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An Experimental studies on Waste plastic coated AggregateBitumen Matrix

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ABSTRACT

Waste plastic generation in India has increased many folds in last few decades, plastic generation is one big problem but its post processing that its disposal is even bigger. Plastic being cheap and durable remains people's first choice as compared to other materials that are used for packing, storing and other purposes but plastic being non – biodegradable remains in environment continues to be in it for thousands of years these plastics get incorporated in ecosystem and have adverse effect on human, animals, plants and other species. Many types and forms of plastic pollution exists, plastic pollution adversely affects lands, waterways and oceans. Therefore it is necessary to utilize the waste effectively with technical development in different fields, many by products are being produces in each field. Our work on above mentioned topic is also an alternative method for effectively utilizing waste plastic in coating of aggregates that are to be used for pavement construction aimed towards improving the properties of aggregates and pavement characteristics and also on other hand seek possibility of utilizing lower quality of aggregate in construction of bitumen pavement wherever there is unavailability of good quality of aggregate. Our work will discuss in details the process and application.

Keyword:Non – biodegradable; bitumen pavement; aggregates; plastic pollution; ecosystem.

I.INTRODUCTION

A material that contains one or more organic polymers of large molecular weight, solid in its finished state and at some state while manufacturing or processing into finished articles, can be shaped by its flow, is called as 'Plastic'. Plastics are durable and degrade very slowly; the chemical bonds that make plastic so durable make it equally resistant to natural processes of degradation. Plastics can be divided into two major categories: Thermoset and Thermoplastics. A thermoset solidifies or ''sets'' irreversibly when heated. They are useful for their durability and strength, and are therefore used primarily in automobiles and construction applications. These plastics are polyethylene, polypropylene, polyamide, polyoxymethylene, terephthalate. A thermoplastic

softens when exposed to heat and returns to original condition at room temperature.According to recent studies, plastics can stay unchanged for as long as 4500 years on earth with increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. Plastic in different forms is found to be almost 5% in municipal solid, 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 can be reused productively. The experimentation at several institutes indicated that the 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 timeUse of plastics along with the bitumen in construction of roads not only increases its life and smoothness but also make it economically sound and environment friendly.Plastic waste is used as modifier of bitumen to improve some of bitumen properties roads that are constructed using plastic waste are known as Plastic Roads and are found to perform better compared to those constructed with conventional bitumen. Further it has been found that such roads were not subjected to stripping when come in contact with water. Use of higher percentage of plastic waste reduces the need of bitumen by 10%, thereby saves approximately Rs.35000 to Rs.45000 per kilometer of a road stretch.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 tensile strength satisfied the specified limits while plastic waste content is beyond 30% by weight of mix. If the consistent mixing time and mixing temperature are not provided for bitumen-modifier mix, modified bitumen cannot exhibit good performance in situ, thus premature failures will occur. Therefore, there are certain recommended mixing time, mixing temperature and modifier content for all the polymers with trademark. This all should be taken in mind while mixing 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.

1.1 Plastic Scenario

Plastics waste scenario in the world, of the various waste materials, plastics and municipal solid waste are great concern. Finding proper use for the disposed plastics waste is the need of the hour. On the other side, the road traffic is increasing, hence the need to increase the load bearing capacities of the the roads. The use of plastics (be consistent in the use of polymer or plastic, since the focus is on plastic waste) coated aggregate for asphalt pavement allows the reuse of plastics waste. Plastics, are versatile packing materials and commonly used by man but they become problem to the environment. The mostly used plastics products are bags, cups, films and foams, made up of polyethylene, polypropylene or polystyrene. In India consumption of plastic will grow 15 million tonnes by 2015 and is set to be the third largest consumer of plastic. They are mostly dropped and left to litter the environment, after the contents have been consumed. The littered plastics, a non-biodegradable

material, get mixed with domestic waste and make the disposal of municipal solid waste difficult. The municipal solid waste is either incinerated or land filled. Both disposal methods are not the best ways to dispose the waste as it causes both land and air pollution. Disposal of plastic wastes in an eco-friendly way is the main thrust area of today's research works. The technique to use the waste plastics for the construction of asphalt pavement is eco-friendly and can promote value addition to the waste plastic.

