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UTILIZATION OF POLYMER WASTE FOR MODIFICATION OF BITUMEN IN ROAD CONSTRUCTION

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ABSTRACT

Generation of polymer waste is increasing day by day and necessity to dispose this waste in proper way is arising. This waste is disposed by using different methods such as incineration, land-filling which affects the environment; but by adding polymer into roads is the eco-friendly process. The addition of polymer into dry bitumen improves the service properties of bitumen. If we use the polyolefins waste with or without crumb rubber upto certain percentage of bitumen then the properties of modified bitumen will be increased. The use of this innovative technology (polymer loading into bitumen) not only strengthen the road construction but also increases the road life as well as will help to improve the environment and also creating a source of income. By utilization of such polymer waste would be a boon for India's hot and extremely humid climate, where temperature frequently crosses 50^0C and torrential rains create havoc, leaving most of roads with big potholes. There are two types of techniques can be used for disposal of polymer waste in road construction.

Dry process is suitable because by this process 15-20 % of plastic waste addition by weight % with respective to aggregate. But considering the limitations of this process that it is applicable to plastic waste only and hence our aim of disposing the total polymer waste for eco-friendly environment cannot be completely achieved. Wet process though it requires strong mechanical stirrer and continuous rotation, batch type production and separate chamber. If processing parameters such as heat losses, temperatures etc. are properly controlled there is reduction in the residence time which minimizes production time and thus improves productivity, hence this process is economically feasible and limitations of dry process can be overcome. As far as type of polymer waste is concerned, wet process is suitable for any type of polymeric waste (rubbery or plastic) or any size and form (either strand or powder). By the actual experimentation, we obtained optimum results for polymer waste at different composition. Hence, from the results, polyolefin waste can be loaded upto 6% HDPE, LDPE upto 6%, PP upto 4% crumb rubber upto 4% and mixture of crumb rubber and HDPE waste upto 8% (4% + 4%) in road construction. Under the similar conditions most of the bitumen roads are performing well at all.

Key words: Plastic waste, Dry process, Wet process, Bitumen, Non-biodegradability, HDPE, LDPE, PP, Crumb rubber.

INTRODUCTION

Plastic products have become an indispensable part of our daily lives as many objects of daily use are meant from some kind of plastic. The growth in various types of industries together with population growth has resulted in enormous increase in production of various types of waste materials world over. Plastic is everywhere in today's lifestyle. It is used for packaging, protecting, serving and even disposing of all kinds of consumer goods. With the industrial revolution mass production of goods started and plastic

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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 information technology has been virtually revolutionized by the applications of plastics. Use of this non-biodegradable product is growing rapidly and creating problem of disposal of plastic waste. Disposal of plastic waste is particularly plastic bag menace and has become a serious problem especially in urban areas in terms of its misuse, its dumping in the dustbin, clogging of drains, reduce soil fertility and aesthetic problems, etc. If a ban is put on the use of plastic on emotional ground, the real cost would be much higher, the inconvenience much more, the chances of damage or contamination much greater. The risk to the family health and safety would increase and above all the environmental burden would be manifold. Today's age is generally known as plastic age. Our future is depended on this plastic. Though it is too useful, improper management of this plastic waste is a subject of concern. There is not any process for disposing the plastic waste. Hence, it is needed that plastic product must be recycled and not end in landfills. Plastic recycling offers viable solutions to these problems. Over the years, different waste management, treatment and disposable methods such as Primary, Secondary, Tertiary and Quaternary recycling of plastic waste have came into existence. Primary recycling means plastic waste or scrap of single clean waste type. A plastic of source is known as industrial waste plastic. Secondary recycling uses the reclaim part of consumer material. It consists of different types of plastic and source is unknown. Tertiary recycling is a process of recovery of monomers or value added products such as recovery of liquid fuels. It is a chemical breakdown of materials and is reused back in main back start monomers. Pyrolysis produces lower molecular weight fragments. Quaternary recycling also known as the energy recovery is the process of recuperation of energy out of the plastic waste. Energy recovery from municipal solid plastic waste can take the routes like burning the waste in stream generated incinerators, burning the refuse in heat exchangers, pyrolysis, hydrogenation and anaerobic digestion[1]. Tyre waste is also the major part of polymer and it is also necessary to dispose. It creates health and environmental problems, if dispose by land filling and incineration. Hence, one is the way of disposing tyre waste as crumb rubber into the road for modification of bitumen. Proper addition of such waste in bitumen improves quality, life and minimizes construction cost of road.

The phenomenal increase in the volume of vehicular traffic on our roads, including commercial vehicle combined with perpetual overloading by transport vehicles and significant variation in daily and seasonal temperature in various parts of the country calls for the improved performance of the road pavement and consequently better quality of bitumen. Every increasing use of polymer in day to day life is generating enormous plastic and rubber waste disposal of which by land filling and incineration is non eco-friendly. The utilization of polymeric waste in bituminous mix to improve the properties of the binder offers as such very promising alternative. Use of plastic in road construction is not new it is already in use as PVC or HDPE pipe mat crossings built by cabling together PVC or HDPE pipes to form plastic mats. Both options help to protect wetland haul roads from rutting by disturbing the load across the surface. But the use of plastic waste has been a concern for scientists and engineers for a quite long time.

