INTERNATIONAL JOURNAL OF RESEARCH IN COMMERCE, ECONOMICS & MANAGEMENT

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STATEMENT OF THE PROBLEM

OBJECTIVES

HYPOTHESIS (ES)

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RESULTS & DISCUSSION

FINDINGS

RECOMMENDATIONS/SUGGESTIONS

CONCLUSIONS

LIMITATIONS

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ECONOMIC FEASIBILITY STUDY OF PLASTIC MIX BITUMEN ROAD

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ABSTRACT

The plastic become integral part of the human requirements in modern society. The plastics are used extensively in manufacturing starting from carry bags, packaging materials, bottles, cups and many others slowly replaced everything made of other materials because of their durability, easy to manufacture, light in weight, unbreakable, odorless and chemical resistant. But the disposal of plastic is a serious problem globally due to their non-biodegradability and hazardous to human health since these are not disposed scientifically thus creates ground and water pollution. The use of these materials in road making which is based on technical, economic, and ecological criteria We conducted comparison study between concrete road and plastic road. It is concluded from the study that the plastic road using waste plastic shows better performance in terms economy, durability, strength as well as load bearing capability.

KEYWORDS

plastic waste, mechanical characteristics, bituminous mix, plastic roads.

NOMENCLATURE

ABS	: acrylonitrile butadiene styrene PP: polypropylene
CPCB	: central pollution control board TPD: tones per day
CRRI	: central road research institute TPA: tones per annum
HDPE	: high density polyethylene PVC: polyvinyl chloride
IRC	: Indian road congress PWM: plastic waste management
LDPE	: low density polyethylene PS: polystyrene
MSW	: municipal solid waste PET: polyethylene terepthalata
PCA	: plastic waste coated aggregate

INTRODUCTION

Plastic products have become basic needs and play vital role in our daily life. It is produced on a massive scale worldwide and its production crosses 150 million tons per year. In India approximately 12 million tons of plastics products are consumed every year which is expected to increase many folds during near future. These are specifically used in packaging films, wrapping materials, shopping and garbage bags, fluid containers, clothing, toys, households and industrial products as well as building materials. It is fact that plastics will never degrade and remains on landscape for several years again the recycled plastics are more harmful to the environment than the virgin products due to mixing of colors, additives, stabilizers, flame retardants etc. It is to mention that no authentic estimation is available on total generation of plastic waste in the country but however 70% of total plastic consumption is discarded as waste, thus approximately 5.6 million tons per annum (TPA) of plastic waste is generated in the country, which is about 15342 tons per day (TPD).

In the present work we intend to analyze the applications of plastic wastes which have been considered in road construction with great interest in many developing countries. The use of these materials in road making is based on technical, economic, and ecological criteria. The lack of traditional road materials and the protection of the environment make it imperative to investigate the possible use of these materials carefully. India has a large network of metro cities located in different parts of the country and many more are planned for the near future. Several million metric tons plastic wastes are produced every year in India. By using this technology (plastic waste coated aggregate bitumen mix), several roads have been laid in the states of Tamil Nadu, Maharashtra, Pondicherry, Kerala, Andhra Pradesh and Goa. To evaluate the performance of the built road using plastic waste coated aggregate (PCA) bitumen mix and also to generate data base for evolving standards, Indian Road Congress (IRC) takes leadership.

On heating at 100 - 160°C, plastics such as polyethylene, polypropylene and polystyrene, soften and exhibit good binding properties. Blending of the softened plastic with bitumen results in a mixed that is amenable for road laying. These roads have withstood loads due to heavy traffic, rain and temperature variation.

