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Reuse of Waste Plastics Coated Aggregates-Bitumen Mix Composite For Road Application – Green Method

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Abstract: - Waste plastics both by domestic and industrial sectors can be used in the production of asphalt mix. Waste plastics, mainly used for packing are made up of Polyethylene Polypropylene polystyrene. Their softening varies between 110°C – 140°C and they do not produce any toxic gases during heating but the softened plastics have tendency to form a film like structure over the aggregate, when it is sprayed over the hot aggregate at 160°C. The Plastics Coated Aggregates (PCA) is a better raw material for the construction of flexible pavement. PCA was then mixed with hot bitumen of different types and the mixes were used for road construction. PCA - Bitumen mix showed improved binding property and less wetting property. The sample showed higher Marshall Stability value in the range of 18-20KN and the load bearing capacity of the road is increased by 100%. The roads laid since 2002 using PCA-Bitumen mixes are performing well. A detailed study on the performances of these roads shows that the constructed with PCA –Bitumen mix are performing well. This process is eco-friendly and economical too.

Abbreviations:

1. PE: Poly Ethylene
2. PS: Poly Styrene
3. PP: Poly Propylene
4. PCA: Polymer-Coated Aggregate/ Plastic Coated Aggregate
5. PVC: Poly Vinyl Chloride
6. IRC: Indian Road Congress
7. ASTM: American Society for Testing and Materials
8. PET: Poly ethylene Terephthalate
9. DTA: Differential Thermal Analysis
10. TGA: Thermo Gravimetric Analysis
11. AC: Asphalt Concrete
12. EVA: Ethylene Vinyl Acetate
13. SBS: Styrene Butadiene Styrene
14. LAR: Los Angeles Abrasion Value
15. TCE: Tri Chloro Ethylene
16. AIV: Aggregate Impact Value
17. ACT: Aggregate Crushing Test
18. PMB: Polymer-Modified Bitumen
19. LDPE: Low Density Polyethylene
20. MSV: Marshall Stability Value
21. FV: Flow Value
22. MQ: Marshall Quotient
23. IS: Indian Standards
24. BS: British Standards
25. DRDA: Department of Rural Development Agency
26. SDBC: Semi Dense Bituminous Concrete
27. Bitumen Types: Pen Grade 80/100 and 60/70

Key Words: Waste Plastics, Plastic Coated Aggregate, Bitumen, Plastic Tar road, Roads, Monitoring

I. INTRODUCTION

1.1. PLASTIC WASTE 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 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. After using them mostly used plastics products are bags, cups, films and foams, made up of polyethylene, polypropylene or polystyrene. India

consumption of Plastics will grow 15 million tonnes by 2015* and is set to be the third largest consumer of plastics in the world. Around 55% is being used for packing. 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 and it causes both land and air pollution [1, 2, 3]. Moreover, if municipal solid waste, contains PVC waste, when burnt, it produces toxic gases like dioxins[1]. Disposal of plastic wastes in an eco friendly way is the main thrust area of today's research works. The author has developed innovative [4] technique to use the waste plastics for the construction of asphalt pavement. This process is eco friendly and can promote value addition to the waste plastic.
* Plastindia 8th International plastics Exhibition & Conference Feb. 1-6 , 2012, New Delhi.

1.2. LITERATURE REVIEW

In the construction of asphalt pavement, hot bitumen is coated over hot stone aggregate mixed, laid and rolled. Bitumen acts as a binder. Yet when water is stagnated over road, it penetrates and results in pot holes, a defective spot on the pavement. The use of anti stripping agents are having limited use only and the process also increases the cost of road construction[5]. Use of plastic (virgin as well as waste) to modify the bitumen and also the use of plastic coated aggregates are being studied to improve performance of the pavement.
Bituminous mixes used in the surface course of the bituminous pavements are being improved in their performance by incorporating various types of additives to bitumen such as rubber latex, crumb rubber, styrene, butadiene styrene, styrene – ethylene –butylenes, recycled Polypropylene ,low density polyethylene [6] Polyethylene [7], Ethylene vinyl acetate (EVA) (5%) [8] and polyolefin [9, 10]. Some of the properties improved are durability, fatigue life [12, 13], resistance to rutting, softening point, visco elastic property [11], etc.
The major obstacle to widespread usage of polymer modified bitumen in paving practice has been their tendency towards gross phase separation under quiescent conditions [16].

2.0. Present Study:

Plastics waste like PE, PP and PS is coated over stone aggregates and the PCA was mixed with bitumen and the mix was used for flexible pavement construction. Higher percentage of plastic waste (10-15%) can be used without separation. Detailed studies are going on this direction [17&4]. Various tests were carried out to find the characterization of the following.
1. Different waste plastics used for coating over the aggregates
2. Plastics coated aggregate
3. Plastics coated aggregate mix with bitumen
4. Plastics coated bituminous road scrap

All the tests were carried out using standard procedures

2.1.0 CHARACTERIZATION OF WASTE PLASTICS
2.1.1. THERMAL CHARACTERISTICS

The thermal behavior of the polymers namely Polyethylene, Polypropylene and Polystyrene was studied using Thermo Gravimetry Analyzer TGA-50 and Differential Scanning Calorimeter DSC-60 to find out the decomposition temperature and the softening point of the polymers (Table-1& Fig.1).