Literature review

Verma[2] had highlighted the developments in using plastics waste to make plastic roads in his research. 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 product is growing rapidly and the problem is what to do with plastic waste. 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 Versus No Plastics' but it is more concerned with the judicious use and re-use of plastic-waste.

Recent studies in these directions have shown some hope in terms of using plastic-waste in road construction i.e. plastic roads. A Bangalore-based firm, KK Poly-flex and team of Engineers from R. V. College of Engineering, Bangalore, have developed a way of using plastic waste for road construction. The vigorous tests at the laboratory level proved that the bituminous concrete mixes prepared using the treated bitumen binder fulfilled all the specified Marshall mix design criteria for surface course of road pavement. There was a substantial increase in Marshall Stability value of bituminous concrete mixture, in the order of two to three times higher value in comparison with the untreated or ordinary bitumen.

The concept of utilization of waste plastic in construction of flexible road pavement has been done since 2000 in India. In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength and life of road pavement. But its resistance towards water is poor. A common method to improve the quality of bitumen is by modifying the rheological properties of bitumen by blending with synthetic polymers like rubber and plastics. Use of plastic waste in the bitumen is similar to polymer modified bitumen. The blending of recycled LDPE to asphalt mixtures required no modification to existing plant facilities or technology[3]. Polymer modified bitumen has better resistance to temperature, water etc. This modified bitumen is one of the important construction materials for flexible Road pavement[4]. Since 90's, considerable research has been carried out to determine the suitability of plastic waste modifier in construction of bituminous mixures[5,6].

Habib et al.[7] worked on the rheological properties of bitumen modified by thermo plastic namely linear low density polyethylene [LLDPE], High density polyethylene (HDPE) and Polypropylene (PP) and its interaction with 80 penetration index bitumen. As it is known that the modification of bitumen by the use of polymers enhances its performance characteristics but at the same time significantly alter its rheological properties. The rheological study of polymer modified bitumen (PMB) was made through penetration, softening point and viscosity test. The results were then related to the changes in the rheological properties of PMB. It was observed that thermo-plastic copolymer shows profound effect on penetration rather than softening paint. The visoelastic behavior of PMB depend on the concentration of polymer, mixing temperature, mixing technique solvating power of base bitumen and molecular structure of polymer used. PP offer better blend in comparison to HDPE and LLDPE. The viscosity of base bitumen was also enhanced with the addition of polymer. The pseudeoplastic behavior was more prominent for HDPE and LLDPE than PP. Best results were obtained when polymer concentration was kept below 3%. Zoorab and Suparma[8] reported the use of recycled plastics composed predominantly of polypropylene and low density polyethylene in plain bituminous concrete mixtures with increased durability and improved fatigue life. Dense bituminous macadam with recycled plastics, mainly low density polyethylene (LDPE) replacing 30% of 2.36-5 mm aggregates, reduced the mix density by 16% and showed a 250% increase in Marshall Stability. The indirect tensile strength (ITS) was also improved in the 'Plastiphalt' mixtures. D. N. Little, work on the same theme and he found that resistant to deformation of ashphaltic, concrete modified with low density polyethylene was improved in comparison with unmodified mixtures[8]. It is found that the recycled polyethylene bags may use full in bitumen pavement resulting in reduced permanent deformation in the form of rutting and reduced low temperature cracking of pavements surfacing[9]. Bindu and Beena[10] investigates the benefits of stabilizing the stone mastic asphalt (SMA) mixture in flexible pavement with shredded waste plastic. Conventional (without plastic) and the stabilized SMA mixtures were subjected to performance tests including Marshall Stability, tensile strength and compressive strength tests Trim axial tests were also conducted with varying percentage bitumen by weight of mineral aggregate (6% to 8%) and by varying percentage plastic by weight of mix (6% to 12% with an increment of 1%). Plastic content of 10% by weight of bitumen is recommended for the improvement of the performance of Stone Mastic Asphalt mixtures. 10% plastic content gives an increase in the stability, split tensile strength and compressive strength of about 64%, 18% and 75%, respectively compared to the conventional SMA mix. Taxied test results show a 44% increase in cohesion and 3% decrease in angle of shearing resistance showing an increase in the shear strength. The dram down value decreases with an increase in plastic content and the value is only 0.09 % at 10% plastic content and proves to be an effective stabilizing additive in SMA mixtures[11]. Stone Mastic Asphalt is a gap graded bituminous mixture containing a high proportion of coarse aggregate and filler, it has low air voids with high levels of macro texture when laid, resulting in a waterproof layer with good surface drainage. Stabilizing additives are needed in the mastic which is rich in binder content to prevent the binder from draining down from the mix. Polymers and fibers are the commonly used stabilizing additives in SMA. Based on many research reports and engineering case studies has been shown that the use of stone mastic asphalt (SMA) on road surfaces can achieve better rut-resistance and durability[10].

Data on plastic consumption and generation of plastic waste

A material that contains one or more organic polymers of large molecular weight, solid in its finish state and at some state while manufacturing or processing into finished articles, can be shaped by its flow is termed as plastics. The plastic constitutes two major categories of plastics: (i) Thermoplastics and (ii) Thermo set plastics. The thermoplastic constitutes 80% and thermo set constitutes approximately 20% of total postconsumer plastics waste generated. Table 1 describes the average municipal solid waste production from 0.21 to 0.50 Kg per capita per day in India.

