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REPLACEMENT OF BITUMEN WITH WASTE THERMOPLASTIC & CRUMB RUBBER

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Abstract- Worldwide, sustainability is an important need of the hour in the construction industry and towards this end use of waste material in road construction is being increasingly encouraged so as to reduce environmental impact. In the highway infrastructure, a large number of originate materials and technologies have been invented to determine their suitability for the design, construction and maintenance of the pavements. Plastics and rubbers are one of them. Now-a-days Plastic is everywhere in today's lifestyle. The disposal of plastic wastes is a great problem. These are non-biodegradable product due to which these materials pose environmental pollution and problems like breast cancer, reproductive problems in humans and animals, genital abnormalities and even a decline in human sperm count and quality. In recent years, applications of plastic wastes have been considered in road construction with great interest in many developing countries. The use of these materials in road making is based on technical, economic, and ecological criteria. Several million metric tons plastic wastes are produced in India every year. If these materials can be suitably utilized in highway road construction, the pollution and disposal problems may be partly reduced. Keeping in mind the need for bulk use of these wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of plastic wastes in road making, in which higher economic returns may be possible. The possible use of these materials should be developed for construction of low-volume roads in different parts of our country. A review of various plastic wastes for use in the construction of roads has been discussed in this paper.

Keywords- Plastic waste Binder, Bitumen, Mix design, Marshall Stability, Macadam

1. INTRODUCTION

In general, pavements are of two types, flexible and rigid pavement. A flexible pavement is the one which has a bitumen coating on top and rigid pavements which are stiffer than flexible ones have PCC on top. The flexible pavements are built in layers and it is ensured that under application of load none of the layers are overstressed. The maximum intensity of stress occurs at top layer, hence they are made from superior material mainly bitumen. Plastic is everywhere in today's lifestyle. It is used for packaging, protecting, serving, and even disposing of all kinds of consumer goods.

1.1 Background

Often times the best raw materials go into making either a truck or passenger car tyre. At its end of life, a tyre poses a great environmental challenge owing to its highly engineering nature, which renders it non-biodegradable. Landfilling only takes up more space and increases fire hazard risks in addition to harboring potential disease-causing insects in the rainy seasons. From its original formulation a tyre consists of natural rubber, synthetic rubber, plasticizers, carbon black, silica and other metallic components from the steel. From a circular economy point of view these constituents can find use in other fields which in the context of our discussion we focus on crumb rubber used to modify bitumen. Crumb rubber modified bitumen, its formulation chemistry and applications will be evaluated as the article seeks to understand the chemical fingerprint of the crumb rubber from its source, production of crumb rubber modified bitumen and its uses in pavement construction. In recent years, applications of plastic wastes have been considered in road construction with great interest in many developing countries. The use of these materials in road making is based on technical, economic, and ecological criteria. The lack of traditional road materials and the protection of the environment make it imperative to investigate the possible use of these materials carefully India has a large network of metro cities located in different parts of the country and many more are planned for the near future. Several million metric tons plastic wastes are produced every year in India.

1.2 Motivations

The use of bitumen and its modification dates back to around early 600 BC were bitumen containing mortar cemented both the foundation of burnt bricks and stone slabs. The 19th century saw the popularity of mixing bitumen and rubber but more as a substitute for rubber rather than as a modifier for bitumen. As time progressed the early 20th century scholars began to suggest and later on describe the colloidal structure of bitumen with the 1940s yielding patents on the bitumen modified with polyisobutylene. With the industrial revolution, mass production of goods started and plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, building construction, communication or InfoTech has been virtually revolutionized by the applications of plastics. Use of this non-biodegradable (according to recent studies, plastics can stay unchanged for as long as 4500 years on earth) product is growing rapidly and the problem is what to do with plastic-waste. Studies have linked the improper disposal of plastic to problems as distant as breast cancer, reproductive problems in humans and animals, genital abnormalities and even a decline in human sperm count and quality. If a ban is put on the use of plastics on emotional grounds, the real cost would be much higher, the inconvenience much more, the chances of damage or contamination much greater. The risks to the family health and safety would increase and, above all the environmental burden would be manifold. Hence the question is not 'plastics Vs no plastics' but it is more concerned with the judicious use and re-use of plastic-waste. Traditionally soil, stone aggregates, sand, bitumen cement etc. are used for road construction. Natural materials being exhaustible in nature, its quantity is declining gradually. Also, cost of extracting good quality of natural material is increasing. Concerned about this, the scientists are looking for alternative materials for highway construction, and plastic wastes product is one such category. If these materials can be suitably utilized in highway construction, the pollution and disposal problems may be partly reduced. In the absence of other outlets, these solid wastes have occupied several acres of land around plants throughout the country. Keeping in mind the need for bulk use of these solid wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of these plastic wastes in road making, in which higher economic returns may be possible. The possible use of these materials should be developed for construction of low-volume roads in different parts of our country. The necessary specifications should be formulated and attempts are to be made to maximize the use of solid wastes in different layers of the road pavement.

