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UTILIZATION OF INDUSTRIAL POLYPROPYLENE (PP) WASTE IN ASPHALT BINDER FOR FLEXIBLE PAVEMENTS

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Abstract - *Various forms of plastic become waste after its use and require large areas of land for storage also inconvenient to recycle. Due to low biodegradability, hazardous plastic fails land filling which not a dominant method for disposal. Innovative method of waste disposal is investigated due to better binding property of plastics in its molten state, by using them in construction of flexible pavement. This paper presents experimental results of the effects of industrial plastic waste added to enhance properties of bitumen and aggregates. A thorough methodological study by Dry Process (5-18%) and Wet Process (1-10%) of mixing added with PP waste by weight of VG-30 bitumen enhances properties of conventional bituminous mix. It is not only determine the physical impact on bitumen and aggregate but also reduces the processing cost in the manufacturing of mix design for the wearing course of flexible pavements by improving strength and durability.*

Key Words: **Industrial PP waste, Bitumen, Aggregate, Non-Biodegradability, Bitumen Mix Design, Cost Analysis.**

1. INTRODUCTION

Due to industrialization, Production of PP industrial waste originated from polymer fibres industry, mat production industry generates huge amount of waste but fails to dispose effectively. Due to its frequent availability towards man, Plastic a building blocks of today's lifestyle. Republic Indians uses 14 million tons of plastics and it is hoped to reach 22 million tons by 2020.

Nowadays, each department of the economy starting from agriculture to packaging, automobile, building construction or InfoTech has been virtually revolutionized by the applications of plastics. Plastics bifurcates as LDPE (PE,PP,PS), HDPE, are used bags, detergent bottles, milk pouches, bottle caps, film wrapping for biscuits, microwave trays for ready-made meals, mineral water bottles, toys, pipes, pens, medical disposables, etc. Production is growing rapidly and the problem is what to do with plastic-waste is standstill. Studies have linked the improper disposal of plastic to problems as distant as breast cancer, reproductive problems in humans and animals, genital abnormalities and much more.

According to recent studies, plastics can stay as long as 4500 years on earth due to their low biodegradability. To solve this problem, waste plastic can be reused productively in the construction of roads. In hot and extremely humid climate, durable and eco-friendly plastic roads are most productive.

Scarcity of bitumen in future needs a deep thinking to ensure fast road construction. Industrial PP waste has useful characteristics and a property which results to enhance the properties of conventional bitumen achieves the cost reduction objective. Lack of convenient method of disposal is one of the major issues for the civic authorities, especially in the urban areas at a same time India needs a large network of roads for its smooth economic and social development. For this purpose most needed innovative method of formation bituminous binder as well as construction of wearing course for flexible pavement is investigate.

1.1 Background and Related Work

Amit Gawande et al, (2012) used modified bitumen with the addition of processed plastic waste of about (5-10% by weight of bitumen) helps in substantially improving the Marshall stability, strength, fatigue life and other desirable properties of bituminous concrete mix. [2]

Sabina, Tabrez A Khan et al, (2009) described the comparative performance of conventional bituminous concrete mixes with bituminous concrete mixes containing plastic/polymer (8% and 15% by weight of bitumen),they concluded that Marshall stability of modified mixes was respectively (1.21 and 1.18) times higher than conventional mixes.[5]

Mohamed et al carried out study in which CRT and LDPE were used to modify virgin asphalt which was added in 3%, 5%, 10%, and 15% by weight. Best results of Marshall Test were obtained below 10% most at 5%.

Prasad et al,(2013),investigated the use of PET waste by mixing 2%,4%,6%,8%,10% with 80/100 grade bitumen and found that MSV, FV, bulk density increases with increase in PET content whereas VFB decreases.OBC was obtained as 5.4% and optimum content of PET was 8%.[1]

1.2 Objective

The main objectives of study are

1. To suggest blending method for industrial PP waste as additive in bitumen.
2. To analyze properties of Bitumen and Aggregate with addition of industrial PP waste as an additive.
3. To select optimum dosage for industrial PP waste in asphalt binder formation.
4. To enhance properties of conventional asphalt binder with an additive as industrial PP waste.
5. To enhance durability of conventional asphalt binder with addition of PP waste.
6. To reduce cost of conventional asphalt binder.
7. To identify alternate method for PP waste reuse in flexible pavement construction and thus, give support to sustainability.

1.3 Conventional Plastic Disposal Methods

Table -1: Conventional Plastic Disposal Methods

Sr. No.	Disposal method	Impact
1.	Land Filling	Ground water and runoff pollution
2.	Incineration	Creates toxic pollutants
3.	Ocean filling	Destruction of sea food
4.	Recycling	Expensive technology is needed
5.	Open dumping	Health hazards and damage to air

2. MATERIALS AND METHODS

2.1 Aggregates

Aggregate was obtained from a local Quarry of required grade and size.