Table 1: Municipal solid waste in Indian Cities[12]

Population range (Millions)	Average per capita value
0.1 -0.5	0.21
0.5 -1.0	0.25
1.0 -2.0	0.27
2.0 -5.0	0.35
> 5	0.50

Table 2: Plastic consumption in India[12]

S. No.	Year	Consumption (Tones)
1	1996	61,000
2	2001	4,00,000
3	2006	7,00,000
4	2011	13500000

Due to the change in scenario of life style, the polymer demand is increasing everyday across the globe. Table 3 gives the polymer demand in India from 1995 to 2011.

Table 3: Polymer demands in India (Million tones)[13]

Type of polymer	1995-96	2001-02	2006-07	2010-11
PE	0.83	1.83	3.27	7.12
PP	0.34	0.88	1.79	3.88
PVC	0.49	0.87	1.29	2.87
PET	0.03	0.14	0.29	0.75
Total	1.69	3.72	6.64	14.62

Table 4: Plastic waste consumption (P/C/ YEAR)[14]

S. No.	Country/continent	Per year consumption (Kg)
1	India	14.0
2	East Europe	10.0
3	South East Asia	10.0
4	China	24.0
5	West Europe	65.0
6	North America	90.0
7	World average	25.0

India has among the lowest per capita consumption of plastics and consequently the plastic waste generation is very low as seen from the Table 5.

Table 5: Plastic waste consumption[15]

S. No.	Description	World	India
1	Per capita per year consumption of plastic (Kg)	24-28	12-16
2	Recycling (%)	25	60
3	Plastic in solid waste (%)	7	9

Table 6: Waste plastic and its source

Waste plastic	Origin
Low density polythylene (LDPE)	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.
High density polyethylene (HDPE)	Carry bags, bottle caps, house hold articles etc.
Polyethylene teryphthalate (PET)	Drinking Water bottles etc.
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent, biscuit, vapors packets, microwave trays for readymade meal etc.
Polystyrene (PS)	Yoghurt post, clear egg packs, bottle caps. Foamed polystyrene : food trays, egg boxes, disposable cups, protective packaging etc.
Polyvinyl chloride (PVC)	Mineral water bottles ,credit cards, toys, pipes and gutters, electrical fittings, furniture, folders and pens, medical disposables etc.

Most of thermoplastics on heating soften at temperature between 130-104^{0}C .The TGA analysis of thermoplastics has proven that there is no gas evolution in the temperature range of 130-180^{0}C and beyond 180^{0}C gas evolution and thermal degradation may occur. Thus, the waste plastic can easily be blended with the bitumen as the process for read construction using bitumen is carried out in the range of 155-165^{0}C. Table 7 gives the source of waste plastic generation.

Table 7: Properties of bitumen

S. No.	Characteristic properties of bitumen	Grades of bitumen		
		30/40	60/70	80/100
1	Specific gravity	0.99	0.99	0.98
2	Water content (% by wt.)	0.2	0.2	0.2
3	Softening point (^oC)	50-65	40-55	35-50
4	Penetration point (100 g/5 sec)	30-40	60-70	80-100
5	Ductility (cm)	50	75	75
6	Flash point (^oC)	175	175	175
7	Solubility in CCl_3	99%	99%	99%
8	Solubility in CS_2	99%	99%	99%

Bitumen

Bitumen is a sticky, black and highly viscous liquid or semi-sold, in some natural deposits. It is also the residue or by-product of fractional distillation of crude petroleum. Bitumen composed primarily of highly condensed polycyclic aromatic hydrocarbons, containing 95% carbon and hydrogen (+87% carbon and + 8% hydrogen) upto 5% sulfur, 1% nitrogen, 1% oxygen and 2000 ppm metals. Also bitumen is mixture of about 300-2000 chemical components, with an average of around 500-700. It is the heaviest fraction of crude oil, the one with highest boiling point (525^oC).

Different forms of bitumen

Cutback Bitumen: A suitable solvent is mixed to reduce viscosity. Bitumen Emulsion; bitumen is suspended in finely divided condition in aqueous medicum 60% bitumen and 40% water. Bituminous Primers: Mixing of penetration bitumen with petroleum distillate. Modified Bitumen: Blend of bitumen with waste plastics & or crumb rubber.

Various grades of bitumen used for pavement purpose

- **Grade 30/40:** These are the thicker material having higher softening point & these are used in high temperature regions.
- **Grade 60/70:** These are semi viscous material having moderate softening point. It is widely used in India because of its availability & cheaper cost. It is a best suitable material in Indian roads and highways.
- **Grade 80/100:** This type of bitumen is thinner material & is used in tropical regions. It is having lower softening point.

Functions of bitumen

The bitumen is used for the construction of roads. These roads come in contact with varying temperature situations. It may undergo many weather effects, rainy, hot etc. Also the volume of traffic is increasing day by day. The bitumen has tendency of cracking. Thus to overcome these problems it should act as binder material, wear resistant, protects the base course.