Experimental study performed by Bindu and Beena [1] using waste plastic as stabilizing additive in Stone Mastic Asphalt. It was found that the flexible pavement with high performance and durability obtained with 10% shredded plastic. Modifying asphalt mixture with HDPE polyethylene enhances the properties far more than LDPE polyethylene studied by Awwad and Shbeeb [2]. Modified bitumen with the addition of processed waste plastic of about 5-10% by weight of bitumen increases the longevity and pavement performance with savings in bitumen usage there by consumes large quantity of waste plastics hence these processes are socially highly relevant giving better infrastructures [3]. Experimental study performed by Khan and Gundaliya [4] on process of modification of bitumen with waste polythene enhances resistance to cracking, pothole formation and rutting by increasing softening point, hardness and reducing stripping due to water, thereby improving the general performance of roads over a long period of time. According to them the waste polythene utilized in the mix forms coating over aggregates of the mixture which reduces porosity, absorption of moisture and improves binding properties. Prusty [5] studied the behavior of BC mixes modified with various percentages of waste polythene. Marshall properties such as stability, flow value, unit weight, air voids are used to determine optimum polythene content for the given grade of bitumen (80/100) and concluded that a more stable and durable mix for the pavements can be obtained by polymer modification. Investigations conducted by Swamy et al. [6] that the total material cost of the project is reduced by 7.99% with the addition of plastic to bitumen between ranges of 5-10%. It was found that the problems like bleeding in hot temperature regions and sound pollution due to heavy traffic are reduced and ultimately improves the quality and performance of the road. Polymer modified bitumen results a high elastic recovery (79%) and better age resistance properties i.e. the loss in weight on heating in thin film oven is 6 times higher as compared to the conventional bitumen concluded by Pareek et al. [7]. Sangita et al. [8] suggested to improve road quality by utilizing plastic waste in road construction will save Rs.33,000 crores a year in repairs, plus reduced vehicle wear and tear. Chavan [9] conducted feasibility study of the use of shredded waste plastics in semi-dense bituminous concrete with 60/70 penetration grade bitumen employing dry process over 50 samples with varying percentage bitumen by weight of mix and percentage plastics by weight of binder were evaluated. It was found that there was a 10% saving of

bitumen content which leads to saving in national economy and also an eco-friendly method for the disposal of waste plastics. The stability value of the mix was increased by about 30%, there was less aging of bitumen and no bleeding. Again the coated aggregates showed no stripping even after 96 hours of water immersion and hence avoid the use of ant-stripping agents in bituminous mixes. Water absorption was found to be less as compared to uncoated aggregates indicating its higher degree of water susceptibility. The polythene/polypropylene bags utilized for integrated development of rural and arterial road network for socio-economic growth studied by Vasudevan [10] and it was found that polymer bitumen blend is a better binder compared to plain bitumen resulting higher Marshall Stability and decreasing the possibilities of potholes formation.

PROBLEM DESCRIPTION

Plastics

Different commercial plastic materials that are in use were collected and the following tests were carried out: (i) Softening Point and (ii) Thickness of the Film. Most of plastics get soften below 170^{0}C except Poly vinyl chloride and Polyethylene terepthalate (Table 3.1). There is no evolution of any gas during softening. The molten plastics can be used as a binder using proper technique.

TABLE 1: THERMAL BEHAVIOR OF POLYMERS

Polymer	Solubility		Softening Temp in ^{0}C	Products re-ported	Decomposition temp in ^{0}C	Products reported on de-composition	Ignition temp range in	Products reported on ignition
	Water	EPT						
PE film	Nil	Nil	100-200	No gas	289-335	CH_4,C_2H_6	> 700	CO,CO_2
PP	Nil	Nil	140-160	No gas	271-329	C_2H_6	> 700	CO,CO_2
PS	Nil	Nil	110-140	No gas	300-350	C_6H_6	>700	CO,CO_2
PE Foam	Nil	Nil	120-125	No gas	309-385	CH_4	> 700	CO,CO_2
Tea Cup	Nil	Nil	130-150	No gas	313-420	C_2H_6	> 700	CO,CO_2

TABLE 2: BINDING PROPERTY

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

Utilization of plastic waste in road construction

The process of road laying using waste plastics is designed and the technique is being implemented successfully for the construction of flexible roads at various places in India.