II. PHYSICAL PROPERTIES

Most of the packing materials* used are made up of PE, PP, PS. These materials were characterized for their thickness, solubility and softening temperature (Table -2). All these materials can be shredded and used for road construction.

Common food packaging plastics and their uses: Table- 2a

Full name	Abbreviation	Examples of use
High density polyethylene	HDPE	Bottles and films
Linear low density Polyethylene	LLDPE	Film
Low density polyethylene	LDPE	Film
Polypropylene	PP	Containers, film
Polyvinylchloride	PVC	Blister packs and bottles
Polyethylene terephthalate	PET	Bottles for soft drinks, films etc.
Polysyrene	PS	Pots , thermo -Cole, trays, toys etc.

*Introduction to Plastics Science Teaching Resources. American Chemistry Council, Inc. Retrieved 24 December 2012.

2.1. CHARACTERISTICS OF PLASTIC COATED AGGREGATE

For the asphalt pavement, stone aggregate with specific characteristics is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity. The aggregate was coated with waste plastic material by the following process. The waste plastics namely films, cups and foams shredded to the required size of 2.5mm – 4.36mm. The aggregate is heated to 170^{o}C. The shredded waste plastic was sprayed over the hot aggregate. Plastics got softened and coated over the aggregate. The extent of coating was varied by using different percentage of plastics. Higher percentage of plastics was used up to 25% to evaluate the binding property, whereas lower percentage of plastics like 1% to 5% to evaluate the properties like moisture absorption and soundness.

2.2.0. BINDING PROPERTIES

The hot plastics coated aggregates was compacted into a block using compacting machine operated hydraulically and cooled. Then the block was subjected to a compressive test using universal testing machine. (Table -3)

2.2.1. MOISTURE ABSORPTION AASHTO T 96 (2001)**:**

A known quantity of plastics coated aggregate was taken. It was then immersed in water for 24hrs. Then the aggregate was dried using dry clothes and the weight was determined. The water absorbed by the aggregate was determined from the weight difference. The test was repeated with plain aggregate for comparison of results. Table-4.

2.2.2. SOUNDNESS TEST AASHTO T 96 (2001)

Soundness is mainly to test the stability towards weathering of the aggregates and its chemical resistance. The plain aggregate when exposed to stagnation of water, the water penetrates easily inside the pores of the aggregates. Since the water contains dissolved salts, the salt gets crystallized and expands inside the pores during evaporation resulting in the breaking of the aggregates. The low soundness property directly depends upon the amount of voids and porosity of the aggregates . This is evaluated by conducting accelerated weathering test cycle. The average loss in weight of aggregate for 5 cycles should not exceed 12 % when tested with sodium sulphate. The plain aggregates and PCA were subjected to this test and the results are tabulated in Table-4 for comparison.

2.2.3. AGGREGATE IMPACT TEST(AASHTO T 96 (2001))

It is used to evaluate the toughness of stone or the resistance of the aggregate to fracture under repeated impacts. The aggregates were subjected to 15 blows with a hammer of weight 14kg and the crushed aggregates were sieved on 2.26mm sieve. The aggregate impact value is the percentage of fine (passing through the 2.36mm sieve size) to the total weight of the sample. The aggregate impact value should not exceed 30% for use in wearing course of pavements. Maximum permissible values are 35% for bituminous macadam and 40 % for water bound macadam. The plastic coated aggregates were subjected to this test and the results are tabulated in Table-4.

2.2.4. LOS ANGELES ABRASION TEST AASHTO T 96 (2001)

The principle of Los Angeles abrasion (L.A.R) test is to find the percentage wear due to relative rubbing action between the aggregate and the steel balls used as abrasive. LAR value should be less than 30% for pavements. For the L.A. abrasion test, the portion of a plastics coated aggregate sample retained on the 1.70 mm (No. 12) sieve was placed in a large rotating drum that contains a shelf plate attached to the outer wall. A specified number of steel spheres were then placed in the machine and the drum was rotated for 500 revolutions at a speed of 30 - 33 revolutions per minute (rpm). The material was then extracted and separated into material passing the 1.70 mm (No. 12) sieve and material retained on the 1.70 mm (No. 12) sieve. The retained material (larger particles) was then weighed and compared to the original sample weight. The difference in weight was reported as a percent of the original weight and called the percentage loss. LAR value should be less than 30 percent for pavements. The results are tabulated in Table-4.

2.3. CHARACTERISTICS OF "PCA-BITUMEN MIX"

The hot plastic coated aggregate was mixed with 80/100 bitumen at 160^{0}C. The bitumen polymer coated aggregate mix was subjected to tests like Stripping test, Bitumen extraction test and Marshall Value determination test

2.3.1. STRIPPING (IS: 6241-1971)

Stripping value is the determination of binding strength of the aggregate and the bitumen. It is tested by immersing bitumen coated aggregate in water for 24hrs at 40^0C. When bitumen coated aggregate was immersed in water, the water penetrates into the pore and voids of the stone resulting in the peeling of the bitumen. This in turn results in the loosening of the aggregate and forming potholes. 200gm of PCA- bitumen mix was taken and cooled to room temperature and weighed. The mixture was immersed in water bath maintained at 40^0C for 24hrs. After 24hrs the stripping was observed and the percentage of stripping was noted and the results are tabulated in Table -5

2.3.2. BITUMEN EXTRACTION TEST ASTM D2172

The extraction tests were carried out in the following order.