1.3 problem statement

Plastic in different forms is found to be almost in municipal solid waste, which is toxic in nature. It is a common sight in both urban and rural areas to find empty plastic bags and other type of plastic packing material littering the roads as well as drains. Due to its biodegradability it creates stagnation of water and associated hygiene problems. In order to contain this problem experiments have been carried out whether this waste plastic and rubber can be reused productively in the construction of roads. The experimentation at several institutes indicated that the waste plastic, when added to hot aggregate will form a fine coat of plastic over the aggregate and such aggregate, when mixed with the binder is found to give higher strength, higher resistance to water and better performance over a period of time. Therefore, it is proposed that we may use waste plastic and crumb rubber in the construction of roads.

1.3 Objectives of this paper

1. To fulfill the demand of construction and to coat the aggregate in waste plastic materials.
2. To check properties of bituminous mix specimen and to compare the property of bituminous mix specimen with properties of coated aggregate.
3. To reduce the material cost which automatically makes the construction cost less and to recycle and reuse the waste material as an alternative.
4. To balance the ecological cycle and to increase profit over materials.

2. LITURATURE REVIEW

[1] Johnson Kwabena Appiah, Berko-Boateng, Trinity Ama Tagbor
"Use Of Waste Plastic Materials For Road Construction In Ghana", Case Studies in Construction Materials 6 (2017) PP1-7:This paper forms part of research to solve two main problems in Ghana: firstly, the management of municipal solid waste (MSW), particularly with regards to used plastics which have overwhelmed major cities and towns; secondly, the formation of potholes on roads due to excessive traffic and axle weight. This study examines the effect of blending waste thermoplastic polymers, namely High density polyethylene (HDPE) and Polypropylene (PP) in Conventional AC-20 graded bitumen, at various plastic compositions. The plastics were shredded and blended with the bitumen 'in-situ', with a shear mixer at a temperature range of 160°C– 170°C.

[2] Amit Gawande, G. Zamare, V.C. Rengea, Saurabh Tayde, G. Bharsakale,
"An Overview On Waste Plastic Utilization In Asphalting Of Roads" Journal of Engineering Research and StudiesEISSN0976-7916Vol. III/ Issue II/AprilJune,2012/01-05: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 unaesthetic view. Since these are not disposed International Journal of Pure and Applied Mathematics Special Issue 1145 scientifically & possibility to create ground and water pollution.

3] Majed A. Alhussain, Feras F. Almansoor
"Asphalt Design Using Recycled Plastic And Crumbrubber Waste For Sustainable Pavement Construction", Procedia Engineering 145(2016):The seasonal change in temperature and loading nature has a significant effect on asphalt behavior because of its viscoelastic nature. Several types of flexible pavement failure/distress occur due to this behavior of asphalt binder, among which rutting and fatigue cracks are very common. In this study, Low Density and High Density Polyethylene and Crumb rubber were used as additions to base bitumen. Complex modulus (G*) and phase angle (δ) obtained from Dynamic Shear Rheometer (DSR) are the basic perimeters used to evaluate the behavior of the binder in respect to rutting and fatigue cracking.

[4]Utibe J. Nkanga, Johnson A. Joseph
"Characterization Of Bitumen/Plastic Blends For Flexible Pavement Application",Procedia Manufacturing 7(2017)PP 490-496:Waste plastic materials including low density polyethylene (LDPE) grocery bags etc. are disposed through landfills: this poses an environmental pollution due to difficult in degradation of polymeric materials by International Journal of Pure and Applied Mathematics Special Issue 1146 environmental factors. Waste plastic materials can improve desired properties of bituminous mix for repair and construction of flexible pavements. In this project, various proportions of polymeric materials blended with bituminous mix were characterized. Strength and performance of bitumen/plastic blends were tested through marshall stability test, extraction test, sieve analysis, water absorption tests and bulk density.

