ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

EFFECTIVE UTILIZATION OF PLASTIC WASTE IN FLEXIBLE PAVEMENT AND ANALYSIS BY EXPERIMENTS.

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ABSTRACT

This paper presents the results of an experimental investigation carried out to study the effects of the use of plastic waste instead of replacing bitumen percentage (6%,8%,10%) on the physical properties of pavements. Plastics are user friendly but not eco-friendly as they are non-biodegradable, generally it is disposed by way of land filling or incineration of materials which are hazardous. The better binding property of plastics in its molten state has helped in finding out a method of safe disposal of waste plastics, by using them in road laying. 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. The plastic waste (PE, PET and PP) contained 6%, 8% and 10% (by weight) are used as a binding material in the manufacturing of the flexible pavements. Tests were performed to determine the physical impact on bitumen and aggregate. The results indicate that the use of plastic waste enhance abrasion resistance and slip resistance of 20% and give pavements with low porosity (less than 5%). The results show continuous improvement in mechanical properties depending upon plastic waste content. Use of plastic waste as a binder significantly improves splitting tensile strength on flexible pavement independently of plastic type. In my research work I have done a thorough study on the methodology of using plastic waste in bituminous mixes and presented the various tests performed on aggregates and bitumen.

KEYWORDS: plastic waste, disposal, bitumen mix, non-biodegradable, mechanical and physical characteristics.

INTRODUCTION

Plastic is everywhere in today's lifestyle. Plastics, a versatile material and a friend to common man become a problem to the environment after its use. Today, in India nearly 14 million tons of plastics are used and it is hoped to reach 22 million tons by 2020. There by plastic waste disposal throws many challenges to the society due to its non-bio degradability (according to recent studies, plastics can stay as long as 4500 years on earth). It's used for packaging, protecting, serving, and even disposing of all kinds of consumer goods. Through 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. Plastics such as polyethylene, polystyrene, high density polyethylene, low density polyethylene, polypropylene etc., are used in bags, sacks, detergent bottles, bottles of disinfectants, milk, fruit juices, bottle caps, film wrapping for biscuits, microwave trays for ready-made meals, mineral water bottles, credit cards, toys, pipes, pens, medical disposables, etc. product is growing rapidly and the problem is what to do with plastic-waste. Plastic is the most hazardous waste affecting the environment. Studies have linked the improper disposal of plastic to problems as distant as breast cancer, reproductive problems in humans and animals, genital abnormalities and much more. They also have very long lifetime and the burning of plastics waste under uncontrolled conditions could also lead to generation of many hazardous air pollutants (HAPs) depending upon the type of polymers and additives used. However, the end-of-life plastics can be recycled into a second life application but after every thermal treatment, degradation of plastics takes place to a certain extent.

Today the availability of the waste plastics is enormous, as the plastic materials have become part of daily life. They either get mixed with Municipal Solid Waste and/or thrown over land area. If not recycled, their present disposal is either by land filling or by incineration. Both the processes have certain impact on the environment. Under this circumstance, an alternate use for the waste plastics is also the needed. The waste plastic can be used effectively as a better binder in the process of construction of road.

The uses of plastic waste helps 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 20% 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 missing and laying of roads is to be done using plastic waste. 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 reliving the earth from all type of plastic waste.

PROBLEM STATEMENT

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 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.

Scarcity of bitumen in future needs a deep thinking to ensure fast road construction.

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.

OBJECTIVES

Main motto is to efficiently utilize the waste plastic in constructive way so that it can be beneficial to society however main objectives of current project work are:

1. To mix the waste plastic with the bitumen in hot mix plant efficiently.
2. To coat the aggregates with the waste plastic materials
3. To check the properties of bituminous mix specimen due to coating of waste plastic materials
4. To compare the properties of bituminous mix specimen with the properties of coated aggregates.
5. To utilize the plastic waste and to reduce its impact on environment.