TABLE 3: PROTOCOL FOR DESCRIPTION OF ROADS LAYING PROCESS

Sl.No	Process	Executing Agency
1.	Collection and segregation of plastic waste (except chlorinated/brominated plastic waste)	Municipal corporation, Nagar Nigam, Nagar Parishad & Nagar and Gram Panchayat
2.	Transportation and storage of plastic waste	Municipal corporation, Nagar Nigam, Nagar Parishad & Nagar and Gram Panchayat
3.	Cleaning and sun drying of plastic waste	Municipal Body or PWD
4.	Shredding of plastic waste (2 to 4 mm size)	Municipal Body or PWD
5.	Heating of stone aggregate (160^{0}C-170^{0}C)	Municipal Body or PWD
6.	Adding of shredded plastic waste (5-10% w/w for 30 to 40 seconds)	Municipal Body or PWD
7.	Coated aggregate is mixed with hot bitumen (Temp 155-163^{0}C)	Municipal Body or PWD
8.	The mix-plastic aggregate bitumen mix (130-140^{0}C). the mix can be used for road laying	Municipal Body or PWD

A brief description of the process is mentioned in the Table 3 and the schematic flow diagram of the process is shown in Figure 1.

FIGURE 1: FLOW DIAGRAM FOR UTILIZATION OF PLASTIC WASTE IN ROAD CONSTRUCTION

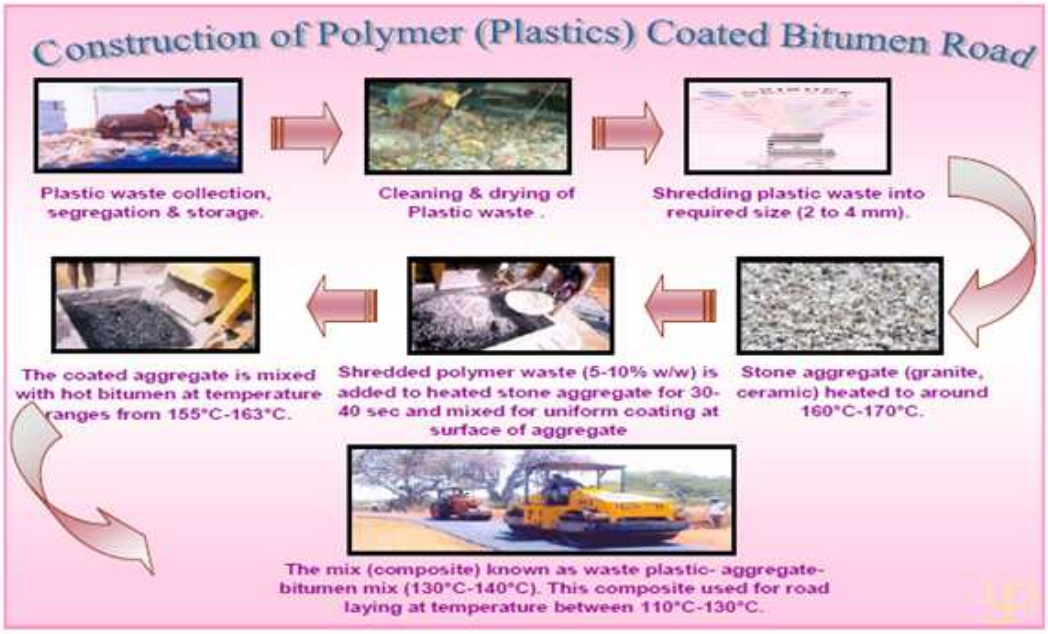
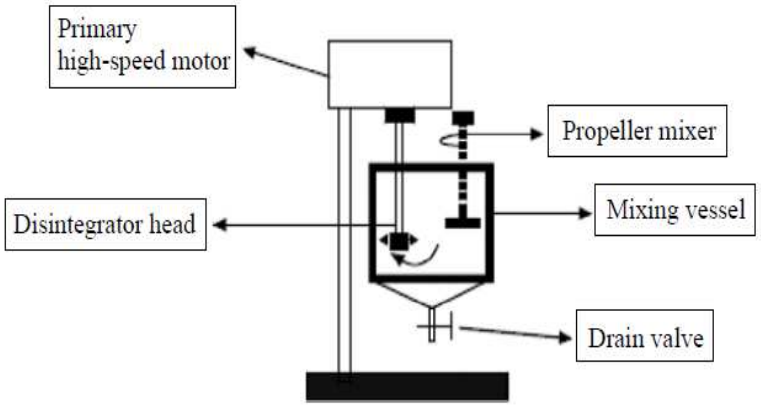