Table -2: Physical properties of aggregates

Test Description	Specification	Values
Combined Flakiness and Elongation Index (%)	IS 2386(Pt. I - 1963)	18
Water Absorption (%)	IS 2389(Pt. I- 1963)	0.5
Specific Gravity	IS 2389(Pt. I- 1963)	2.65
Impact value (%)	IS 2389(Pt. I- 1963)	16

2.2 Plastic Waste as Modifier

Industrial plastic waste name as polypropylene is one of the low density polyethylene polymers collected from the Mat production industry in shredded form.

Properties of Waste Material:

1. Low density polymer
2. Good chemical resistance with binding property
3. Tough and ability to protest friction
4. Good fatigue resistance and heat resistance
5. High impact strength

Table -3: Characteristics of PP

Characteristics	PP Waste
Tensile Strength	0.95-1.30 N/mm^2
Impact Strength	3-30 kj/m^2
Max. Temperature Use	80°C
Melting point	160°C
Density	0.905 g/cm^2

2.3 Bitumen

VG-30 grade of bitumen was used in these investigations to prepare samples.

Table -4: VG bitumen and equivalent penetration grade

Viscosity Grade (VG)	General Applications	Equivalent Penetration Grades
VG - 40	Intersections of roads, truck parking, heavy traffic, higher temperatures	30 – 40
VG - 30	Most suitable for Indian road condition	60 - 70
VG - 20	Areas of cold climate at high altitude	...
VG - 10	Spraying applications, very cold regions	80 – 100

3. EXPERIMENTAL METHODS

3.1 Laboratory Tests

A) Tests on Aggregate

1. Specific Gravity & Water Absorption Test [IS:2386(Part 3)]
2. Aggregate Impact Value Test [IS:2386(part 4)]
3. Stripping Value Test [IS:6241]

B) Tests for Bitumen

1. Softening Point Test [IS:1205-1978]
2. Ductility Test [IS:1208-1978]
3. Flash Point and Fire Point [1448(P:69)1969]
4. Specific Gravity

C) Marshall Stability Test

3.2 Processes for Sample Preparation

1) Dry process

Process includes primary mixing of shredded PP waste over hot aggregates. After coating, coated aggregates are added into hot bitumen along with cement filler and Crush sand to obtained homogeneous bituminous mix for wearing course of flexible pavement.

2) Wet process

Process starts with initial mixing of shredded PP waste in hot bitumen with continuous stirring. Simultaneously, hot aggregates are added into modified bitumen along with crush sand and cement filler to obtained homogeneous bituminous mix for wearing course of flexible pavement.

