Plastic	0%	5%	8%
Weight of Aggregates	48 Kg	48 Kg	48 Kg
Weight of Bitumen	2.40 Kg	2.28 Kg	2.21 Kg
Weight of Plastic	0.00 Kg	0.12 Kg	0.190 Kg

Bitumen is heated at 120 ^{0}C – 140 ^{0}C. & then plastic coated aggregates is added then mixed thoroughly the Bituminous tack coat is spread before lying the bituminous mix to bond to existing layer.

8. CONCLUSIONS

- The Optimum Plastic to be coated in the aggregate is 8 % of Bitumen.
- The Bitumen content is reduced up to 8 % & then this can be replaced by adding the plastic.
- The use of the innovative technology not only strengthened the road construction but also increased the road life as well as will help to improve the environment and also creating a source of income.
- Plastic roads would be a boon for India's hot and extremely humid climate, leaving most of the roads with big potholes.
- Hence the use of waste plastics for pavement is one of the best methods for easy disposal of waste plastics.

8.1 Future scope of work

Various types of plastics should be used. Various % of plastic should be used for mixing i.e 10%, 12%, 13%, 14%, 15% and so on. Various combination of plastic should be used for mixing purpose and testing of materials as per IRC Standards

8.2 Cost Saving Per Km for 7m wide Road

Plastic used in wearing coat. Qty of Carpet =7000 Sqm, then bitumen required is 7000x2.4=16.80 tons. If we use 8 % less bitumen & more plastic= (16.80X8)/100=1.344 tonne then **cost saving per Km = 1.344X33000 Rs per tons = Rs.44, 352.**

Finally, this waste plastic Bituminous mixture has good effect. However, there are more advantages therefore, according to my research I suggest this plastic Bituminous mixture will perform well in the field than the conventional Bituminous mixture.

ACKNOWLEDGEMENT

The authors would like to thanks our Institute Chairman Prof. Dr. G. K. Deshmukh, Secretary Mr. Amol Nana Chavan, Principal Dr. Shailesh Deshpande, Vice Principal Prof. U.S. Mugale, HOD Prof. A.A. Patil, Project Co-ordinator Prof. S.S. Bugade, Guide Prof. S.S. Manekari and All Faculty members of Civil Engineering Department for giving all encouragement needed for successful completion of Project.

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