[5] Shivraj Sarojero Patil,
"**Experimental Study On Bitumen With Synthetic Fiber",** Journal of Information, Knowledge and Research in Civil Engineering, **ISSN: 0975 – 6744** Nov 14 to Oct 15 | Volume 3, Issue 2 pp213216:Disposal of waste materials including waste plastic bags has become a serious problem and waste plastics are burnt for apparent disposal which cause environmental pollution. Utilization of waste plastic bags in bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems. Plastic waste which is cleaned is cut into a size such that it passes through 1-2 mm sieve using shredding machine. The aggregate mix is heated and the plastic is effectively coated over the aggregate.

3. PROPOSED METHODOLOGY

3.1 Necessity

Plastic pollution is the accumulation of plastic objects and particles (e.g. plastic bottles, bags, rubber and microbeads) in the Earth's environment that adversely affects humans, wildlife and their habitat. Plastics that act as pollutants are categorized by size into micro-, meso-, or macro debris. Plastics are inexpensive and durable making them very adaptable for different uses; as a result manufacturers choose to use plastic over other materials. However, the chemical structure of most plastics renders them resistant to many natural processes of degradation and as a result they are slow to degrade. Together, these two factors allow large volumes of plastic to enter the environment as mismanaged waste and for it to persist in the ecosystem. So to overcome this problem of plastic and rubber waste it is beneficial to us to use this waste as a binder in construction of flexible pavement.

3.2 Material Used

Information of materials Used for Construction of Road by using this technique

1. Thermoplastic
2. Bitumen
3. Aggregate
4. Crump Rubber

3.3 Procedure of Road Laying

On heating at 100 - 160°C, plastics such as polyethylene, polypropylene and polystyrene, and crumb rubber soften and exhibit good binding properties. Blending of the softened plastic and crumb rubber with bitumen results in a mix that is suitable for road laying.

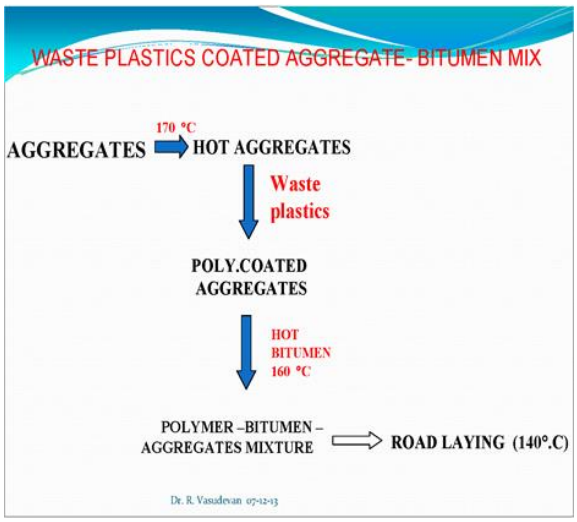

Figure 3.1 Procedure of Road Laying

Procedure:

1. The stone aggregate mix (as per specification) is transferred to the mix cylinder where it is heated to 165^0c (as per the IRC specification) and then it is transferred to the mixing puddler(Temperature can be monitored using IR thermometer), while transferring the hot aggregate into the puddler, calculated quantity of shredded plastics is sprayed over the hot aggregate within 30seconds. The sprayed plastic films melts and gets coated over the aggregate, thus forming an. oily coating
2. Similarly, the bitumen is to be heated to a maximum of 160^0c in a separate chamber and kept ready (The temperature should be monitored to have good bindinsg and to prevent weak bonding).
3. At the mixing paddler, the hot bitumen is added over the plastic coated aggregate and the resulted mix is used for road construction. The road laying temperature is between 110^0c to 120^0c. The roller used is normal 8-tonne

4. TESTING OF MATERIAL

4.1 Testing of Bitumen:

BITUMEN: Bitumen is an oil based substance. It is a semi-solid hydrocarbon product produced by removing the lighter fractions (such as liquid petroleum gas, petrol and diesel) from heavy crude oil during the refining process.

4.1.1 Penetration Test

This test is done to determine the penetration of bitumen as per IS: 1203 – 1978. The principle is that the penetration of a bituminous material is the distance in tenths of a mm, that a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature, load and time.

