UTILIZATION OF WASTE POLYMERS FOR FLEXIBLE PAVEMENT FOR LOW VOLUME RURAL ROADS

P.Naga Malleswara Rao[1], B Khadar Mohammed[2]

[1,2]PG SCHOLAR (Transportation Engineering), Assistant Professor(Civil Department)
MVR College of Engineering & Technology Krishna District Andhra Pradesh

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ABSTRACT: In recent years due to heavy magnitude of wheel loads, tyre pressure and heavy traffic, the severity of rutting, cracks, raveling and edge drops is increasing on roads. Various attempts are being made to improve the structures of flexible pavement thus improving the strength and durability of the roads. Many additives are being added to improve the binding property of the bitumen. Use of polymers in flexible pavement construction is also in progress for the past two decades. Different types of polymers are mixed with bitumen and polymer modified bitumen is being used. Use of PMB has improved the quality of the road to some extent. Yet there are many limitations like the use of higher percentage of polymers, use of different type of polymers etc., In most of the process not much of scientific explanations are available.

In this process, the polymer is coated over the hot aggregates and the coated aggregate is mixed with hot bitumen. The mixture is used for the construction of flexible pavement. This is an eco-friendly process. The polymer used are only waste polymer materials like carry bags, cups, foams etc., The use of higher percentage of polymer like 10-15% is easily adopted in this process as it involves only coating over aggregate. This process also helps to reduce the consumptions in bitumen to an extent of 10-15% which is being substituted by waste polymers. The coating of polymers over aggregate also helps to improve the characteristics of aggregate.

A detailed study has been made in this regard. It has been observed that the coating of polymers over the aggregate has modified the properties of the aggregate. 1. by reducing voids 2. by reducing moisture absorption 3. Increasing soundness 4. increasing various strength like. Los Angels Abrasion, Aggregate Impact, Crushing Strength etc.

The coating has also helped to prevent stripping, which is the major factor for pothole formation. The binding strength of the Polymer Coated Aggregate (PCA) bituminous mix is also increased by about 50-100% due to the influence of increasing bonding effected due to polymer coating. This is reflected in the Marshall Stability value.

A detailed study on the performance of polymer modified flexible pavement namely structural evaluation and functional evaluation was undertaken as per specifications warranted by CRRI, CPCB & HRS. It has been observed from test results collected from selected area based on the variation of climate, temperature, rainfall and traffic volume etc., that these plastic roads are performing very well without any raveling, rutting, cracks etc., They also satisfy the scientific parameters, (Deflection studies, Field Density, Roughness, Pavement Condition Survey, Skid resistance and texture depth) suggested for the better performance of the road. It has also been observed that no maintenance is required for these roads so for. Mathematical modelling has been developed to validate performance characteristics.

Keywords: waste polymers, Flexible pavement

1. INTRODUCTION

Plastics, a versatile material and a friend to common man become a problem to the environment after its use. Disposal of a variety of plastic wastes in an ecofriendly way is the thrust area of today's research. The authors' innovative techniques to use the waste plastics and the tyre waste for the construction of flexible pavement, for making pathway blocks, and for making laminated roofing sheets form a good solution for the waste disposal problem of both plastic waste and municipal solid waste.

2. CHARACTERIZATION OF WASTE PLASTICS

2.1 Process: I (using Mini Hot Mix Plant)

At first, the aggregate mix was prepared as per IRC specification and then heated in the cylindrical drum to 170 C. It was then transferred to the puddling compartment where polymer waste (size between 1.6mm and 4.75mm) was added. As the temperature of the aggregate was around 170 C and the softening temperature of polymer waste is around 135 C, the polymer waste got softened and got coated over the aggregate within 30 to 60 seconds. Immediately the hot bitumen 60/70 grade (160C) was added and mixed in the puddling chamber. The bitumen got coated over the aggregate. As the polymer and the bitumen were in liquid state they got mixed well. The mixture was transferred to the road and it was spread and compacted using 8 Ton rollers.