DISPOSAL OF PLASTICS

The present day disposal of plastic waste, especially Municipal Solid Waste containing plastics, is carried out by

1. **Land filling** and 2. **Incineration**

Land filling- is a process in which the waste materials are buried in a specific area, away from the city. This process is purely temporary. This may result in
(1) Affecting water recharge,
(2) Reducing soil microbial activity
(3) Clogging the drainage and
(4) Water line clogging.

Such clogging may result in the production of gases like methane, which affects Green House effect. Above all, land availability for filling is also a problem.

Incineration is normally carried out above 700 degree C. Incineration of polymers like PE, PP, PS produces gases like CO, CO2 etc. and these gases cause global warming, air pollution, monsoon failure, etc. If PVC is mixed with the waste, it may result in the production of HCl, Cl2 and sometime Dioxin, the poisonous gas. Incineration could also aggravate pollution problem if strict standards are not enforced and the process also needs scientific monitoring.

MATERIALS

PLASTIC

The plastic used was the waste plastic bottles, LDPE/HDPE bags, wrappers, collected from the nearby houses and apartments and from the dump yards.

Steps involved in the plastic recycling process

i) **Selection/analysis:** The recyclers/ reprocesses have to select and analyses the waste/scrap, which are suitable for recycling/reprocessing.

ii) **Collection/segregation:** The plastics waste collected/segregated as per the **codes 1-7** mentioned in the BIS guidelines (IS: 14534:1998).

Fig. steps in recycling.

iii) Transporting/processing/recycle

After selection and segregation of the used plastic waste; it shall be washed, shredded, agglomerated, extruded and granulated. Waste plastic segregated, and shredded using shredding machine (particle size 2-3 mm).

BITUMEN

Bitumen is a sticky, black and highly viscous liquid or semi-solid, 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), up to 5% sulfur, 1% nitrogen, 1% oxygen and 2000ppm 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 (525ºC).

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 medium 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; Grade: 60/70; Grade: 80/100.

The desirable property of bitumen for pavement:

1. Good cohesive and adhesive binding property.
2. Water repellant property.
3. It is its thermoplastic nature, (stiff when cold liquid when hot), that makes bitumen so useful.

Drawbacks of Bitumen

Temperature Effect: At high temperature bleeding of road occurs reducing performance of road **Oxidation Effect**: Due to oxidation bitumen may led to cracking & crazing phenomenon.

Water Effect: Due to water, bitumen strip off from the aggregate forming pothole on roads as being water repellent material. Reducing life of roads.

High Cost – Being petroleum product it costs much higher.

AGGREGATES

Aggregate was obtained from a local Quarry. The physical properties of aggregates are given in Table .Recommended gradation limits for BT works are shown in Table

Physical properties of aggregates

Test description	Specification	Values
Combined flakiness and elongation index (%)	IS 2386 (Pt. I – 1963)	18
Water absorption (%)	IS 2386 (Pt. I – 1963)	0.5
Specific gravity	IS 2386 (Pt. I – 1963)	2.65
Impact value (%)	IS 2386 (Pt. I – 1963)	16

Gradation of aggregates for pavement purpose

Sieve size (mm)	19	12.5	9.5	4.75
Permissible Limits (%)	100	85-95	75 MAX.	20-28

Sieve size (mm)	2.36	0.60	0.30	0.18
Permissible Limits (%)	16-24	12-16	10-14	06-08

PROCESSES FOR MANUFACTURING BITUMEN MIX ROAD USING WASTE PLASTIC

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 0C) is mixed with hot bitumen (160 0C) 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.