EXPERIMENTAL

Raw material

Waste plastic HDPE, LDPE, PP, crumb rubber were procured from the local scrap plastic supplier. The bitumen (60/70 grade) and aggregates were obtained from Kothari Builders, Akola.

Methodology

Waste plastic is made powder and varying percent plastic is mixed with bitumen. Plastic increase the melting point of the bitumen and makes the road flexible during winters resulting in its long life. Use of shredded plastic waste acts as a strong "binding agent" for tar making the asphalt last long. By mixing plastic with bitumen the brittleness was overcome and elastic nature enhances. The plastic waste is melted and mixed with bitumen in a particular ratio. There are two important processes namely dry process and wet process used for bitumen mix flexible pavement.

Dry process

For the flexible pavement, hot stone aggregate (170°C) is mixed with hot bitumen (160°C) and the mix is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding property, penetration value and viscoelastic property. The aggregate, when coated with plastics improved its quality with respect to voids, moisture absorption and soundness.

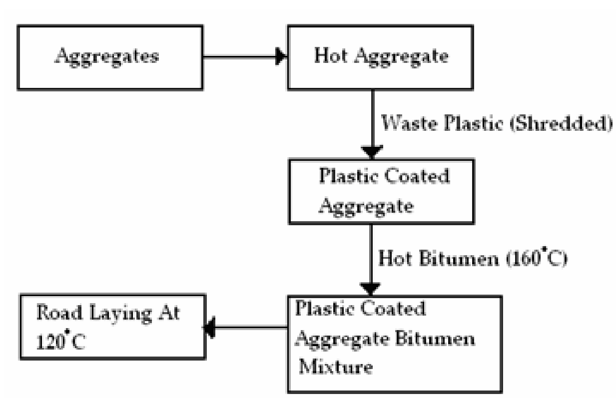

Fig. 1: Flow chart of dry process

The coating of plastic decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement. It is to be noted here that stones with < 2% porosity only allowed by the specification.

Wet process

These are the method used for formation of polymer based modified bitumen, in which the waste polymer directly added with bitumen and heated upto temperature of 160^{o}C so that proper blend is to be formed with proper dispersion of waste polymer into bitumen, then the hot mix is then cooled upto 120^{o}C into another chamber, which is then added to the aggregate in paddling chamber. The mix is to be cooled because when hot mix poured on aggregate then there are chances to form air pocket into small gap of aggregate and chances in lower the strength of rods and chances of rutting of roads. After addition of modified bitumen at 110^{o}C on aggregate, it is then laid on the road and then spreader material is compacted by 8 tone roller.

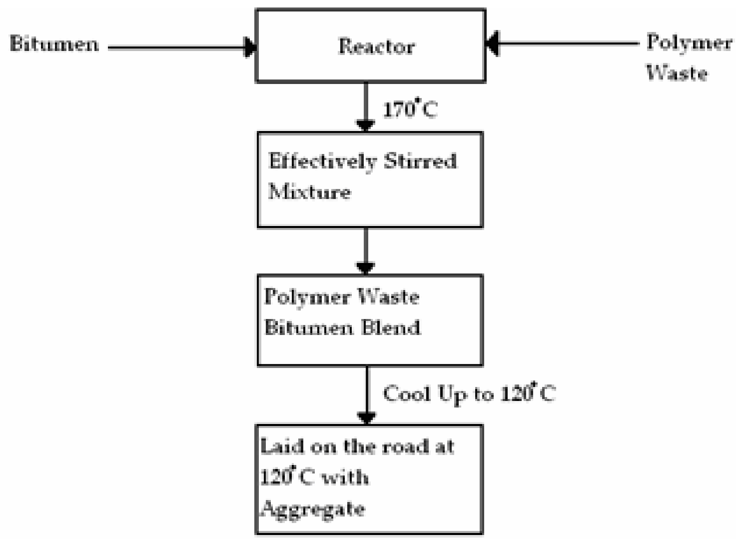

Fig. 2: Flow chart for wet process

Characteristics of plastic coated aggregate (used for flexible pavement)

Following are the important test carried out for plastic coated flexible pavement.

Moisture absorption and void measurement

For the flexible pavement, hot stone aggregate (170°C) is mixed with hot bitumen (160^{o}C) and the mix is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding property, penetration value and viscoelastic property. The aggregate, when coated with plastics improved its quality with respect to voids, moisture absorption and soundness. The coating of plastic decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement. It is to be noted here that stones with < 2% porosity only allowed by the specification.

Soundness test

Soundness test is intended to study the resistance of aggregate to weathering action. The weight loss is attributed to the poor quality of the aggregate. The plastic coated aggregate, did not show any weight loss, thus conforming the improvement in the quality of the aggregate.

Aggregate crushing value test

The aggregate crushing value (A. C. V.) of an aggregate is the mass of material, expressed as a percentage of the test sample which is crushed finer than a 2.36 m.m. sieve when a sample of aggregated passing the 13.2 m.m. and retained on the 9.5 m.m. sieve is subjected to crushing under a gradually applied compressive load of 400 K.N.

Aggregated impact value

A study on the effect of plastic coating was extended to study on the aggregate impact value. Aggregate was coated with 1% and 2% plastics by weight and the plastic coated aggregate was submitted to Aggregate Impact Value test and the values were compared with values for non coated aggregate.