2.2 Process: II (using Central Mixing Plant)

In this process, the polymer waste was mixed quantitatively with the aggregate using a mechanical device before the addition of bitumen. Central Mixing Plant helps to have better control of temperature and better mixing of material and thereby enabling to have a uniform coating. The material collected at the tipper was uniform and had a temperature of 140 ºC. This was transported to the spot and road was laid using 'pavers' and 8 Ton roller. The spreading was good and

the laying was easy. During the process the materials got mixed

1. at the tipper
2. During the transfer from tipper to pavers and
3. by the pavers during spreading for road laying

Fig. 1: Cleaning Process

Fig. 2: Heating of Aggregate to 170º C in Mini Hot Mix Plant

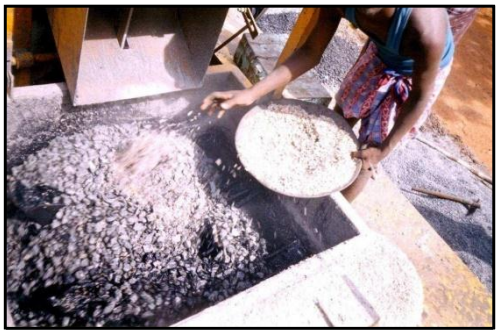

Fig. 3: Adding Waste Polymers to Hot Aggregates

2.3 Binding Property

The molten plastics waste exhibits good binding property. Various raw materials like granite stone, ceramics etc... were coated with plastics and then molded into a stable product. On cooling, it was tested for compression and bending strengths.

Table 1. Binding Property

Percentage of plastics coating over aggregate	Compression Strength (Tonnes)	Bending Strength (Kg)
10	250	325
20	270	335
25	290	350
30	320	390

The increase in the values of the compression strength and bending strength shows that the plastics can be used as a binder.

3.0CHARACTERISTICS OF PLASTIC COATED AGGREGATE (USED FOR FLEXIBLE PAVEMENT)

3.1 Moisture Absorption and Void Measurement

For the flexible pavement, hot stone aggregate (1700c) is mixed with hot bitumen (1600c) 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.

3.2 Soundness Test

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

3.3 Aggregated Impact Value

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

Table 2

Percentage of Plastics	*Aggregate Impact value*
	25.4
1%	21.20
2%	18.50

It is clearly observed that the coating of plastics improves Aggregate Impact Value. Coating of plastics over the stone aggregate improves the quality of the aggregate. Moreover a poor quality of aggregate can be made useful by coating with polymers.(Table 2). This in turn helps to improve the quality of flexible pavement.

3.4 Los Angel's Abrasion Test

The repeated movement of the vehicle with iron wheeled or rubber tire will produce some wear and tear over the surface of the pavement. This wear and tear percentage of an aggregate is determined with the help of Los Angeles abrasion study. Under this study the percentage of wear and tear values of the plastic coated aggregate is found to be in

decreasing order with respect to the percentage of plastics (Eg. 37% without plastic, 32% with 1% plastic and 29% with 2% plastic). When the Los Angeles abrasion value of plain aggregate value is compared with the Plastic coated aggregate the values are less for polymer coated aggregate.

4. CHARACTERISTICS OF POLYMER MODIFIED BITUMEN

An alternate use of plastic waste is also under study where plastics is mixed with bitumen and used for preparing the mix. The mix was used to study the basic properties of bitumen like softening point, penetration point and ductility. The penetration value was decreased to a very low value and similarly the ductility. More than 3% addition of waste plastics to the bitumen results in a hard polymer modified bitumen with very poor viscoelastic property (The minimum values for a suitable bitumen

P.V = 80; Ductility ≈ 50).

Table 3. Properties of Polymer Modified Bitumen

% of Plastics	*Ductility (cm)*	*Penetration (mm)*	*Softening Point (°c)*
1%	64	95	54
2%	55	90	50
3%	20	80	50
5%	11	55	72
10%	7	Nil	75

On comparison it may be inferred that the use of higher percentage of plastics in polymer modified bitumen is not favorable (Table 3).

5.0 STUDY ON CRUMB RUBBER MODIFIED BITUMEN

The waste tires are made into powder by grinding into some special type of grinders. The powder is collected and it is used for modification of bitumen. The bitumen is heated to 100-120oc and the powdered crumb rubber is added to the bitumen and stirred well with help of mechanical stirrer. The mix is stirred at the speed of 3000 RPM to get a homogenous mixture. The stirring is carried out for 2- 3 hours. The crumb rubber blended bitumen is subjected to different tests like penetration point, ductility, softening point. Here we have taken 80/100 bitumen and it is modified with different percentage of crumb rubber powders starting from 1% to 5%

Table 4 Data on Crumb Rubber Modified Bitumen

% of crumb rubber	% of plastics	Ductility Values (cm)	Softening point (0C)	Penetration at 25oC (mm)
1%	5	75	53	90
2%	5	72	54	88
3%	5	70	56	85
5%	5	61	58	70

6.1 Testing of the Roads

As per our discussion above the load withstanding capacity of the road is increased by a large amount. This is proved by conducting various tests on the built plastic tar roads at different places at different times. This test has been carried out with the help of National Transport Planning and Research Centre, Trivandrum. The tests show very good results some of the tests are listed below.