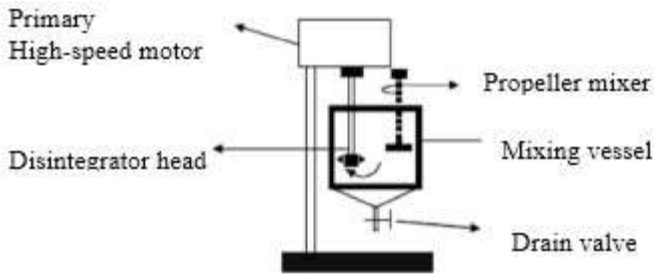


Fig.13: Polymer-bitumen mixing assembly

Advantages of dry process

- Plastic is coated over stones – improving surface property of aggregates.
- Coating is easy & temperature required is same as road laying temp.
- Use of waste plastic more than 15% is possible.
- Flexible films of all types of plastics can be used.
- Doubles the binding property of aggregates.
- No new equipment is required
- Bitumen bonding is strong than normal
- The coated aggregates show increased strength.
- As replacing bitumen to 15% higher cost efficiency is possible.
- No degradation of roads even after 5 -6 yrs after construction.
- Can be practiced in all type of climatic conditions.
- No evolution of any toxic gases as maximum temperature is 180ºC.

Disadvantages of dry process

a. The process is applicable to plastic waste material only.

2. Wet process

Waste plastic is ground and made into powder; 6 to 8 % plastic is mixed with the bitumen. Plastic increases the melting point of the bitumen and makes the road retain its flexibility 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 ability of the bitumen to withstand high temperature increases. The plastic waste is melted and mixed with bitumen in a particular ratio. Normally, blending takes place when temperature reaches 45.5°C but when plastic is mixed, it remains stable even at 55°C. 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 the mix, of the order of two to three times higher value in comparison with the untreated or ordinary bitumen. Another important observation was that the bituminous mixes prepared using the treated binder could withstand adverse soaking conditions under water for longer duration.

Advantages of wet process:

• This Process can be utilized for recycling of any type, size, shape of waste material (Plastics, Rubber etc.)

Disadvantages of wet process:

• Time consuming- more energy for blending.
• Powerful mechanical is required.
• Additional cooling is required as improper addition of bitumen may cause air pockets in roads.
• Maximum % of waste plastic can be added around 8 %.

MIXING PROCEDURE AT HOT MIX PLANT:

Step I: Plastics waste like bags, bottles made out of PE and PP cut into a size between 2.36 mm and 4.75mm using shredding machine. Care should be taken that PVC waste should be eliminated before it proceeds into next process.

Step II: The aggregate mix is heated to 165°C and then it is transferred to mixing chamber. Similarly the bitumen is to be heated up to a maximum of 160°C. This is done so as to obtain a good binding and to prevent weak bonding. During this process monitoring the temperature is very important.

Step III: At the mixing chamber, the shredded plastics waste is added over the hot aggregate. It gets coated uniformly over the aggregate within 30 to 45 seconds. It gives an oily coated look to the aggregate.
Step IV: The plastics waste coated aggregate is mixed with hot bitumen. Then this final resulted mix is used for laying roads. The road laying temperature is between 110°C 120°C. The roller used should be of is 8-ton capacity.

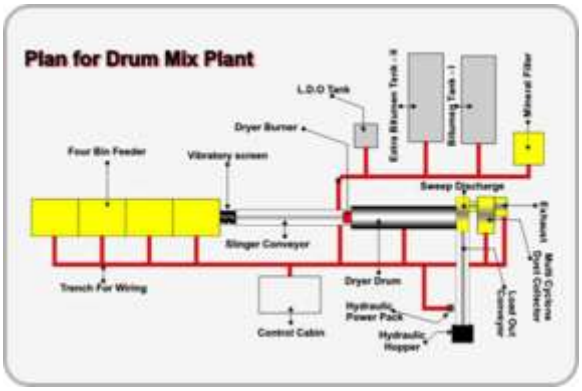


Fig. Plan for hot mix plant

MIXING BY MINI HOT MIX PLANT
Step I: Plastic waste made out of PE, PP and PS cut into a size between 2.36mm and 4.75mm using shredding machine.
Step II: Similarly the bitumen is to be heated to a maximum of 160°C to have good binding and to prevent weak bonding. (Monitoring the temperature is very important)
Step III: At the mixing chamber the shredded plastic waste is to be added to the hot aggregate. It gets coated uniformly over the aggregate within 30 Secs, giving an oily look Plastic coated aggregate is obtained.
Step IV: Hot bitumen is then added over the plastic coated aggregate and the resulting mix is used for road construction. The road laying temperature is between 110°C to 120°C. The roller used is 8-ton capacity.