Marshall stability

Marshall stability measures the maximum load sustained by the bituminous material at a loading rate of 50.8 mm/min. Marshall stability is related to the resistance of bituminous materials to distortion, displacement, rutting and shearing stresses.

Softening point test

This test is conducted using ring and ball apparatus. 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.

Penetration index test

It is measured using Penetrometer. The penetration of a bituminous material is the distance in tenths of a millimeter, which a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature, load and time.

Ductility index test

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

Flash and fire point test

In the interest of safety, legislation has been introduced in most countries fixing minimum flash point limits to prevent the inclusion of highly inflammable volatile fractions in kerosene distillates.

RESULTS AND DISCUSSION

The indigenous way of disposing plastic waste is by adding it into bitumen so that an eco-friendly solution is obtained. The experimentation of this project comprises many factors. The wastes like olefin, waste, crumb rubber, HDPE waste, LDPE, PP Waste and mixture of crumb rubber- HDPE waste were taken into consideration for the purpose of experimentation. The reason behind taking this waste is its availability and tremendous consumption in our day today life. When these plastics are added into bitumen, various differentiating results have obtained. The addition of this waste is determined by means of weight % of bitumen. It is called out by two processes; viz, dry and wet process. Dry process is used for aggregate while wet process is used for bitumen. Aggregate were in very small shapes (6 mm) while bitumen was in semi-viscous form.

Table 8: Crushing test and impact test of aggregate with and without plastics

Stone aggregate	%Wt. of plastics	Stone test aggregate (Kg)	Plastic waste (g)	Crushing test (%)	Impact test (%)
Without plastic	0%	4	0	21.3	19.6
With plastics	1%	4	40	17.5	15.2
	2%	4	80	14.9	13.5
	3%	4	120	11.2	10.7
	4%	4	160	10.3	9.6
	5%	4	200	9.7	8.9

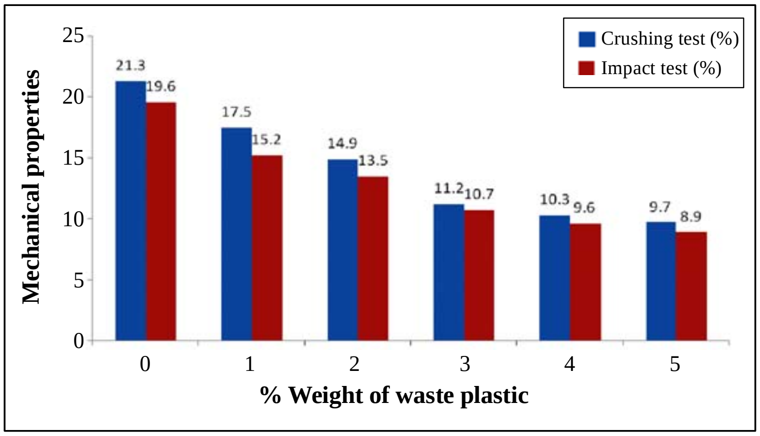

Fig. 3: Mechanical properties vs. % weight of waste plastic

Table 9: Modified bitumen by mixed (Olefins) waste plastic

% Wt. of waste plastic (g)	Amount of bitumen(g)	Mixed plastic waste (g)	Penetration (mm)	Ductility (cm)	Softening point (^{0}C)
0	250	0	69	75	42
2	250	5	68.5	70	43
4	250	10	63	65	54
6	250	15	58	63	56
8	250	20	44	57	62

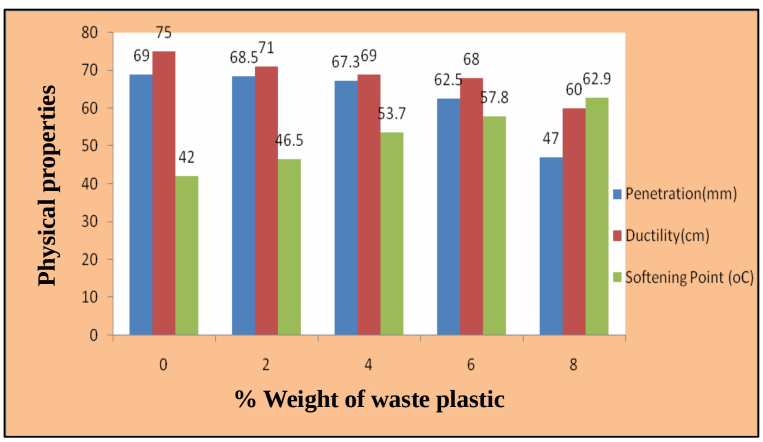

Fig. 4: Physical properties vs. % weight of waste plastic

Table 10: Modified bitumen by HDPE platics waste

% Wt. of HDPE waste	Amount of bitumen (g)	HDPE waste (g)	Penetration (mm)	Ductility (cm)	Softening point (^{o}C)
0	250	0	69	75	42
2	250	5	68	68	48.2
4	250	10	66.3	63	52.5
6	250	15	62	58	55.3
8	250	20	46	48	60.5