1. Bitumen coated aggregate was treated with TCE and the bitumen was extracted. Here the extraction was almost complete
2. PCA bitumen mix was first treated with TCE and the bitumen extracted was separated and estimated. Complete removal of bitumen did not take place
3. So further extraction was carried out using another solvent, namely decaline, which can act as a solvent to extract plastics also.
4. The PCA bitumen mix obtained from step 2 is then treated with decaline for another 30 minutes and separated bitumen was estimated.
5. The extraction was again repeated after refluxing the mix for 5 minutes. Further separation took place.

The process was repeated using aggregate, coated with different percentage of plastics. The results are tabulated (Table-6).

2.3.3. MARSHALL STABILITY ASTM: D 1559 - 1979

Marshall Stability value is the basic study on the stability of the mix with application of load. The standard mixture was prepared in accordance with IRC specifications . The aggregates were coated with plastics waste as described earlier. This plastics coated aggregates mix was then mixed with 5% of total quantity of 80/100 bitumen. The mixture was transferred to the mould. It was compacted with 75 blows on either side. The specimens (64 mm height and 10.2 mm diameter) were prepared by 1. Varying the percentage of plastics waste and 2. by varying bitumen quantity. These specimens were tested. The voids present in the mix also play an important role in deciding the performance of the mix. The following properties were determined: Voids filled with Mineral Aggregate, Air Voids, Voids filled with bitumen, Bulk Density, Specific Gravity and Voids in Mix. The results are reported in the Table-8.

Marshal Stability Value is indicative of load withstanding property of the flexible pavement. The minimum value is fixed as 4KN by IRC with 5% of bitumen and 95% of stone aggregate Table (7 &8).

III. DISCUSSION OF RESULTS WASTE PLASTICS CHARACTERIZATION

3.1. THERMAL ANALYSIS

The results obtained from the thermal analysis using DSC and TGA (Table-1) show that polymers namely PE, PP and PS softened easily around 130 – 140 Deg C without any evolution of gas and around 270 deg. C. They decomposed, releasing gases like methane, ethane etc. and above 700 Deg.C. They undergo combustion, producing gases like CO and CO_2. Hence it is safe to use molten waste plastics below 100-150^0C. This is supported by TGA and DSC graphs shown in Figure1. (Table.1)

3.2. Binding Property

The aggregate coated with higher percentage of plastics was compacted into a block and compacted blocks showed a compressive strength not less than 12 N/mm^2. This shows that the molten plastics have a good adhesion property. The increase in the values of the compression strength and bending strength show that the plastics can be used as a binder. Moreover the strength increases with the increase in the percentage of plastics used for coating. It is also depended on the types of plastics used like PE, PP and PS (Table-2a). The following is the increasing order of strength of block produced PS<PE<PP<Laminated films<BOPP. This order is in agreement of the chemical nature of the above polymers[1] Table- 3.

3.3. Aggregate characterization:

It was found that there is significant improvement in the strength properties of the aggregates change to coated with molten plastics. This is due to the fact that when the plastic was coated over the aggregate, the aggregate surface is covered with the thin film of polymer. The film of polymer also fills the pores at the surface and there is no water absorption. Hence there is significant improvement in the general properties of the aggregate like soundness, abrasion resistance, etc., Moreover, the PCA mixed with bitumen shows better stripping property.

- **Soundness:** Plastics coated aggregate showed no value for soundness. This can be explained as follows. The coating of plastics fills the pores and voids present at the surface of the aggregate. There is no penetration of water and there is no salt deposition. Hence there was no disintegration. (Table-4).
- In **Los Angeles Abrasion,** the hardness of aggregate is measured. Plastics coated aggregates show better resistance to higher wear and tear load (Table-4). The resistance increases with the increase of coating thickness of the plastics coated. This is because coating of polymers over aggregate gives better adhesion over the surface particles. It reduces the roughness of the aggregate and thus resulting in the reduction of abrasion over the surface of aggregate.
- **Impact value**. The brittleness of the aggregate is measured as Impact value. Coating of waste polymers over the aggregate reduces the voids and the air cavities present in the aggregates (Table-4). The film formed helps in preventing the cracking The toughness of the stones is also increased. Hence, the impact value of the plastics coated aggregate is lower when compared with the plain aggregate.

IV. PLASTIC COATED AGGREGATE - BITUMEN MIX CHARACTERIZATION

3.4. Extraction Characteristics:

The experimental results of extraction of bitumen (Table- 6) from the PCA - bitumen mix clearly show explain the bonding nature of the mixture. It was observed that the TCE could remove bitumen almost from the plain bitumen coated aggregates , whereas in the PCA- bitumen mix the removal of the bitumen by TCE was a slow process and not all the bitumen was removed. The TCE cannot remove completely all the bitumen from PCA- bitumen mix. Decaline, an organic solvent remove both bitumen and plastic on further treatment. Complete removal is possible only by refluxing the PCA -bitumen mix with decaline for more than 30 minutes.

The following observations were made from the results of extraction test. In the case of PCA bitumen mix, TCE removed only loosely bonded bitumen. It could not remove the bitumen bonded with the aggregate through the plastics. Decaline (being a solvent to plastic) could remove the bonded bitumen further. Only after refluxing was complete removal of Bitumen and plastic achieved. Moreover, when the percentage of coating of plastics was more, the extent of bitumen removal was correspondingly less. This observation helps to conclude the bonding of bitumen over plastic coated aggregate is strong.