METHODOLOGY

Following Tests were conducted to investigate the properties of the aggregate as well as bitumen.

TESTS FOR AGGREGATE

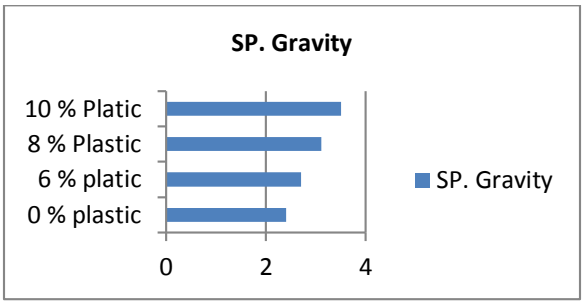
1. Specific Gravity & Water Absorption Test [IS: 2386 (Part 3) 1963]
2. Aggregate Impact Value Test [IS: 2386 (part 4) 1963]
3. Aggregate Crushing Value [IS: 2386 (Part 4) 1963]
4. Los Angeles Abrasion Value

TESTS FOR BITUMEN

1. Penetration Test [Is: 1203-1978]
2. Softening Point Test [Is: 1205-1978]
3. Ductility Test [IS: 1208-1978]
4. Flash Point and Fire Point

Specific Gravity and water absorption [IS: 2386 (Part 3) 1963]
The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. Because the aggregates may contain water-permeable voids, so two measures of specific gravity of aggregates are used apparent specific gravity and bulk specific gravity.

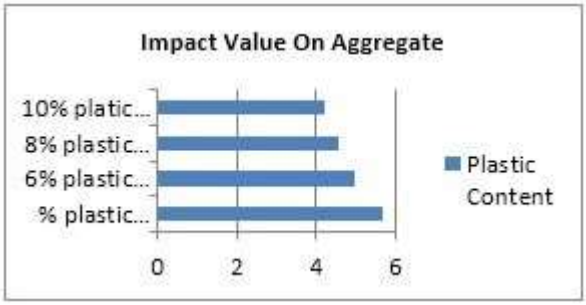
Water absorption- The difference between the apparent and bulk specific gravities is nothing but the water permeable voids of the aggregates. We can measure the volume of such voids by weighing the aggregates dry and in a saturated, surface dry condition, with all permeable voids. The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.5. Water absorption values ranges from 0.1 to about 2.0 percent for aggregates normally used in road surfacing.



Graph 1- comparison of plastic content aggregate and plain aggregate by specific gravity test.

Aggregate Impact Value Test [IS: 2386 (part 4) 1963]

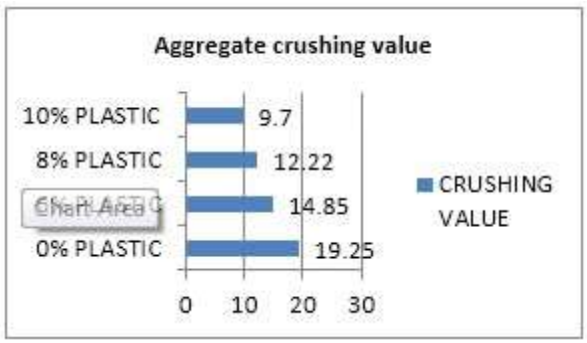
The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 numbers of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 number of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as percentage of aggregates passing sieve (W2) to the total weight of the sample (W1). Aggregates to be used for wearing course, the impact value shouldn't exceed 30 percent. For bituminous macadam the maximum permissible value is 35 percent. For Water bound macadam base courses the maximum permissible value defined by IRC is 40 percent. The coating of plastics improves Aggregate Impact Value, thus improving the quality of the aggregate. Moreover a poor quality of aggregate can be made useful by coating with polymers. It helps to improve the quality of flexible pavement. This shows that the toughness of the aggregate to face the impacts. Its range should be less than 10%.