1.2Data related to waste plastic consumption in India

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 plastic. The plastic constitutes two major category of plastics; i) Thermoplastics and (ii) Thermoset plastics. The thermoplastics, constitutes 80% and thermoset constitutes approximately 20% of total post-consumer plastic waste generated. The following table 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

Population Range(Millions)	Average per Capita value
0.1 – 0.5	0.21
0.5 – 1	0.25
1 – 2	0.27
2 – 5	0.35
>5	0.50

1.3Plastic Waste Classification

Most of thermoplastics on heating soften at temperature between 130-140°C. The TGA analysis of thermoplastics has proven that there is no gas evolution in the temperature range of 130-180°C and beyond 180°C gas evolution and thermal degradation may occur. Thus the waste plastic can easily be blended with the bitumen as the process for road construction using bitumen is carried out in the range of 155-165°C.

Table 2 Waste plastic and its source

Type of waste plastic(polymer)	Characteristics	Sources
High density polyethylene (HDPE)	Tough, flexible, translucent	Beverage, bottles, pipes, cable, film, milk, bags
Low density polyethylene(LDPE)	Moisture proof, inert	Trash bags, coatings, plastic bottles
Polyethylene terephthalate(PET)	Tough, shatter resistant, gas permeation resistant	Soft drink, detergent and drink bottles
Polypropylene	Stiff, heat and chemical resistant	Battery cases, screw on caps, food tubes
Polystyrene(PS)	Brittle, clear, rigid, good thermal properties	House wares, electronics, fast food packaging, food utensils

Poly vinyl chloride(PVC)	Strong, clear, brittle unless treated with plasticizers	Sport goods, luggage, pipes, auto parts, miscellaneous

Plastics can be classified in many ways, but most commonly by their physical properties. Plastics may be classified also according to their chemical sources. The twenty or more known basic types fall into four general groups: Cellulose Plastics, Synthetic Resin Plastics, Protein Plastics, Natural Resins, Elastomers and Fibres. But depending on their physical properties, may be classified as thermoplastic and thermosetting materials. Thermoplastic materials can be formed into desired shapes under heat and pressure and become solids on cooling. If they are subjected to the same conditions of heat and pressure, they can be remoulded. Thermosetting materials which once shaped cannot be softened/remoulded by the application of heat.

II.MATERIAL

2.1Aggregate test and analysis

The aggregates used for testing were locally available and to carry out tests, these were washed under jet of water to remove dust and fine particles and they were oven dried for 24 hrs.for the purpose of setting standard results. Following Tests were conducted to investigate the properties of the aggregate:

1. Aggregate Impact Test
2. Los Angeles Abrasion Test
3. Aggregate Crushing Value
4. Water Absorption and Specific Gravity
5. Flakiness & Elongation Index (shape test) of aggregate.

Table 3 Results of test performed on plain aggregate

S.No	Test	Result	Remarks
1.	Aggregate impact test	18.16%	Satisfactory
2.	Los angel's abrasion value	15.58%	
3.	Aggregate crushing value	21.51%	
4.	Water absorption	1.5%	
5.	Specific gravity	2.7	
6.	Elongation index	16.3%	
7.	Flakiness index	20.5%	

2.2 Bitumen

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark colored solid or viscous cementations substances consists chiefly

high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide.

Bitumen is the residue or by-product when the crude petroleum is refined. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties.

2.2.1 Requirements of Bitumen

The desirable properties of bitumen depend on the mix type and construction. In general, Bitumen should possess following desirable properties.

- The bitumen should not be highly temperature susceptible: during the hottest weather the mix should not become too soft or unstable, and during cold weather the mix should not become too brittle causing cracks.
- Theviscosity of the bitumen at the time of mixing and compaction should be adequate. This can be achieved by use of cutbacks or emulsions of suitable grades or by heating the bitumen and aggregates prior to mixing.
- There should be adequate affinity and adhesion between the bitumen and aggregates used in the mix.

2.2.2 Tests on Bitumen

There are a number of tests to assess the properties of bituminous materials. The following tests are usually conducted to evaluate different properties of bituminous materials.

1. Penetration test IS: 1203-1978.
2. Ductility test IS: 1208-1978.
3. Softening point test IS: 1205-1978.
4. Specific gravity test IS: 1202-1978.
5. Viscosity test IS: 1206-1978.
6. Flash and Fire point test IS: 1209-1978.
7. Float test IS: 1210-1978.
8. Water content test IS: 1211-1978.
9. Loss on heating test IS: 1212-1978.

Table 4 Results of test performed on bitumen

S.No	Test	Result	Remarks
1.	Penetration test	26	Satisfactory
2.	Ductility test	24 cm	
3.	Softening point test	56°C	

4.	Specific gravity test	0.99	
5.	Flash and fire point test	180°C, 210°C	

III.METHODOLOGY

There are two important processes namely dry process and wet process used for bitumen mix flexible pavement.