FIGURE 2: POLYMER-BITUMEN MIXING ASSEMBLY



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 3.2). Moreover, the coated plastics did not leach out by the leaching liquid (5% acetic acid).

Waste plastic bags of various polymers cited above, were cut into pieces using a shredding machine. It was sieved and the plastics pieces passing through 4.75 mm sieve and retaining at 2.36 mm sieve were collected. These samples prepared, were added slowly to hot molten bitumen of temperature around 170-180 °C.

All samples were first mixed at low polymer concentrations as follows:

- For mixing with 60/70 grade bitumen: Beginning with 2% by weight of the bitumen, further in the concentrations of 4%, 6%, 8%, 10% and 12%.
- For mixing with 80/100 grade bitumen: Beginning with 1% by weight of the bitumen further in the concentrations of 1%, 2%, 3%, 4%, and 5%.

The mixture was stirred well using stirrer for about 20-30 minutes. Blends of different compositions were prepared.

Bitumen

The bitumen was 60/70 & 80/100 penetration grade obtained from H.P.C.L. Mumbai. Physical properties of the bitumen were presented in Table 4.

TABLE 4: SPECIFICATIONS OF BITUMEN 60/70 AND SPECIFICATIONS OF BITUMEN 80/100

Characteristic	Test result		Test method	
	60/70 Grade	80/100 Grade	ASTM	IS
Specific gravity @25^{0}C	1.01/1.06	1.01/1.05	D-70	IS:1202-1978
penetration @25^{0}C	60/70	80/100	D-5	IS:1203-1978
Softening point @25^{0}C	49/56	45/52	D-36	IS:1205-1978
Ductility @25^{0}C, cm	100	100	D-113	IS:1208-1978
Flash & fire point (^{0}C)	> 250	> 225	D-92	IS:1209-1978
Loss on heating (wt. %)	< 0.2	< 0.2	D-6	IS:1212-1978

Aggregates

Aggregate was obtained from a local Quarry. The physical properties of aggregates are given in Table 3.6. Recommended gradation limits for BT works are shown in Table 3.7.

TABLE 5: PHYSICAL PROPERTIES OF AGGREGATES

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

TABLE 6: GRADATION OF AGGREGATES FOR PAVEMENT PURPOSE

	Percentage of passing of stone aggregates							
Sieve size (mm)	19	12.5	9.5	4.75	2.36	0.60	0.30	0.18
Permissible limits (%)	100	85-95	75	20-28	16-24	12-16	10-14	06-08

Material balance

According to Law of conservation of mass Energy can neither be created nor be destroyed, only one form of energy can be converted to other. In its general form it can be written as:

(Mass flow in the system) = (Mass leaving the system) + (Mass accumulated in the system)

As there is no specific reaction taking place, during blending, between bitumen and polymer, there is no specific change in terms of mass takes place. Material balance for samples, various types of plastic waste added to virgin bitumen is given as in Table 4.1.