Result

The value of penetration reported should be the mean of not less than three determinations expressed in tenths of mm.

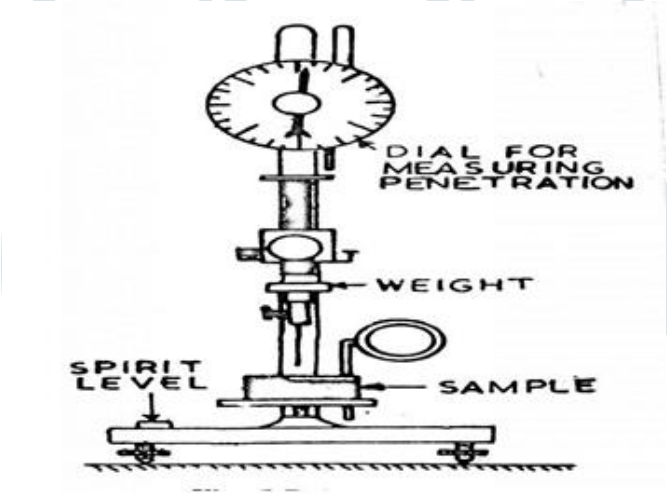

Fig.No. 4.1 A Penetration Test

Table no 4.1 Penetration Test

SAMPLE	PENETRATION (MM)
I	66
II	68
III	60

4.1.2 SOFTENING POINT TEST

This test is done to determine the softening point of asphaltic bitumen and fluxed native asphalt, road tar, coal tar pitch and blown type bitumen 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.

Fig.No 4.2 1b Softening Point Test Equipment

RESULTS

Record the temperature at which the ball touches the bottom.

Table 4.2 Softening Point Test Equipment

SAMPLE	SOFTENING TEMPERATURE (^{0}C)
I	40^{0}C
II	39^{0}C
III	42^{0}C

4.1.3 DUCTILITY TEST

This test is done to determine the ductility of distillation residue of cutback bitumen, blown type bitumen and other bituminous products as per IS: 1208 – 1978. The principle is .The ductility of a bituminous material is measured by the distance in cm to which it will elongate before breaking when a standard briquette specimen of the material is pulled apart at a specified speed and a specified temperature.

Fig.No 4.3 Ductility Test Equipment

RESULTS

A normal test is one in which the material between the two clips pulls out to a point or to a thread and rupture occurs where the cross-sectional area is minimum. Report the average of three normal tests as the ductility of the sample, provided the three determinations be within ± 0.5 percent of their mean value.

If the values of the three determinations do not lie within ± 0.5 percent of their mean, but the two higher values are within ± 0.5 percent of their mean, then record the mean of the two higher values as the test result.

Table 4.3 Ductility Test Equipment

SAMPLE	DUCTILITY IN MM
I	50
II	48
III	58

4.1.4 FIRE AND FLASH POINT

This test is done to determine the flash point and the fire point of asphaltic bitumen and fluxed native asphalt, cutback bitumen and blown type bitumen as per IS: 1209 – 1978. The principle behind this test is given below : **Flash Point** – The flash point of a material is the lowest temperature at which the application of test flame causes the vapours from the material to momentarily catch fire in the form of a flash under specified conditions of the test.

Fire Point – The fire point is the lowest temperature at which the application of test flame causes the material to ignite and burn at least for 5 seconds under specified conditions of the test.

Fig.No. 4.4 Flash And Fire Point Equipment.

RESULTS

i) The flash point should be taken as the temperature read on the thermometer at the time of the flame application that causes a distinct flash in the interior of the cup.

ii) The fire point should be taken as the temperature read on the thermometer at which the application of test flame causes the material to ignite and burn for at least 5 seconds.