3.1Dry 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 viscous elastic 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.

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.

Disadvantages of Dry Process -:

- The process is applicable to plastic waste material only.

3.2 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 stirrer is required.
- Additional cooling is required as improper addition of bitumen may cause air pockets.
- Maximum % of waste plastic can be added around 8%.

3.3 Methodology Used

The methodology that is used in our project is similar to dry process but on smaller scale not the one in central mixing plant. In the phase of our project we performed different sets of experiments to assess the properties of coarse aggregates by coating the aggregates at different percentage of plastic(% by weight) at various sets of experiments were conducted like abrasion value test, crushing value test, impact value test, flakiness and elongation index, specific gravity and bulk modulus ,water absorption . The coating of aggregates was carried out in laboratory and different sets of aggregates were coated at 1%, 1.3%, 1.5%, 1.8%and 2% (% by weight). The plastic used for coating was basically in shredded form in size range varied from 4.75mm-10mm. The size used was different than the size already used in previous researches which were of range 1.18rnm-2.36mm. The coating of aggregate with plastic was carried out in open pan at controlled temperature around 165-175 °C. The aggregates were heated to this temperature and then the shredded plastic was sprayed in controlled manner (temp. Controlled) to make sure that plastic don't get segregated as the size of the plastic used was not as fine as used previously, the mixing time was around 5 minutes /kg to coat the aggregate effectively to get desired glossy look and then the aggregates were air dried and different tests were performed of aggregates coated at different percentage. The step wise detailed process is shown below:

Step 1 – Washing of aggregates in bulk to remove all the dirt and fines and then dry at temperature around 100°C.

Step 2 – The required quantity was taken that is 1kg each time in pan and then put on heart to heat around 165-170°C.

Step 3 – The shredded plastic were then sprayed on heated aggregates to get the coating done over the aggregates.

Figure 1 Heating of aggregates and shredded plastic

Step 4 – The coated aggregates were air dried.

Figure 2 Plastic coated aggregates

Step 5 – Different tests such as impact value test, crushing value test, losAngeles abrasion test, specific gravity bulk density, flakiness and elongation index and water absorption were carried out.

Step 6 – Results were analyzed and compared with that of plain aggregates.

Step 7 – MarshallTest were conducted using plain aggregate and with plastic coated aggregate and analyzed, process used was dry method.

IV.RESULT AND ANALYSIS

The result of the experiments iscompiled below -:

Table 5 result of different test at different % plastic coating

S.No	% plastic coating	Aggregate impact test (%)	Los angel's abrasion value (%)	Aggregate crushing value (%)	Water absorption (%)	Elongation index (%)	Flakiness index (%)	Specific gravity
1.	1%	12.54	12.02	15.59	0.8	16.3	20.5	2.74
2.	1.3%	11.43	11.21	15.53	0.7	16.3	20.5	2.76
3.	1.5%	10.44	11	15.49	0.5	16.3	20.5	2.78
4.	1.8%	8.95	10.12	15.47	0.2	16.3	20.5	2.81
5.	2.0%	7.55	9.05	15.53	0.1	16.3	20.5	2.82

4.1 Marshall Mix Design

The Marshall Stability and flow test provides the performance prediction measure for the Marshall Mix Design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow(deformation) due to loading. The flow value is recorded in 0.25mm (0.01inch) increments at the same time when the maximum load is recorded.

Table 6 Result of Marshall Test on plain aggregate

S. No	% Bitumen Content	G_m	G_t	V_v	V_b	VMA	VMA	Stability(kg)	Flow value(mm)
1.	4.5	2.38	2.51	5.1	10.39	15.49	67.07	990	3.2
2.	4.5	2.39	2.51	4.8	10.39	15.19	68.40	998	3.3
3.	5.0	2.40	2.50	40	11.59	15.59	74.34	1180	3.5
4.	5.0	2.41	2.50	3.6	11.59	15.19	76.30	1184	3.4
5.	5.5	2.39	2.47	3.2	12.58	15.78	79.72	1002	3.6
6.	5.5	2.38	2.47	3.6	12.58	16.18	77.75	994	3.7
7.	6.0	2.39	2.46	2.8	13.66	16.46	82.98	975	4.0
8.	6.0	2.38	2.46	3.2	13.66	16.86	81.02	984	3.8