1. To measure the roughness of the pavement surface.
2. To measure the resistance offered by the pavement surface against skidding of vehicles.
3. To measure the pavement macro texture for the geometrical deposition.
4. To assess the structural evaluation of flexible pavement for the strength of the pavement
5. To Measure the Field Density of the road.
6. To study the Gradation of the laid road.
7. To carry out different tests on recovered bitumen.
8. Examine the condition of the road (cracks, raveling, potholes, rutting, corrugation edge Break)

Table 5 Summary of Results

Road	Average Daily Traffic	Unevenness (mm	Skid number
Road	95	/km)	50
1	280	3200	55
2	180	3000	59
3	1000	3010	50
4	600	3250	66
5	1000	3100	55

Table 6 Summary of Results

Road	Texture Depth (mm)	Rebound Deflection (mm)
Road	0.53	0.70
1	0.55	0.75
2	0.56	0.61
3	0.50	0.70
4	0.47	0.62
5	0.90	1.55

- From the skid resistance studies of the five stretches it has been proved that the entire road was having good skid resistance values.
- From the surface texture studies of the five stretches it has been proved that the roads inside the campus and the other two outside roads have good texture values.
- From the deflection studies of the five stretches it has been proved that all the stretches are reasonably strong.
- From the bump integrator studies of the five stretches it has been proved that the unevenness index value of these three road sections are nearly to 3000 mm/km, which indicates a good surface evenness.

Table 7. Economics of the process

Size of the road	1kmX 3.75 m
Bitumen needed	9 tonnes
Plastics needed	1 tonnes
Bitumen save	1 tonnes
Cost reduced	Rs,18,000

The plastics waste collected is around 650 tonnes/ annum. The roads available are approximately 400km and their annual requirement of plastic waste to lay plastic road is more than 600 tons. So the total waste generated could be used for road laying. The life of the road is increased and hence the maintenance expenditure is reduced.

7. CONCLUSION

The generation of waste plastics is increasing day by day. The major polymers namely polyethylene, polypropylene, polystyrene show adhesion property in their molten state. Stone aggregate is coated with the molten waste plastics. The coating of plastics reduces the porosity, absorption of moisture and improves soundness. The polymer coated aggregate bitumen mix forms better material for flexible pavement construction as the mix shows higher Marshall Stability value and suitable Marshall Coefficient. Hence the use of waste plastics for flexible pavement is one of the best methods for easy disposal of waste plastics. The use of polymer coated aggregate is better than the use of polymer modified bitumen in many respects. Moreover the polymer coated aggregate helps to use Crumb rubber modified bitumen resulting in better result. In India more than 3.3 million km of road is available. If they are constructed as plastic tar road, there will be less waste plastic available on the road. The process is ecofriendly. The use of waste plastics in the manufacture of pathway blocks and laminated roofing also help to consume large quantity of waste plastics. These processes are ecofriendly and socially highly relevant, giving better infrastructure. Let us grow with these newer technologies.

The polymer coated aggregate with higher percentage of polymers is compacted into a block. The block shows good compressive strength and bending strength explaining the power of adhesion of the polymers. This property helps to improve the stability of the PCA bituminous mix. Moreover during the mixing of bitumen with PCA the temperature is around 140- 150º C and both polymers and bitumen are in the fluid state. They mix at the surface, and bitumen spreads well resulting in increased bonding between aggregate and bitumen.

The removal of bitumen is very slow and difficult and nearly 85 percentage only is removed. The rest is held at the surface of the aggregate by the coated polymers. The residue, when washed further with a solvent for polymer called decline both bitumen and polymer are removed. The molten polymer acts as a good binder and hence this acts as a good substitute in the preparation of flexible pavement mix. The quantity of bitumen is reduced to the extent of polymer used, in the mix preparation.

PCA helps to

1. Improve the quality of aggregate
2. Improve binding and bonding of bitumen
3. Improve Marshall Stability Value which is the resultant of the above property.

The study clearly shows that the property of bitumen is unaltered in this process and rather the strength of the PCA bituminous mix is increased. The following advantages were observed during the structural and functional evaluation of the polymer modified flexible pavement:

- Better binding property as observed in extraction of binder test
- Lower penetration value (65mm) and hence higher load carrying capacity
- The Marshall stability value of the Semi Dense Bituminous Concrete (SDBC)has increased by about 30 percentage on using PCA
- Water absorption was found to be less in PCA by 30.80 percentages as compared to plain aggregate which indicates a higher degree of water susceptibility.

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