The fire point of Bitumen is…195……^{0}c
The flash point of bitumen is…175….^{0}

4.1.5 MARSHALL STABILITY TEST

This test is done to determine the Marshall stability of bituminous mixture as per ASTM D 1559. The principle of this test is that Marshall stability is the resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on the lateral surface. It is the load carrying capacity of the mix at 60oC and is measured in kg. The apparatus needed to determine Marshall stability of bituminous mixture is

Fig No. 4.5 Marshall Stability Equipment

The sample needed is From Marshall stability graph, select proportions of coarse aggregates, fine aggregates and filler in such a way, so as to fulfill the required specification. The total weight of the mix should be 1200g

4.2 PROCEDURE TO DETERMINE MARSHALL STABILITY OF BITUMINOUS MIXTURE

i. Heat the weighed aggregates and the bitumen separately upto 170ºC and 163ºC respectively.
ii. Mix them thoroughly, transfer the mixed material to the compaction mould arranged on the compaction pedestal.
iii. Give 75 blows on the top side of the specimen mix with a standard hammer (45cm, 4.86kg). Reverse the specimen and give 75 blows again. Take the mould with the specimen and cool it for a few minutes.
iv. Remove the specimen from the mould by gentle pushing. Mark the specimen and cure it at room temperature, overnight.
v. A series of specimens are prepared by a similar method with varying quantities of bitumen content, with an increment of 0.5% (3 specimens) or 1 bitumen content.
vi. Before testing of the mould, keep the mould in the water bath having a temperature of 60ºC for half an hour.
vii. Check the stability of the mould on the Marshall stability apparatus.

4.3 PREPARATION OF DESIGN MIX

4.3.1 Plain Bituminous Mix:

Bitumen is a black, oily,viscous material that is a naturally-occurring organic byproduct of decomposed organic materials. Also known as asphalt or tar, bitumen was mixed with other materials throughout prehistory and throughout the world for use as a sealant, adhesive, building mortar, incense, and decorative application on pots, buildings, or human skin. The material was also useful in waterproofing canoes and other water transport.
A good design of bituminous mix is expected to result in a mix which is adequately
(i) strong (ii) durable (iii) resistive to fatigue and permanent deformation (iv) Environment friendly (v) economical and so on.

4.3.2 Selection of Mix Constituents

Binder and aggregates are the two main constituents of bituminous mix. This section discusses some of the issues involved in selection of binder and aggregates.

4.3.3 Binder

Generally binders are selected based on some simple tests and other site-specific requirements. These tests could be different depending of the type of binder viz. penetration grade, cutback, emulsion, modified binder etc. For most of these tests, the test conditions are pre-fixed in the specifications. Temperature is an important parameter which affects the modulus as well as the aging of binder. Superpave specifications [Superpave 1997, 2001] suggest that these acceptability tests are to be carried out at the prevalent field temperatures, not in a laboratory specified temperature. This is an important consideration because, binder from two different sources may show same physical properties at a particular temperature, but their performances may vary drastically at other temperatures. In Superpave specifications, therefore, only the acceptable test values are recommended, and not the test temperatures. The temperature values are found out from the most prevalent maximum and minimum temperatures at the field at a given probability level. Rolling Thin Film Oven Test (RTFO), Pressurized Aging Vessel (PAV), Dynamic Shear Rheometer, Rotational Viscometer, Bending Beam Rheometer, Direct Tension Tester are some of the tests recommended in Superpave binder selection.

4.3.4 Aggregate

Number of tests is recommended in the specifications to judge the properties of the aggregates, e.g. strength, hardness, toughness, durability, angularity, shape factors, clay content, adhesion to binder etc. Angularity ensures adequate shear strength due to aggregate interlocking, and limiting flakiness ensures that aggregates will not break during compaction and handling.Theoretically, it is difficult to predict the aggregate volumetric parameters, even the resultant void ratio, when the gradation curve is known. The Fuller's experimental study for minimum void distribution still forms the basis of these exercises. Strategic Highway Research Program (SHRP), USA formed a 14 member Expert Task Group for evolution of appropriate aggregate gradation to be used for Superpave. The group, after several rounds of discussions decided to use 0.45 power Fuller's gradation as the reference gradation, with certain restricted zones and control points. The restricted zone and control points are incorporated in order to ensure certain proportion of fines for (i) proper interlocking of aggregates (ii) to avoid the fall in shear strength of mix due to excess of fines and (iii) to maintain requisite Voids in Mineral Aggregates (VMA).

4.3.5 Various Mix Design Approaches:

There is no unified approach towards bituminous mix design, rather there are a number of approaches, and each has some merits are demerits. Table-1 summarizes [RILEM 17 1998] some of the important bituminous mix design approaches.