TABLE 7: LAYER WISE REQUIREMENT OF BITUMEN FOR ROAD CONSTRUCTION

Pavement layer of road	Thickness	Bitumen required (Kg/sq m of road)
BBM on WBM surface	50 mm	1.75
	75 mm	2.00
BBM on existing BT	50 mm	2.25
Surface	75 mm	2.50
Carpet	20 mm	2.06
Sealcoat	06 mm	1.12
Total bitumen consumption	50 mm	5.43
	75 mm	5.68

TABLE 8

Sl.No	Stretch	NH No.	Length (KM)	Total project cost (Rs.Cr.)	Funded by	Awarded by	Date of start	Date of completion	Contractor	Status	Total cost of bitumen in New Road (Rs. Cr.)	Total savings from 8% plastic mix bitumen (Rs. Cr.)
1.	Panikholi-Rimoli(approved length 106 km)	215	163	1410	BOT	Aug-11	May-13	Jun-16	Gayatri Project Ltd Sai consulting Engg. Pvt Ltd- Indian	Under implementation & ongoing	14.5885	0.83293
2.	2/4 laning of Talcher-Dubari-Chandikhole	23 & 200	132.35	996.37	NHAI	Oct-14	Jun-15	Dec-17	Corson corviam construction S.A-Indian	Under Implementation	11.845325	0.6763085
3.	Krishnanagar-Berhampore	34	78	702.16	Annuity	Feb-11	Feb-12	Feb-17	SEW Infra and YJ Eng. Company Ltd. In association with Feedback Infra. Services Pvt. Ltd-Indian	Under Implementation	6.981	0.39858
4.	4-Laning of Madurai-Ramanathpuram & 2-Laning with PS KM 81	49	115	1387.11	NHAI	Apr-15	May-15	Nov-17	KNR construction Ltd-Indian	Under implementation	10.2925	0.58765

Concrete road vis-s-vis plastic road

The durability of the roads laid out with shredded plastic waste is compared with roads with asphalt with the ordinary mix. Roads laid with plastic waste mix are found to be better than the conventional ones. The binding property of plastic makes the road last longer besides giving added strength to withstand more loads. While a normal 'highway quality' road lasts four to five years it is claimed that plastic-bitumen roads can last up to 10 years. Rainwater will not seep through because of the plastic in the tar. So, this technology will result in lesser road repairs. And as each km of road with an average width requires over two tones of polyblend, using plastic will help reduce non-biodegradable waste. The cost of plastic road construction may be slightly higher compared to the conventional method. However, this should not deter the adoption of the technology as the benefits are much higher than the cost. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes. Already, a kilometer long test-track has been tested in Karnataka using this technology. The government is keen on encouraging the setting up of small plants for mixing waste plastic and bitumen for road construction. It is hoped that in near future we will have strong, durable and eco-friendly roads which will relieve the earth from all type of plastic-waste.

Analysis of the materials (with plastics/without plastics)

A detailed description of the material required for laying of semi dense bituminous concrete (SDBC) 25 mm road (on existing road) is described below:

TABLE 9

Stone aggregate	% of plastic	Moisture absorption	Soundness	Aggregate impact value	Aggregate crushing test	Los Angel's abrasion value	Voids
Without plastic coating	0	4%	5+/- 1%	25.4	26%	37%	4%
With plastic coating	1%	2%	Nil	212	21%	32%	2.2%
	2%	1.1%	Nil	18.5	20%	29%	1%
	3%	Traces	Nil	17.0	18%	26%	Nil

Process features of the polymer-waste-bitumen mix road

Plastic is coated over stone coating easily and the temperature needed is the same as the road laying segregating plastic from the MSW at municipal yard involves application of resources, the cost of which runs into crores of rupees. A substantial amount of this can be saved. Lab tests and real time tests have revealed that the life expectancy of a plastic road, compared to a normal road is at least 100% more. This technique adds a cumulative benefit to national economy also gives contribution to environmental benefits, employment generation and agricultural efficiency.

RESULTS AND DISCUSSIONS

In wet process, waste plastic is used for modification of bitumen, whereas in dry process, waste plastic is used for coating over aggregates.

A detailed description of the material required for lying of Semi Dense Bituminous Concrete (SDBC) 25 mm road (on existing road) is described below:

Cost of waste plastics Rs. 7/- per Kg.