3.5. Stripping Value:

In the case of polymer coated aggregates (Table-4), the surface is covered by the polymer film and there are no pores. The molten polymer not only fills the voids of the aggregate and binds the aggregate together but also strongly binds with bitumen forming an organic bonding. Water cannot penetrate over polymer coated aggregate, hence peeling out of bitumen from the PCA was zero even after 96 hours (Table-5), thus having better stripping value.

3.6. Marshall Stability Value:

Marshall Stability Value (kN), Flow Value (mm) and Marshall quotient (kN/mm) were obtained for plain aggregate bituminous mixes and polymer coated aggregate bituminous mixes of varied compositions.(Table 7&8)

For an effective asphalt pavement, the flow values should be in the range 2-5 and the ratio of MSV and FV (referred to as Marshall Quotient) should not not more than 500. The results obtained for the PCA are within this range. Voids filled with bitumen (VFB) are expected to be around 65%. The observed value is around 58%. The reduction is attributed to the reduction in the use of percentage of bitumen (90%) and the reduction in voids. The data (Table 7 & 8) also suggest that with the use of plastics waste coated aggregate, the quantity of bitumen needed for a good mix can be reduced by 0.5% of the total weight. This accounts for 10% reduction in the quantity of bitumen needed to be used. It is a good saving of natural resource.

The following observations are made

- The use of PCA increases the MSV of the mix
- As the percentage of the waste plastics coated increases the MSV is also increased
- Higher percentage of plastics (more than 15%) results in lesser compatibility with bitumen and lesser bonding resulting in lower MSV.
- The use of PP gives higher MSV value than PE
- The foams of PP and PE also gives better MSV results
- The waste plastics available as foams or films can also be used
- The use of optimum percentage of plastics was arrived using mathematical modelling and it is found to be 10% of bitumen used.

- The flow value and the voids filled with bitumen are within the tolerance value
- The MSV of PCA - bitumen mix is compared with PMB mix. It was observed that the values of the PCA bitumen mix are 50% to 60% higher than that of the PMB mix(Table-8), showing that the binding strength is higher in the case of PCA bitumen mix.

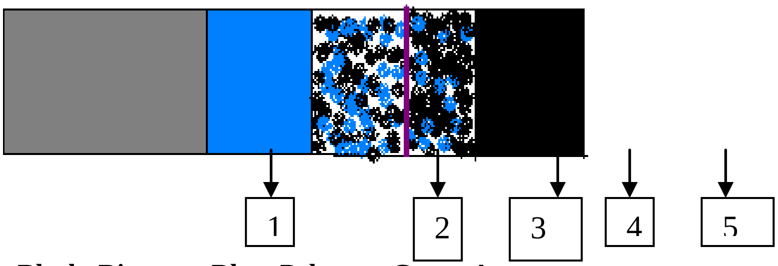
3.7. Theoretical Explanation:

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 140^0 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 follows. Waste polymers namely PE, PP and PS are hydrocarbons with long chains. The bitumen is a complex mixture of asphaltenes and maltenes which are also long chain hydro carbon. When bitumen was mixed with plastic coated aggregate a portion of bitumen diffuse through the plastic layer and binds with aggregate. The plastic layer has already bonded strongly with aggregate. During this process three dimensional internal cross linked net work structure results between polymer molecules and bitumen constitutes. Therefore the bond becomes stronger and the removal of bonded bitumen becomes difficult as explained earlier in section 3.4

The results of the studies on the extraction of bitumen (Table - 6) by dry process showed that the bonding between stone aggregate and bitumen is improved due to the presence of polymers. This may be explained by the following structural models. Using these models the extraction pattern is explained.

A plastic aggregate bitumen interaction model for the Plastics waste coated aggregate bitumen mix (Not to Scale)



Key: Black- Bitumen; Blue- Polymer; Grey - Aggregate

Aggregate
1. Area of Plastics bonded with aggregate (polymer coating)
2. Area of Bitumen–plastics blend (due to diffusion between molten plastics & hot bitumen)
3. Area of Loosely bonded bitumen with dispersed plastics
4. Area of Plain bitumen layer

On the whole, the coating of plastics over the stone aggregate helps bitumen to have a strong bonding at the surface.

Basing on the above observations, the increased value of MSV, nil stripping and improved strength of road is explained

3.6. Reduction of Carbon dioxide Emission:

Littered waste plastics are otherwise burnt along with domestic waste resulting in the production of green house gases thus aiding global warming.

In the Dry process, waste plastics are used as a coating material by softening the plastic and not by burning. Hence there is no evolution of gases like carbon dioxide. For a distance of one Kilometer single lane plastic bitumen road, a minimum of one ton of waste plastics is used. This accounts for a reduction of Carbon Dioxide to a tune of 3 tons. Using this technology we have laid more than 2500kms of plastic bitumen road at various places in India. This amounts to a prevention of burning of waste plastics to an extent of 2500tonnes. This means that the process prevented the formation of Carbon Dioxide to an extent of 7500tonnes. (If this waste plastic is burnt along with MSW, nearly 2, 50,000tonnes of Carbon Dioxide would have been produced)

Chemical Reaction (700^0C)

$$\text{PE, PP,PS} \xrightarrow{\Delta} \text{C, CO,}CO_2 \text{ but no } Cl_2$$

Use of PE, PP and PS cannot liberate dioxin even on burning (Table-1).