4.3.6 Coated Bituminous Mix:

The generation of waste plastics is increasing day by day. The major polymers are namely polyethylene, polypropylene, polystyrene show adhesion property in their molten state. The plastic coated aggregate bitumen mix and plastic modified bitumen forms better materials for flexible pavement construction as the mixes shows higher Marshall Stability value and suitable Marshall Coefficient. Hence the use of waste plastics for flexible pavement is one of the best methods of easy disposal of waste plastics. The use of polymer coated aggregate is better than the use of polymer modified bitumen in many aspects.The studies on the thermal behavior and binding property promoted a study on the preparation of plastic waste-bitumen blend and its properties to find the suitability of the blend for road construction.

4.4 CASTING & TESTING OF CUBES

Casting of Marshall Stability Mould

For each mould 1200 gm material is required and Bitumen percentage is 5.25% of total material (By weight.)

Casting of control cubes.

- 13 mm aggregate - 300 gm
- 6 mm aggregate - 300 gm
- Dust -576 gm
- Cement - 24 gm
- Bitumen -59 gm

Casting of 5% replacement CUBES

- 13 mm aggregate - 300 gm
- 6 mm aggregate - 300 gm
- Dust -576 gm
- Cement - 24 gm
- Bitumen -55 gm (5.25% of 1200gm material)
- Waste Plastic - 4 gm

Table 4.1 Casting & Testing Of Cubes

MATERIAL NEEDED	PLAIN BITUMEN PROCESS	PLASTIC-TAR ROAD
80/100	11250kg	10125kg
Plastic waste	-	1125kg
Cost	Rs.393750	(BIT) Rs.354375+(plastic)Rs.13500=Rs.367875
Cost reduced	NIL	Rs.25875.00
Carbon credit achieved on avoiding burning of plastic	NIL	3.50tonnes

%OF PLASTIC	MOISTURE ABSORPTOIN	SOUNDNESS	VOIDS	AGGREGATE CRUSHING TEST	LOSANGELES ABRASION	AGGREGATE IMPACT VALUE
NILL	4%	5%	4%	26%	37%	25.4%
1%	1%	NIL	2.2%	21%	32%	21.20
2%	1%	NIL	1%	20%	29%	18.50
3%	.5%	NIL	NIL	NA	NA	NA
5%	.35%	NIL	NIL	NA	NA	NA
10%	.12%	NILL	NIL	NA	NA	NA

5. RESULT & DISCUSSION

IMPROVED CHARACTERISICS OF PLASTIC AND CRUMB RUBBER COATED AGGREGATES WATER ABSORPTION (%)

Table 5.1 Improved Characterisics Of Plastic And Crumb Rubber Coated Aggregates Water Absorption

% OF POLYMER COATED OVER AGGREGATE	WT.OF ADDED PLASTIC IN (GM)	SAMPLE1	SAMPLLE2	SAMPLE3	AVERAGE
-	-	0.56	0.57	0.55	0.56
0.5	2.50	0.44	0.40	0.42	0.42
0.75	3.75	0.32	0.28	0.28	0.29
1.0	5.00	0.24	0.22	0.20	0.22

Cost will be decreased due to using waste plastic in Construction of road the following is cost benefits analysis is 25mm SDBC-10m sq.

Conclusion

It is observed from graphs that with increase in bitumen concentration the Marshall stability value increases up to certain bitumen content and there after it decreases. Plastics will increase the melting point of the bitumen. 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, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes. It is hoped that in near future we will have strong, durable and eco-friendly roads which will relieve the earth from all type of plastic-waste. It is observed that addition of plastics waste up to 10 - 15% by weight of bitumen resulted into higher values of softening point and lower values of penetration, which are appreciable improvements in the properties of the binder. This has resulted and withstood higher traffic load and high temperature variation. Several experimental stretches have been laid in more than 15 locations in Tamilnadu using both Mini hot-mix and central mixing plants. There are different types of bitumen roads. They are, Dense Bituminous Macadam, Bituminous Macadam. These roads differ in 3-ways i.e. 1. Composition of the aggregate; 2. Type of bitumen used; and 3. Thickness of layer. Bitumen is an useful binder for road construction. Different grades of bitumen like 30/40, 60/70, and 80/100 are available on the basis of their penetration values and these grades can be used as IRC Specifications. Waste plastics (10% in place of bitumen) can be used for these different types of bitumen roads. The technology of road laying is very much the same as prescribed by the Indian Roads Congress (Section 500, IV revision) Specifications.

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