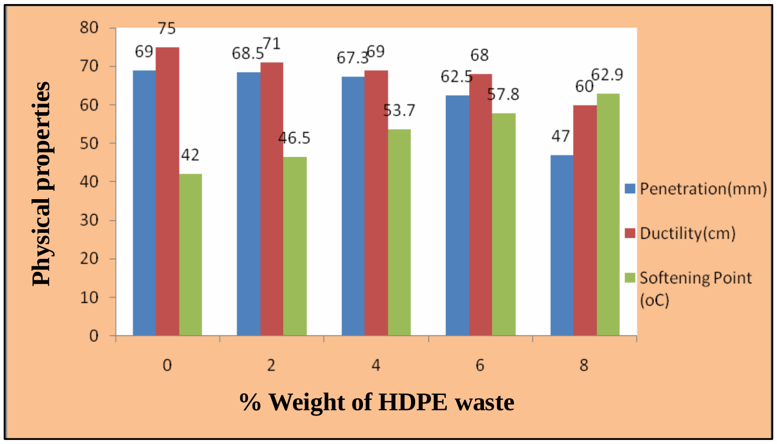

Fig. 5: Physical properties vs. % weight of waste HDPE plastic

Table 11: Modified bitumen by LDPE platics waste

% Weight of waste LDPE	Amount of bitumen (g)	Waste LDPE (g)	Penetration (mm)	Ductility (cm)	Softening point (^{0}C)
0	250	0	69	75	42
2	250	5	66	69	47
4	250	10	64	66	51
6	250	15	60	64	53
8	250	20	48	58	57

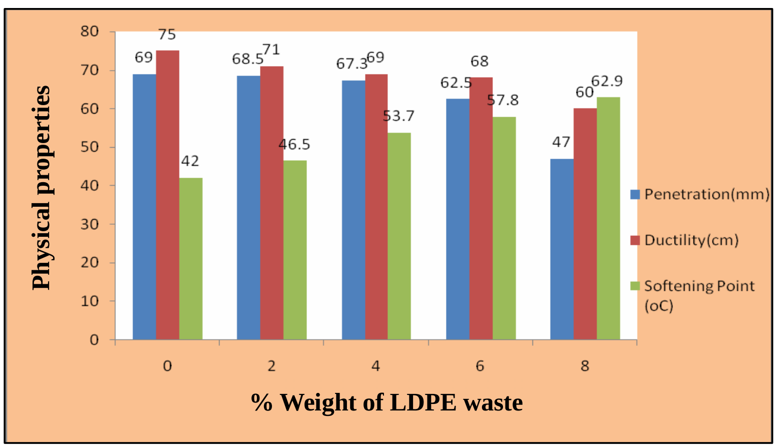

Fig. 6: Physical properties vs. % weight of waste LDPE plastic

Table 12: Modified bitumen by PP plastics waste

% Weight of waste PP	Amount of bitumen (g)	PP Waste plastic (g)	Penetration (mm)	Ductility (cm)	Softening point (^{0}C)
0	250	0	69	75	42
2	250	5	68	66	54

Cont…

% Weight of waste PP	Amount of bitumen (g)	PP Waste plastic (g)	Penetration (mm)	Ductility (cm)	Softening point (^{0}C)
4	250	10	67	64	56
6	250	15	64	59	59
8	250	20	52	52	64

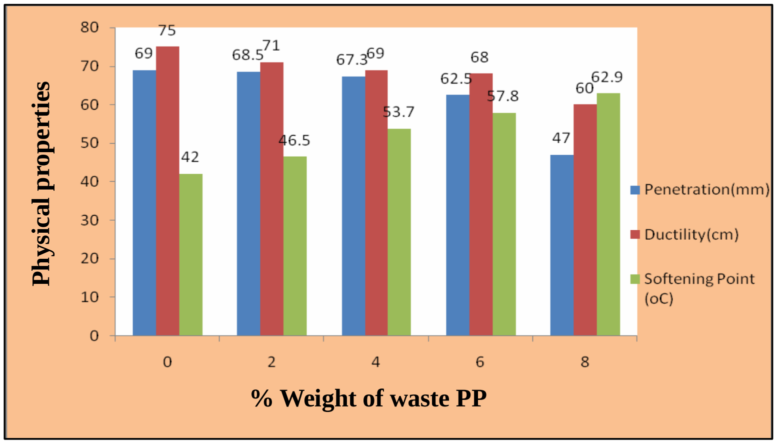

Fig. 7: Physical properties vs. % weight of waste PP plastic

Table 13: Modified bitumen by crumb rubber

% Wt. of crumb rubber	Amount of bitumen (g)	Crumb rubber (g)	Penetration (mm)	Ductility (mm)	Softening point (^{0}C)
0	250	0	69	75	42
2	250	5	68.9	74.5	42
4	250	10	68.2	74.2	44
6	250	15	67	74.8	45
8	250	20	61	74.6	45.3