Cost of processing: Rs. 5/- per Kg.

Total cost of waste plastics: Rs. 12/- per Kg.

Optimum percentage of plastic in the blend as per the test results is around 8% (% wt. of bitumen). Generally, roads in India are constructed in basic width of 3.0 m, 3.75 m. and 4.0 m.

Consider 1Km length road of width 3.75 m and thickness 25 mm. It uses approximately 21300 kg (for new work) and 11925 Kg (for up gradation).

Cost of Bitumen per drum (200Kg) – Rs. 8400 /-

Cost of Bitumen per Kg – Rs.42 /-

A. COST OF NEW ROAD/ KM

TABLE 10

BBM, Carpet and seal cost in Rs.	Bitumen Kg/Km	Cost of bitumen in Rs.	Waste plastic, co-processed with bitumen for PMB (8% by wt.) in Kg.	Cost of waste plastic in Rs.	Cost of bitumen saved in Rs.	Total savings in Rs.
18,95,000/-	21,300	8,95,000/-	1,704	20,450/-	71,550/-	51,100/-

B. COST OF ROAD (UPRADATION)/KM

TABLE 11

Carpet and Seal coat in Rs.	Bitumen Kg/Km	Cost of Bitumen in Rs.	Waste plastic, co processed with bitumen for PMB (8% by wt.) in Kg.	Cost of waste plastic in Rs.	Cost of Bitumen saved in Rs.	Total savings in Rs.
10,80,000/-	11,925/-	5,01,000/-	954	11,450/-	40,050/-	28,600/-

Optimum amount of waste plastic used in dry process – 10% (by weight of aggregates).

Total amount of aggregates used in road construction (1Km x 3.75 m x 25 mm) = 3750 m^2 x 12.5 kg/m^2 (avg). = 46,875 Kg.
Therefore, the total amount of waste plastic used in road (10% by weight) = 4687.5 kg.
The total amount of waste plastic used in road construction using both the processes together (i.e combination of wet and dry process) = 1704 + 4687.5 = 6391.5 kg.
So, the total cost of waste plastic used in road using mix process = Rs, 76,700/-
Extra cost for construction of road (cost of waste plastic used in road construction – total savings using modified bitumen) = 76,700/- – 51,100/- =Rs. 25,600/- per Km

C. IMPLICATIONS OF POLYMER-WASTE-BITUMEN MIX ROAD

As road pavement life is doubled when we use this novel technique for road construction, we have to pay only Rs. 25000/- more, instead of spending Rs. 10, 80,000/- for its up gradation in just 2-3 years, thus saving Rs. 10, 50,000/- per Km.
In India more than 4.25 million Km of road is available. If only some of them are constructed or repaired using this technique, there will be less waste plastic littered on the road. The process is eco-friendly. Some of the additional benefits are as follows:

- Road strength is twice stronger than normal roads, resistance towards water stagnation i.e. no potholes are formed, less bleeding during summer and doesn't involve any extra machinery.
- Burning of plastics waste could be avoided
- It doesn't increase cost of road construction and it helps to reduce the consumption of bituminous mix vis-à-vis reduce cost
- It is observed that addition of plastics waste upto10-15% by weight of bitumen resulted into higher values of softening point and lower values of penetration, which are appreciable improvements in the properties of the binder.
- This has resulted and withstood higher traffic load and high temperature variation.
- Several experimental stretches have been laid in more than 15 locations in Tamilnadu using both Mini hot-mix and Central mixing plant.

CONCLUSION

In the modified process (dry process) plastics-waste is coated over aggregate. This helps to have better binding of bitumen with the plastic-waste coated aggregate due to increased bonding and increased area of contact between polymer 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 reduced rutting, raveling and there is no pothole formation. The road can withstand heavy traffic and show better durability. This technique adds a cumulative benefit to national economy also gives contribution to environmental benefits, employment generation and agricultural efficiency.

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