PVC $\xrightarrow{\Delta}$ C, CO, CO_2 and Cl_2 and HCl

$C+O_2+Cl_2$ Cu II catalyst 300-350 ^{o} C

PVC alone on heating may result in dioxin formation (300-350^{0}C) (reverse cooling).

V. FIELD STUDY

4.1. Performance Study:

This work is intended to examine several aspects related to the use of polymer coated aggregate for strengthening of flexible pavement. The objective of the work is to have functional evaluation and structural evaluation of polymer coated aggregate flexible pavement. This is achieved by performing the following specific tasks:

4.1.1Non Destructive Test:

a. Structural Evaluation

I. Carrying out structural evaluation of flexible pavement for the strength of the pavement by deflection measurement using Benkelman beam

II. Measuring the field density of the road using sand pouring cylinder

III. b. Functional Evaluation

IV. Measuring the roughness of the pavement surface using Bump integrator / Merlin

V. Examining the pavement condition of the road (cracks, raveling, potholes, rutting, corrugation edge break etc) by carrying out visual inspection of road surface

VI. Measuring the resistance offered by the pavement surface against skidding of vehicles using portable skid resistance tester

VII. Measuring the pavement macro texture for the geometrical deposition of individual aggregates. Texture depth was measured using sand patch method

4.1.2. Destructive Test:

i. Studying the gradation of the laid road.
ii. Carrying out different tests on recovered bitumen.
iii. Investigation of the properties of Plain aggregate and Polymer modified aggregate

VI. CONSTRUCTION OF THE TEST ROADS

Six sites were chosen (Table -10). Sites 1 to 5 for roads constructed using plastic coated aggregates and the site 6 road constructed with conventional bituminous mixtures . The above tests were conducted as per the specification (IRC) and the values were compared with standard values which are given in the Table-6 as tolerance value. The tests were conducted periodically from Jan 2007 to Dec'12. The average values are tabulated (Table 9)

It is observed from the results that the plastic roads laid since 2002 to 2012 are showing results which are the characteristics of a good road. They are showing better results and maintain good quality compared to the plain bitumen roads laid in 2002 .Hence it can be concluded that the plastic tar roads are performing much better than the plain bitumen road.

In addition to this, the physical surface condition survey of the plastic tar road (procedure adopted by Central Road Research Institute, New Delhi) shows that there is no pot hole formation, cracking, deformation, rutting, raveling and edge flaw. The photos of these roads taken recently are also attached for having a visual exhibition (Table -10). Hence it can be concluded that the plastic tar roads are having good skid resistance values, good texture values, good surface evenness, reasonably good strength and field density with least change.

VII. 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. 10M^{2} SDBC road the following calculation has been arrived

Material needed	Plain bitumen process	Plastics coated aggregate (PCA)

80/100 Bitumen	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 plastics		3.5tonnes

- Cost Bitumen Approx: 35,000/ton and Waste Plastic : Rs. 12000/tons
- Savings of bitumen = 1 ton
- Use of Plastics waste – (11,25, 000) carry bags (1.125 ton)
- Bitumen needed– 10125kg
- Plastics waste needed – 1125 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.

VIII. CONCLUSION

In Dry process, the aggregate is modified by coating with polymers and producing a new modified raw material for flexible pavement. Patent has been obtained for this process (Fig-2). Coating of polymers on the surface of the aggregate has resulted in many advantages and ultimately helps to improve the quality of flexible pavement. The coating of plastics over aggregate also improves the quality of the aggregate.

In addition to the improvement of the quality of the road, this technology has helped to use the waste plastics obtained from domestic and industrial packing materials. This has added more value to the dry process as this process helps to dispose 80 percentages of the waste polymers usefully by an eco-friendly method. This has already been accepted by the Central Pollution Control Board, New Delhi. They have already released a guideline on the technique of the road laying by dry process and its advantage.

By this technique, which is in-situ, waste polymer like carry bags, foam, laminated sheets, cups are all used for road laying.

Moreover, the use of polymers helps to reduce equivalent quantity of bitumen, thus reducing the cost of the road laying.

In a net shell the Dry Process thus helps to

1. Use higher percentage of plastics waste.
2. Reduce the need of bitumen by around 10%.
3. Increase the strength and performance of the road.
4. Avoid the use of anti stripping agents.
5. Reduce the cost to around Rs. 30000/ km of single lane road as on date.
6. Carry the process in situ.
7. Avoid industrial involvement.
8. Avoid disposal of plastics waste by incineration and land filling.
9. Generate jobs for rag pickers.
10. Add value to plastics waste.
11. Develop a technology, which is eco-friendly.

Our studies on the performance of plastic tar road conclusively proves that it is good for heavy traffic due to better binding , increased strength and better surface condition for a prolonged period of exposure to variation in climatic changes Above all, the process helps to dispose waste plastics usefully and easily.

REFERENCES

[1] Nabil Mustafa, " Plastics Waste Management " Canadian Plastics Institute, Toronto, Ontario, Canada, Marcel Dekker, Inc 1993.

[2] A support manual for Municipal Solid Wastes, Central Pollution Control Board, July 2003.

[3] S.K.Garg, Environmental Engineering, Vol.II Khanna Publishers, 1999.

[4] R.Vasudevan, S.Rajasekaran, S.Saravanavel, "Reuse of Waste plastics for Road Laying" Indian Highways, (Journal of Indian Roads Congress) Vol. 34. Issue 7 ,Page No: 5 – 20 July 2006.