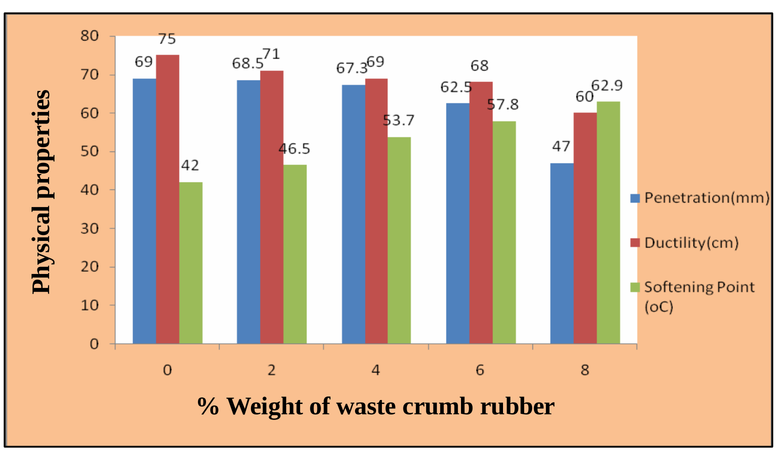

Fig. 8: Physical properties vs. % weight of crumb rubber

Table 14: Modified bitumen by mix (Crumb rubber + HDPE waste)

% Wt. of crumb rubber	% Wt. of HDPE waste	Amount of bitumen (g)	Crumb rubber (g)	HDPE waste (g)	Penetration (mm)	Ductility (cm)	Softening point (°C)
0	0	250	0	0	69	75	42
2	2	250	5	5	68.5	71	46.5
4	4	250	10	10	67.3	69	53.7
6	6	250	15	15	62.5	68	57.8
8	8	250	20	20	47	60	62.9

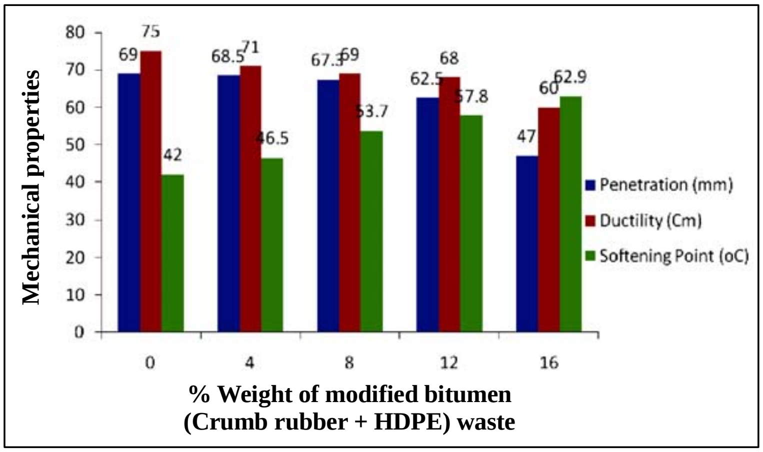

Fig. 9: Physical properties vs. % weight of modified bitumen

Table 15: Flash point test results for 60/70 grade bitumen base bitumen 60/70 flash point-198°C

Polymer % in bitumen (by weight)	HDPE waste flash point (°C)	LDPE Waste flash point (°C)	PP Waste flash point (°C)	Crumb rubber waste flash point (°C)	Crumb rubber + HDPE waste flash point (°C)
2	215	200	199	190	205
4	222	219	214	202	212
6	240	223	220	218	229
8	257	240	237	227	242