Graph 2- comparison by impact value

Aggregate Crushing Value

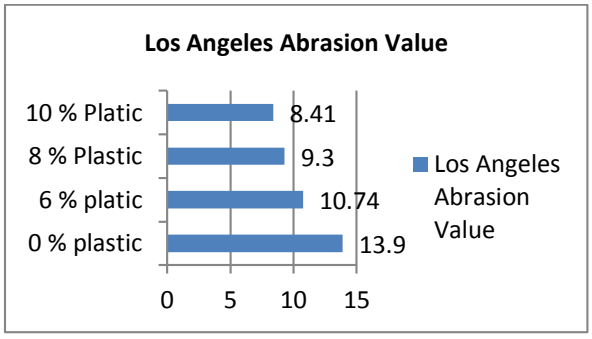
The aggregate with lower crushing value indicate a lower crushed fraction under load and would give a longer service life to the road. Weaker aggregate would get crushed under traffic load. It is clearly seen from Table- that plastic coated aggregates shows the lower crushing value and which can be withstand to traffic load more efficiently than the plain aggregates. The results show that the aggregates are within the range according to ISS. Its range should be less than 30-35.



Graph 3- comparison by crushing value on aggregate

Los Angeles Abrasion Value

The repeated movement of the vehicle will produce some wear and tear over the surface of pavement. This test gives that wear and tear in percentage. Under this study the percentage of wear and tear values of plastic coated aggregate is found to be in decreasing order with respect to the percentage of plastics. When the Los Angeles abrasion value of plain aggregate value is compared with the plastic coated aggregates the values are less for coated aggregates. The results obtained are within the range hence can be used for the construction. Its range should be less than 35%.



Graph 4- comparison by Los Angeles abrasion value on aggregate

TESTS FOR BITUMEN

1. 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

2. 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.

3. 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.

4. 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.

Test	Result	Ranges
Softening Point	49.80ºC	45º-600º C
Flash Point Test	285º	>180º C
Fire Point Test	307º	>180º C
Penetration value	62 mm	60-70 mm
Ductility Test	75.50	40 mm

Table – Results of test on bitumen

ECONOMY OF THE PROCESS

Based on the experimental evidences and the amount of raw materials used for 25mm Semi Dense Bituminous Concrete (SDBC- this top layer of the bituminous road. 10M2 SDBC road the following calculation has been arrived.

Material Needed	Plain bitumen process	Plastics coated aggregate (PCA)
80/100 Bitumen	5475 Kg	5037 Kg
Plastic waste		438 Kg
cost	Rs 284700	Rs 268494/-
Cost reduced	NIL	Rs 16206/-
Carbon Credit Achieved on avoiding burning of plastics		3.5 tonne
Total saving for project		3.5 lacs

Table – Economical consideration

Cost Bitumen Approx.: 52000/ton and Waste Plastic: Rs. 15000/tons for 1 km

I. Savings of bitumen = 438 kg
II. Use of Plastics waste – (438 kg) carry bags (0.438 ton)
III. Bitumen needed– 5037kg
IV. Plastics waste needed – 438 kg.

Three kilograms of bitumen were saved and three kilograms of waste plastics were used. The cost of bitumen is much higher than that of plastics and this process also helps to save the natural resources. There is no maintenance cost for a minimum period of five years. Hence the process is cheap and eco-friendly.