[5] Shuler, T.S, Collins J.H., and Kirkpoatrick, J.P, "Polymer Modified Asphalt Properties Related to asphalt concrete performance", Asphalt Rheology Relationship to Mixture, ASTM: STP: 941, O.E, Briscoe Ed ASTM, Philadelphia, 1987.

[6] Zoorab S.E, and Suparma L.B, "Laboratory Design and Performance of Improved Bituminous Composites Utilizing Recycled Plastics Packaging waste", Presented at technology Watch and Innovation in the Construction Industry, Palais Descongres, Brussels, Belgium 5-6, April 2000, pp. 203-209.

[7] Denning,J.H, and Carswell.j., " Improvements in rolled Asphalt Surfacing by the Addition of organic Polymers ", Department of the Environment Department of Transport. Report LR 989. Transportation Road Research Laboratory (TRRL), Crow throne, 1981.

[8] Salter, R.J., and Rafati-Afshar, F., "Effect of Additives on Bituminous Highway Pavement Materials Evaluated by the Indirect Tensile Test", Transportation Research Record 1115, 1987. pp 183-195.

[9] Dallas, N. Little : AN Additive of Asphalt Additives to Reduce Permanent Deformation and Cracking in Asphalt Pavements: A brief Synopsis of On going Research", Proceedings of the Association of Asphalt Paving Technologists(AAPT), Vol. 55, 1986, pp 314-320.

[10] Walter j. Tappeinier , " Performance and Economical Advantage of Polymer Modified Asphalt", Richard Felisinger, Vienna, Austria 1999.

[11] King, G.N., Muncy, H.W., and Prudhome, J.B., " Polymer Modification: Binder's Effect on Mix Properties", Proceedings of the Association of Asphalt Paving Technologists(AAPT), Vol. 55 , 1986 pp 519-540.

[12] Sunil Bose, and Jain, P.K," Laboratory Studies on the Use of Organic Polymers in Improvement of Bituminous Road Surfacing", Highway Research Bulletin 38, 1989, New Delhi.

[13] Sunil Bose, and Jain, P.K, Sangita, and Arya, I.R., "Characterization of Polymer Modified Asphalt Binders for Roads and Air Field Surfacing, Polymer Modified Asphalt Binders", ASTM: S.T.P:1108, American Society of Testing Materials, Philadelphia, USA, 19923. Pp.331-355.

[14] Mahabir Panda and Mayajit Muzumdar, "Development and Evaluation of a Bituminous Paving Binder Containing Reclaimed Polyethylene", Indian Highways, Indian Roads Congress, New Delhi, Vol. 25(5), 1997.

[15] Punith .V.S. and Dr. Veeraragavan.A "Fatigue characteristics of Recycled Plastics Modified Bituminous Concrete Mixes". Highways Research Bulletin, Indian Road Congress, Nov.2004.

[16] Rheological Properties of Bitumen Modified with Polyethylene and Polyethylene Based Blends, Oscar González Uranga, Department de cynical Technologic de Polymers. Faulted de Química, Universidad del País Vasco. Spain. 2000.

[17] Dr. R. Vasudevan, S.Rajasekaran & S.Saravanavel, " Utilization of plastics waste in construction of flexible pavement" Proceeding of the National Seminar on " Integrated Development of Rural & Arterial Road Network for Socio-Economic Growth"Dec.2003. P-II. 243 and Journal of IRC July'2006

[18] Indicative Operational Guidelines on the construction of Polymer – Bitumen roads, Probes/101/ 2005-2006; Central Pollution Control Board, New Delhi.

[19] Performance Evaluation of polymer coated bitumen built roads; Probes/121/2008-2009; Central Pollution Control Board, New Delhi.

[20] AASHTO T 96-2001- "Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

[21] ASTM D2172 Standard Test Methods for Quantitative Extraction of Bitumen From Bituminous Paving Mixtures

[22] IRC 82-1982 Tentative Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique

[23] IS 6241-1971 Method For Test For Determination Of Stripping Value Of Road Aggregate.

TABLES AND FIGURES

Table 1. Thermal properties of polymers

Polymer	Solubility		Softening Temperature range in Deg.C	Products reported	Decom position Temp. range in Deg.C	Products reported	Ignition temp. range in Deg. C	Products reported
	Water	EPT*						
PE	Nil	Nil	100-120	No gas	270-350	CH_4, C_2H_6	>700	CO, CO_2
PP	Nil	Nil	140 - 160	No gas	270-300	C_2H_6	>700	CO, CO_2
PS	Nil	Nil	110-140	No gas	300-350	C_6H_6	>700	CO, CO_2
PVC	Nil	Nil	200-220	HCl	320-350	C_2H_6, HCl	>700	CO, CO_2, Cl_2 & HCl

* 5% Acetic acid

Type of plastics and variation in Bending Strength:

Table 3

Type of Plastic	Percentage of Plastics	Bending Strength in Kg	Compression Strength Tons
Poly ethylene	10	325	250
	20	340	270
	25	350	290
Poly propylene	10	350	280
	20	370	290
	25	385	310
Polystyrene	10	200	155
	20	210	165
	25	215	170
Polyethylene Foam	10	310	250
	20	325	265
	25	335	290
Polypropylene Foam	10	340	270
	20	360	290
	25	365	310
Laminated Plastics	10	360	290
	20	385	310
	25	400	335
BOPP	10	380	300
	20	400	310
	25	410	330