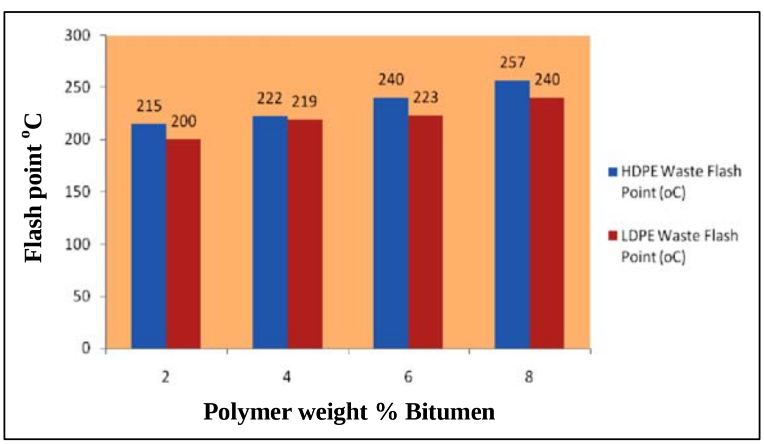

Fig. 10: Flash point vs. polymer weight % in bitumen

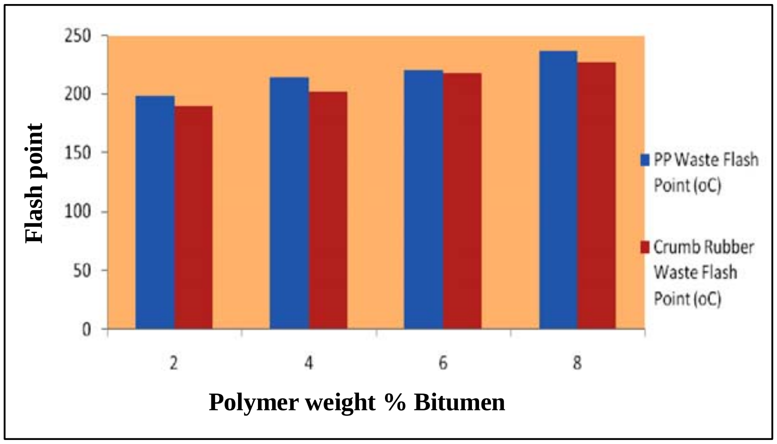

Fig. 11: Flash point vs. polymer weight % in bitumen

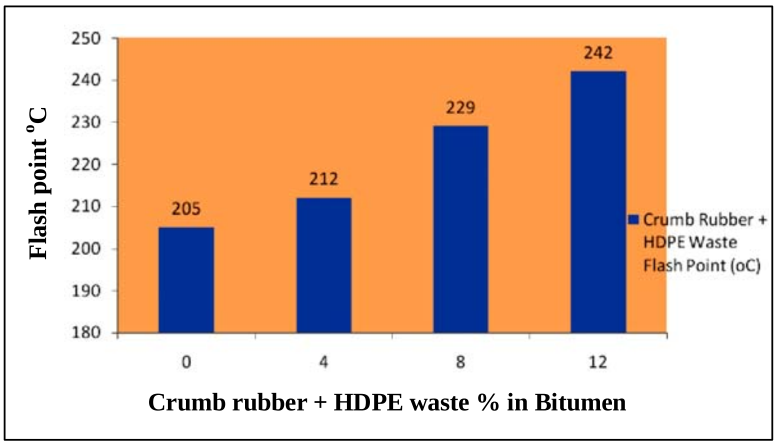

Fig. 12: Flash point vs. bitumen modified with crumb rubber and HDPE waste

The waste obtained and mixed in different forms i.e. olefin waste was in shredded form and HDPE waste in strand form and crumb rubber was in powder from. After sample preparation by Wet Process, if is observed that polymer olefin waste is effectively added in aggregate. Whereas other waste including olefins were effectively added in bitumen crumb rubber could not added in aggregate (8%), different values are obtained. The addition of polymers into bitumen improves the service properties of bitumen improves the service properties of bitumen. This is the only reason for selecting polymer waste as a modifier for bitumen. The use of this innovative technology not only strengthen the road construction but also increases the road life. The two types of techniques used for disposed of polymer waste in road construction i.e. dry and wet processes were experimentation work the polymer waste like mixed polyolefin waste, HDPE, LDPE, PP, crumb rubber waste and combination of crumb rubber + HDPE plastic waste were added in different loading weight percent into bitumen (60-70 penetration grade). The plastic waste used in this experimental work was available in the form of strands, shredded form particularly rubber waste in the form of powder. In dry process the aggregate were used in small shape (6 mm) while bitumen in semi viscous form. The different percentage of mixed plastics (polyolefin's) waste with respect to weight of aggregates were coated on it by applying temperature mixing. As the percentage loading of waste plastic coated on aggregates increased there waste was a gradual enhancement in the properties of aggregate observed. The aggregate crushing value, aggregate impact values were studied upto 5% weight of mixed plastic coated on aggregates. Its results showed upto 5% loading of mixed plastic waste. Hence, dry process is suitable because 15-20% plastic waste addition by weight % with respect to weight of aggregate was possible. But considering the limitations of this process that it is applicable to plastic waste only not rubber waste.

Following results showing maximum loading of waste into bitumen for road construction, which is obtained for each blend. For olefin waste, optimum results were obtained as 6% loading by weight addition of plastic waste in bitumen. As the plastic content increases there is reduction in ductility, because the plasticity of bitumen increases at services temperature. Minimum value of ductility (in cm) is required for proper application of bitumen in road is 62; otherwise. It will tend to from cracks and crazes at heavy load,

(i) For Crumb rubber, it is found that 4% of waste can be successfully added in bitumen but there is non-uniform mixture observed as increase in the % addition of crumb rubber which affects the surface of road.

(ii) The mixture of crumb rubber-HDPE loading obtained optimum results. This kind of mix polymer waste was added upto 8% i.e. 4% crumb rubber and 4% HDPE.

(iii) The HDPE & PP Plastics waste were added separately but the only limitation was that doesn't disperse uniformly in the bitumen. Maximum amount of loading observed was upto 4% because further addition of HDPE and PP Plastics waste reduces ductility of bitumen.

(iv) The addition of LDPE waste plastic optimum results were obtained at 6% percent loading with respect to weight of bitumen.

(v) The addition of crumb rubber and HDPE waste optimum result were obtained upto 8% loading with respective weight of bitumen. The maximum amount of polymer waste that can be added in bitumen was 8%. Above which the properties of bitumen considerably falls.

(vi) Discussion for flash and fire point result – At high temperatures depending upon the grades of bitumen materials leaves out volatiles. These volatiles are susceptible for to catch fire which is cause (explosion) or hazardous. Hence, it is essential to qualify this temperature for each bitumen grade.

Flash and fire point of bitumen used in this experimentation significantly increased with increased in polymer (%) concentration thus the possibility of hazardous situation becomes less.

CONCLUSION

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 on income. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50^{o}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 types of plastic-waste.

The combination of wet and dry process can be used, part of the plastic waste is coated on aggregate for improvement of impact and crushing strength of aggregate by applying dry process and remaining part of plastic waste is mixed in bitumen by applying wet process therefore the total loading of plastic waste can be increased as well as the improvement in mechanical properties will occurred.

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