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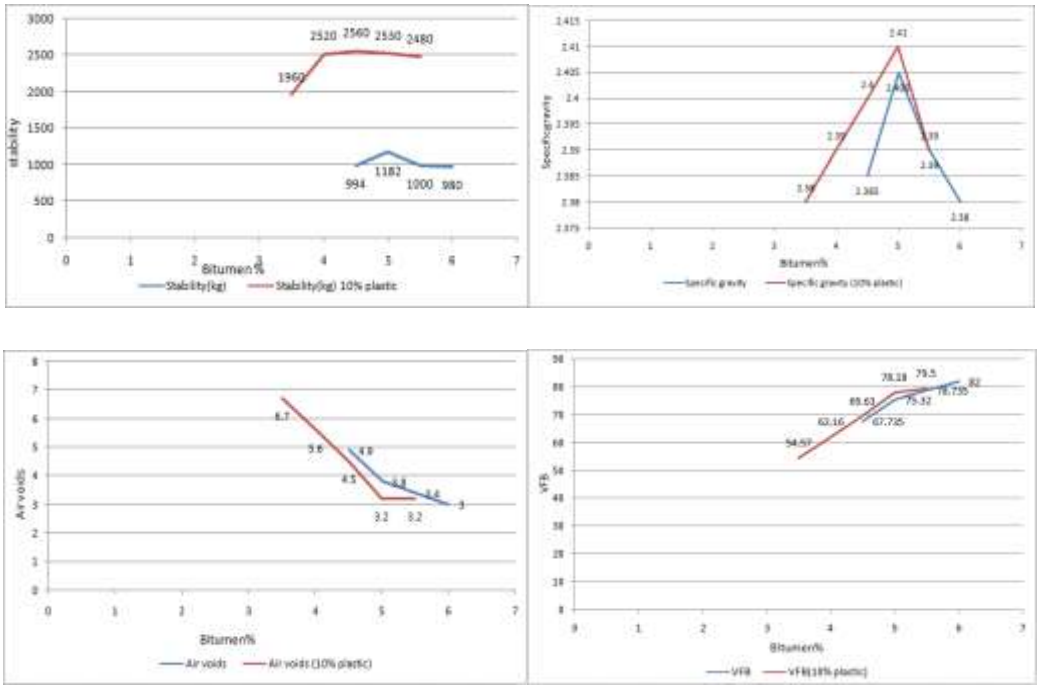
Table 7 Marshall Test on plastic waste coated aggregate (varying bitumen at 10% plastic) observations

S.No	% Bitumen content	G_m	G_t	V_v	V_b	VMA	VFB	Stability(kg)	Flow value(mm)
1.	3.5	2.38	2.55	6.7	8.05	14.75	54.57	1960	4.1
2.	4.0	2.39	2.53	5.6	9.20	14.80	62.16	2520	4.51
3.	4.5	2.40	2.51	4.5	10.33	14.83	69.63	2560	4.83
4.	5.0	2.41	2.49	3.2	11.47	14.67	78.18	2530	4.70
5.	5.5	2.39	2.47	3.2	12.45	15.65	79.50	2480	4.85

Where, G_m = Bulk specific gravity, G_t = Theoretical specific gravity, V_v = Percentage air voids, V_b = Percent volume of bitumen, VMA = Void in mineral aggregate, VFB = Voids filled with bitumen.

Graphical representation of Marshall Test -:



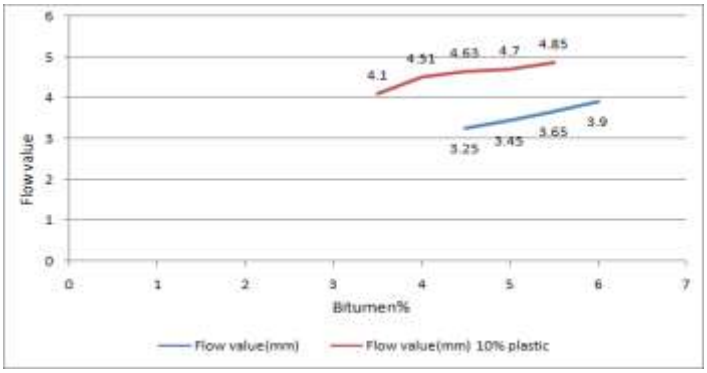


Figure 6 Graphical representation of Marshall Test

V.CONCLUSIONS

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. Thepolymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in reducing rutting, ravelling 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 18.16%. It reduced to 12.54% for 1.0% coating , 11.43% for 1.3%,10.44% for 1.5% coating, 8.95% for 1.8%and 7.55% at 2% coating .The average impact value significantly decreased as the coating percent was increased. This shows there is increase in toughness property of aggregates.
2. Crushing Value of control specimen was 21.51%. At 1%, 1.3%, 1.5%, 1.8% and 2% coating crushing value is 15.59%, 15.53%, 15.49%, 15.47%and 15.53% respectively. Low aggregate crushing value indicates strong aggregates, as the crushed fraction is low. Results showed that there is not much change in value on changing the percentage of coating.
3. Los angles abrasion value reduced from 15.58% for control sample to 12.02%,11.21%,11.0%,10.12% and 9.05% at 1% ,1.3%,1.5%.1.8%,2.0% respectively. This shows increases in the hardness property of the aggregates.
4. Water absorption values showed significant decrease in the porosity after the coating of aggregates the values decreased from 1.5% to 0.8%, 0.7%,0.5%,0.2%,0.1% at 1% ,13%,1.5%.1.8%,2.0% respectively. This shows thatpotholes problems that is due to stripping off of bitumen may be reduced up to certain extent.
5. Specific Gravity of the aggregate increases from 2.70 for control specimen to 2.74,2.76,2.78,2.81,2.82 for 1 %, 1.3%, 1.5%, 1.8% and 2%plastic coating respectively. This shows in denseness of aggregate mix.

5.1 Marshall Test observations

1. It is observed that the Marshall Stability values obtained were generally much higher than Marshall Stability value obtained for bitumen pure mix.
2. From our Experimental results it is observed that the addition of lowerpercentage of bitumen with plastic waste coated aggregate shows much higher Marshall Stability value. It is also observed that the addition of plastic reduces the quantity of bitumen needed for an effective mix composition. It is also observed that voids filled with bitumen were also increased and air voids reduced.
3. On keeping the percentage of bitumen as 4.5 % , the quantity of plastics waste coated over the varied and the Marshall Stability values were determined for different samples The experimental results suggests that the minimum quantity of bitumen for an effective mix may be reduced if polymer coated aggregate is used. The reduction depends on the amount of plastics waste used for coating.

5.2Theoretical Explanation

The shredded plastics on spraying over the hot aggregate melted and spread over the aggregate giving a thin coating at the surface. When the aggregate temperature is around 1400 C to 160°C the coated plastics remains in the softened state. Over this, hot bitumen (160°C) is added. The added bitumen spreads over the aggregate. At this temperature both the coated plastics and bitumen are in the liquid state, capable of easy diffusion at the inter phase. This process is further helped by the increase in the contact area (increased surface area). These observations may be explained as, waste polymers namely PE, PP, PS are hydrocarbons with long chains. The bitumen is a complex mixture of asphaltenes and maltenes which are also long chain hydrocarbon.When bitumen was mixed with plastic coated aggregate. The plastic layer has already bonded strongly with aggregate. During this process three dimensional internal cross linked network structure results between polymer molecules and bitumen constitutes. Therefore the bond becomes stronger and the removal of bonded bitumen becomes difficult. The results of the studies of the various experiments by dry process showed that the bonding between stone aggregate and bitumen is improved due to the presence of polymers.

REFERENCES

[1] D. R. Vasudevan and D. S. Paulraj, "Reuse of Waste Plastics Coated Aggregates-Bitumen Mix," American Journal of Engineering Research (AJER), vol. 02, no. 11,p. 13, 2013.

[2] M. v. Swami, A. Jirge, K. patil , S. patil and K. salokhe, "Use of waste plastic in construction of bituminous road," International Journal of Engineering Science and Technology(IJEST), vol. 4, no. 5, p. 5, 2012.

[3] J.M. Mauskar, "Performance Evaluation of Polymer Coated Bitumen Built Roads," Central Pollution Control Board. New Delhi,2009.

[4] M. A. J. Chavan, "Use of Plastic Waste In Flexible pavement," International Journal Of Application or Innovation in Engineering & Management, vol. 2, no. 4, p. 13, 2013.

[5] D. A. S. Wayal and M. D. Wagle, "Use of Waste Plastic and Waste Rubber in Aggregate and Bitumen for Road Materials," International Journal of Emerging Technology and Advanced Engineering, vol. 3, no. 7, p. 6, 2013.

[6] R. devi, L. Stephen and M. M I, "Reduction of optimum bitumen content in bituminous mixes using plastic coated aggregates," International Journal of Innovative Research in Science. Engineering and Technology, vol. 2, no. 3, p. 8, 2013.

[7] A. Gawande, G. Zamre and V. C. Renge, "Utilization of waste plastic in ashphalting of of roads," Scientific Reviews and Chemical Communications, p. 1 I, 10 may 2012.

[8] R, Vasudevan, "Methods For Construction OfFlexible Pavements Using Plastics,"International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2 no. 4, p. 22, 2011.