Physical properties of waste plastics Table – 2

Commercial Plastic material	Nature of Plastics	Thickness µ	Softening Point Deg.C
Cup	Poly ethylene	150	100-120
Carry bag	Poly ethylene	10	100-120
Water bottle	PET	210	170-180
Cool drinks bottle	PET	210	170-180
Chocolate covers	Poly ester+Poly ethylene+metalised polyester	20	155
Parcel cover	Poly ethylene	50	100-120
Supari cover	Polyester+Poly ethylene	60	120-135
Milk Pouch	LDPE	60	100-120
Biscuit covers	Polyester+Poly ethylene	40	170
Decoration papers	BOPP	100	110
Film	Polyethylene	50	120-130
Foam	Polyethylene	NA	100-110
Foam	Polystyrene	NA	110

Table 4. Aggregate technical properties

Stone Aggregate	Plastic content	Moisture Absorption	Soundness	A I V	A C T	L AR	Voids
Without plastic coating	0	4%	5+/- 1 %	25.4	26%	37%	4%
With plastic coating	1%	2%	Nil	21.20	21%	32%	2.2%
With plastic coating	2%	1.1%	Nil	18.50	20%	29%	1%
With plastic coating	3%	traces	Nil	17.00	18%	26%	Nil

Table – 5. Stripping Value of PCA bitumen Mix (Percentage of Plastic – 10%)

		Plain aggregate				Plastic coated Aggregate			
PCA+ Bitumen Mix	Stripping Value	2 hrs	24 hrs	72 hrs	96 hrs	2 hrs	24 hrs	72 hrs	96 hrs
		0	0	2	5	0	0	0	0

Table -6. Results of the bitumen extraction test for the bitumen mix containing the PCA

Plastic content (% by weight)	Bitumen extracted after 5 min %	Bitumen extracted after 10 min %	Bitumen extracted after 15 min %
0	96.0	98.0	99.0
0.5	63.5	88.7	92.3
0.75	63.2	86.7	90.7
1.0	61.3	76.7	83.6

Table -7. Marshall Stability Value for Polymer Coated Aggregate

% of Bitumen	% of Polymer w.r.t wt of bitumen	Type of Polymer	PCA	Marshall Value (kN)	Flow Value (X 0.25mm)	Void Percentage	Marshall Quotient kN/mm
4.5	5	PP	PCA	16	4	53	4
4.5	10	PP	PCA	20	5	55	4
4.5	5	LDPE	PCA	16	4	55	4
4.5	10	LDPE	PCA	17.5	4	55	4.38
4.5	10	PE Foam	PCA	20	4	58	5
4.5	15	PE Foam	PCA	22.5	4	56	5.63
4.5	20	PE Foam	PCA	26.5	4	56	6.62

Table -8. Marshall Stability Value for Polymer Modified Bitumen

% of Bitumen	% of Polymer w.r.t wt of bitumen	Type of Polymer	PMB	Marshall Value (kN)	Flow Value (x 0.25mm)	Void Percentage	Marshall Quotient kN/mm
4.5	**5**	PP	PMB	14.50	3	56	4.83
4.5	**10**	PP	PMB	17.00	3.3	62	5.15
4.5	**10**	PE FOAM	PMB	18.00	3.4	66	5.29
4.5	**5**	LDPE	PMB	15.00	3.3	62	4.55
4.5	**10**	LDPE	PMB	17.00	3.5	62	4.86

Table-9. Summary of Results

Road	**Year laid**	**Unevenness (mm /km)**	**Skid number**	**Texture Depth (mm)**	**Field Density Kg/M³**	**Rebound Deflection (mm)**
Jambulingam Street	**2002**	**2700**	**41**	**0.63**	**2.55**	**0.85**
Veerabadhra Street	**2003**	**3785**	**45**	**0.70**	**2.62**	**0.60**
Vandiyur road,	**2004**	**3005**	**41**	**0.66**	**2.75**	**0.84**
Vilachery Road, mai	**2005**	**3891**	**45**	**0.50**	**2.89**	**0.86**
Canteen Road, TCE	**2006**	**3100**	**45**	**0.65**	**2.86**	**0.86**
Plain Bitumen Road*	**2002**	**5200**	**76**	**0.83**	**2.33**	**1.55**
Tolerance Value**	**------**	**4000**	**<65**	**0.6-0.8**	**2.86**	**0.5-1**

* - Reference road constructed with plain bitumen
**- Theoretical value for the effective performance of a good road

Table -10. SURFACE CONDITION SURVEY:

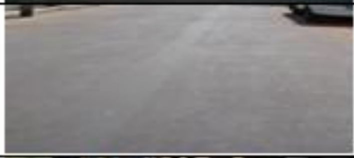
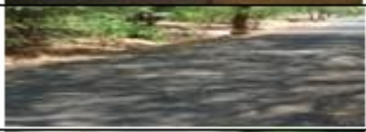
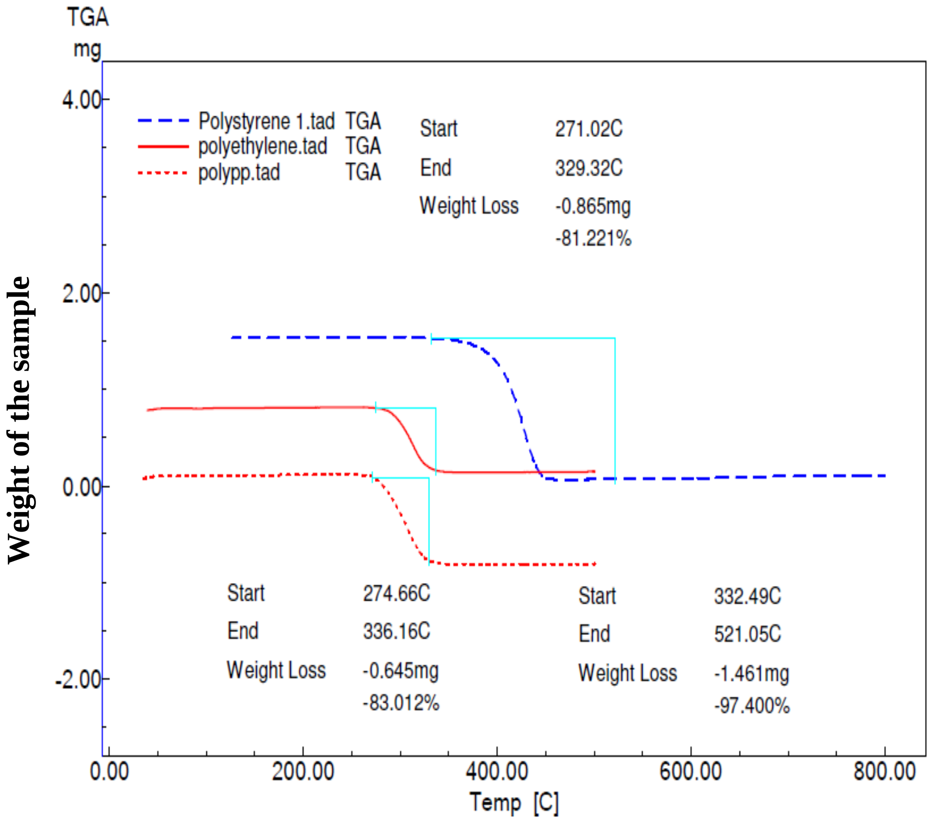
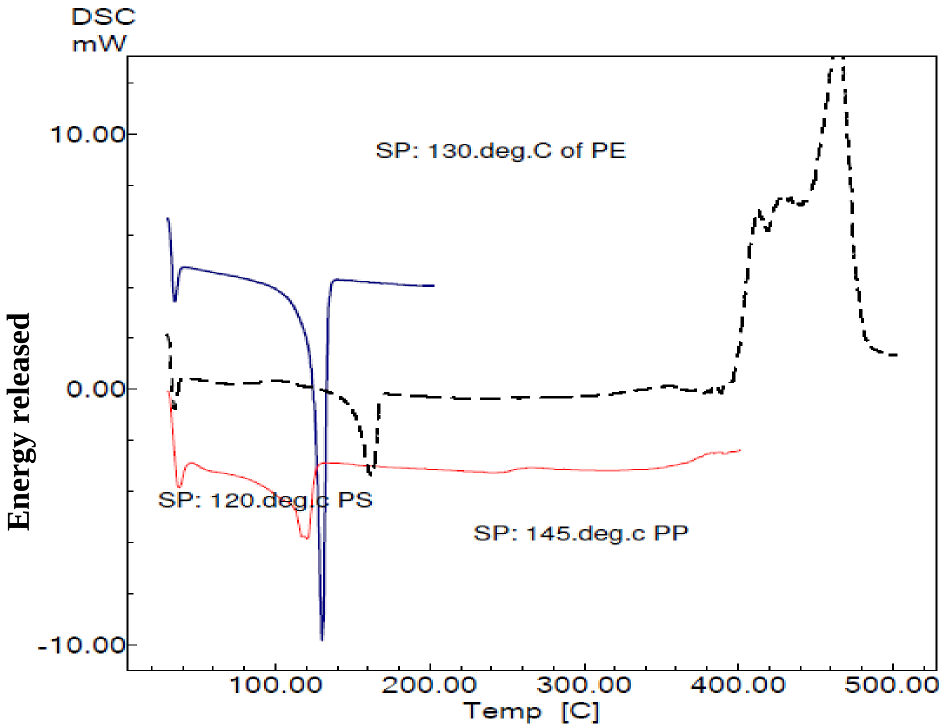
Site Name	Surface Condition Survey	Photo
Jumbulingam road, Chennai (2002) Photo Date: 21-12-2012	1. No Pothole 2. No Cracking 3. No Deformation 4. No Edge Flaw	
Veerbadhra Street, Erode(2003) Photo Date: 04-01-2013	1. No Pothole 2. No Cracking 3. No Deformation 4. No Edge Flaw	
Vandiyur Main road (2004) Photo Date: 01-02-2013	1. No Pothole 2. No Cracking 3. No Deformation 4. No Edge Flaw	
Vilachery Main road (2005) Photo Date: 11-02-2013	1. No Pothole 2. No Cracking 3. No Deformation 4. No Edge Flaw	
Canteen road (2006) Photo Date: 05-01-2013	1. No Pothole 2. No Cracking 3. No Deformation 4. No Edge Flaw	
Plain bituminous road (2002) Photo date: 21.12.2012	1. Pothole developed 2. Cracking is there. 3. Deformation is there 4. Edge Fault	

Fig I. Thermal Analysis Graph



Thermo Gravimetric Analysis



Differential Scanning Calorimeter

Fig.2