CONCLUSION

Plastic coating on aggregates is used for the better performance of roads. This helps to have a better binding of bitumen with plastic wasted coated aggregate due to increased bonding and increased area of contact between polymers and bitumen. The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in reducing rutting, raveling and there is no pothole formation. The roads can withstand heavy traffic and show better durability. Following are some points which are drawn from the study:

1. Aggregate Impact value of control specimen was 5.75%. It reduced to 4.91% for PP8 and 4.2% for PP10. Reduction in value was 22% for PP10. This shows that the toughness of the aggregate was increased to face the impacts.
2. Crushing Value was reduced from 19.25% to 12.25% and 9.70% for PP8 and PP10 respectively.Value reduced by 30% for PP8 and 50% for PP10.Low aggregate crushing value indicates strong aggregates, as the crushed fraction is low.
3. Specific Gravity of the aggregate increases from 2.45 or control specimen to 2.85 for PP8 and 3.35 for PP10 due to plastic coating.
4. Water Absorption is also reduced to nil for PP8 and PP10 from 1.7% for control specimen.
5. Los Angeles Abrasion Value of the control specimen was found to be 13.42%. Coating of polymer over aggregate for PP8 increased abrasion value by 19.97% and 29.88%for PP10. This indicates the hardness of the aggregate.

In brief, we can conclude that, using plastic waste in mix will help reduction in need of bitumen by around 8% to 10%, increase the strength and performance of road, avoid use of anti -stripping agent, avoid disposal of plastic waste by incineration and land filling and ultimately develop a technology, which is eco-friendly. Increased traffic conditions will and are reducing the life span of roads. Plastic roads are means of prevention and ultimately will be the cure. It will save millions of dollars in future and reduce the amount of resources used for construction.

REFERENCES

[1] Abdul Razzakh Abdul Jaleel Al-Essa, Mohammed Ali Mutar and Ammar Ali Hussein The Development of Durable Asphalt Pavement Using Modified Polymers and Resol as Reinforcing Materials" Iraqi Journal of Science,Vol.51,No.1,2010,PP.18-27.

[2] Afroz Sultana S K, K.S.B. Prasad "Utilization of Waste Plastic as a Strength Modifier in Surface Course of Flexible and Rigid Pavements" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Vol. 2, Issue 4, July-August 2012, pp.1185-1191.
[3] Amit Gawande , G. S. Zamre, V. C. Renge, G. R. Bharsakale and Saurabh Tayde, 2012 ," Utilization of Plastic waste in Asphalting of Roads", Journal of Engineering Research and Studies (JERS) /Vol. III/ Issue II/April-June, 2012/01-05.
[4] R Vasudevan., Nigam S.K., Velkennedy R., Ramalinga Chandra Sekar A. Sundarakannan B. "Utilization of Waste Polymers for Flexible Pavement and Easy Disposal of Waste Polymers", International Conference on Sustainable Solid Waste Management, 5 - 7, Chennai, India pp-105-111, 2007.
[5] Shiva Prasad K, Manjunath K. R, K. V R Prasad, " Study on Marshall Stability Properties of BC Mix Used In Road Construction by Adding Plastic waste Bottles", Journal of Mechanical and Civil Engineering, Volume 2, Issue 2 (Sep.-Oct. 2012), PP 12-23
[6] S.S.Verma. "Roads from Plastic Waste", The Indian Concrete Journal, p. 43-44. November 2008.
[7] S. Punith and A. Veeraraghavan, "Laboratory Fatigue Studies on Bituminous Concrete Mixed Utilizing Waster Shredded Plastic Modifier", Proceedings of 21st ARRB Transport Research (ARRB), Volume 38, Issue 5 (September 2010)
[8] Vasudevan R, "Tar Road with Plastics Waste –A Successful Experiment in Mumbai", Environmental information system (Envis) Indian Centre for Plastics in the Environment, Vol.3, pp 1-2, 2005
[9] www.cpcb.com
[10] www.irc.gov.in
[11] www.pmgsy.gov.in
[12] www.sciencedirect.com