4. OBSERVATIONS

4.1 Tests on Aggregate

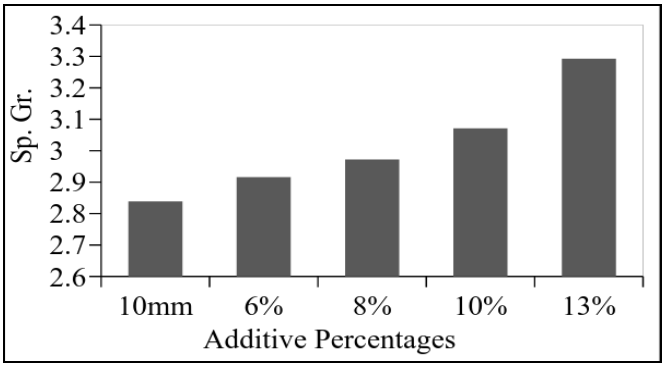


Chart 1- Specific Gravity Test

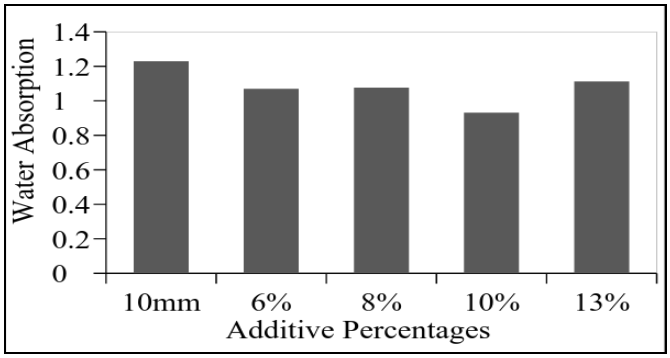


Chart 2- Water Absorption Test

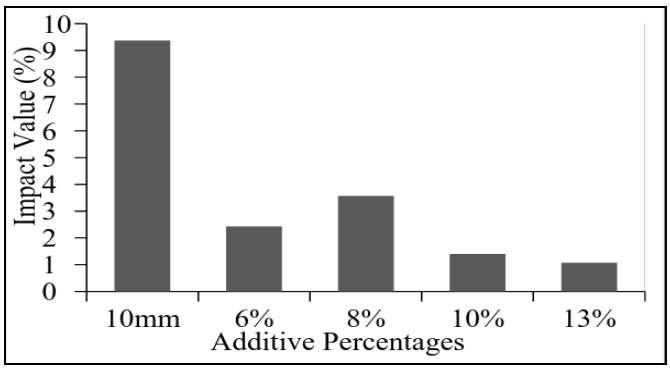


Chart 3- Impact Value Test

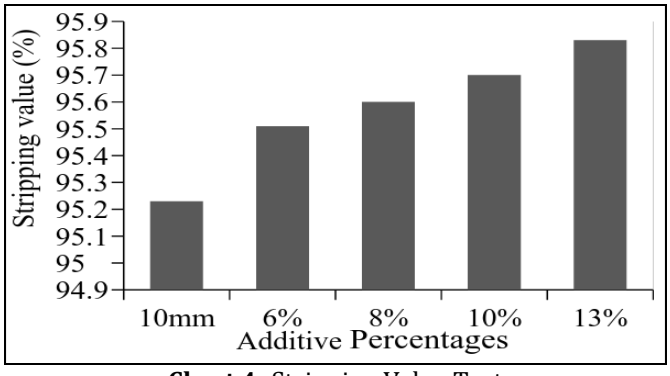


Chart 4- Stripping Value Test

4.2 Tests for Bitumen

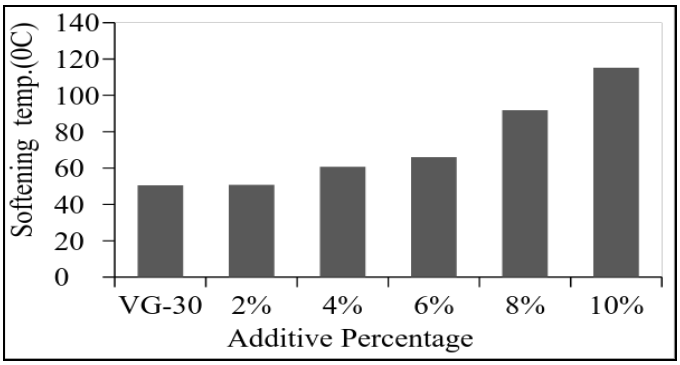


Chart 5- Softening Point Test

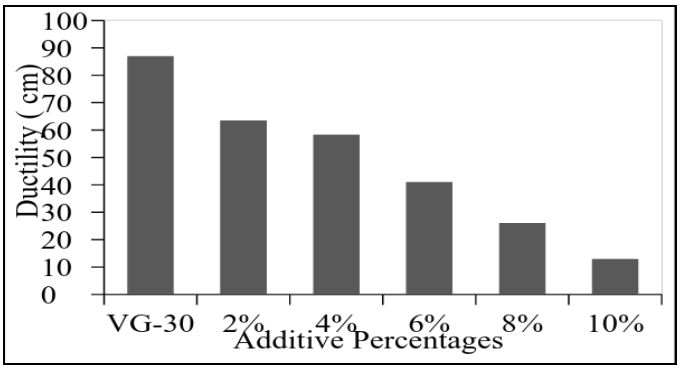


Chart 6- Ductility Test

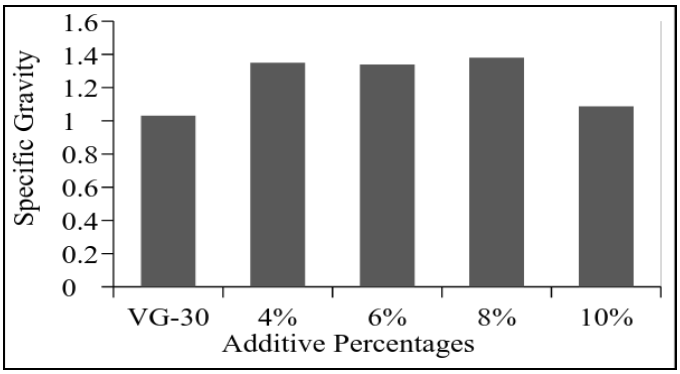


Chart 7- Specific Gravity Test

Table -5: Flash and Fire Point Test

Sr. No.	Additive (%)	Flash Point (^{0}C)	Fire Point (^{0}C)
1	VG-30	176	210
2	4%	148	169
3	6%	152	180
4	8%	162	194
5	10%	190	224

5. CASE STUDY

AIPL, being a leading road construction company in Pune. Currently, the company works on the project name as

"Development and construction of 45 m wide Mumbai Pune Express Highway to Bhakti Shakti Chowk". For that project a Link road is attaches from Highway to Mukai Kivale of 2.5 km Patch. The mix design for the wearing course of flexible pavement of link road to highway is as follows;

Table -6: Mix Design followed by AIPL

Sr. No.	Type of Aggregates	%	Exact Weight
1	10mm	35 %	420 gm
2	6mm	15 %	180 gm
3	Stone Dust	48 %	576 gm
4	Cement Filler	2 %	24 gm
5	Total	100 %	1200 gm
6	Bitumen (VG-30)	5.5 %	66 gm

From site study, the amount of bitumen required is 540 Tons having cost Rs. 28, 85,240. Main aim is to reduce cost as well as amount of bitumen effectively. Testing of modified material for asphalt binder mix will carry under the guidance of Central testing lab at AIPL, Rawet, Pune.

6. BITIMINOUS MIX DESIGN

According to Marshall Stability Test results, Conventional VG-30 bitumen is modified with PP waste for Wearing Course of Flexible Pavement. (Results and mix design data is strictly confidential)

Table -7: Dry Process of Mix Design

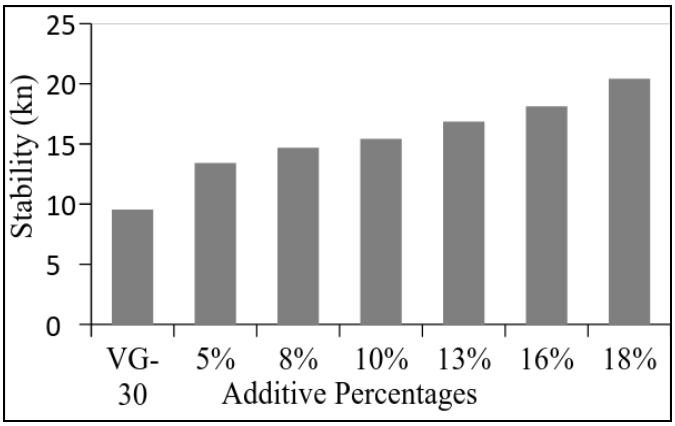
Final Report for BC - 5 %		
Sr. No.	Particular	
1	Aggregate	Proportion
2	10 mm	30.00%
3	6 mm	20.00%
4	Stone Dust	48.00%
5	Cement filler	2.00%
6	PP Waste	8% /wt. of bitumen
7	VG-30 Bitumen % in Total Mix	5.00%
8	Compacted Density (Lab)	2.512 gm/cc

Table -8: Wet Process of Mix Design

Final Report for BC - 5.29 %		
Sr. No.	Particular	
1	Aggregate	Proportion
2	10 mm	30.00%
3	6 mm	20.00%
4	Stone Dust	48.00%
5	Cement filler	2.00%
6	PP Waste	4% /wt. of Bitumen
7	VG-30 Bitumen % in Total Mix	5.29%
8	Compacted Density (Lab)	2.528 gm/cc

7. MARSHALL STABILITY TEST

As per the varying percentages of PP waste, Stability of Dry Process ranges 13.30 – 21.13 KN while flow was between 3.57 – 5.42 mm and Stability of Wet Process ranges 13.65 – 25.38 KN while Flow was between 4.82 – 6.81 mm while bitumen reduces 5.5-5% which satisfies IS recommendations and MORTH limits.



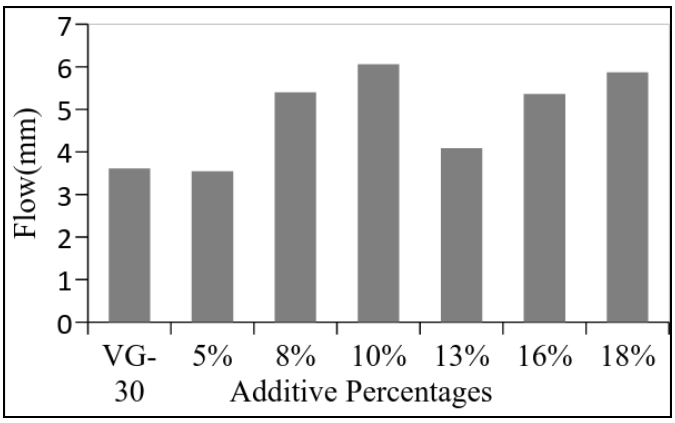
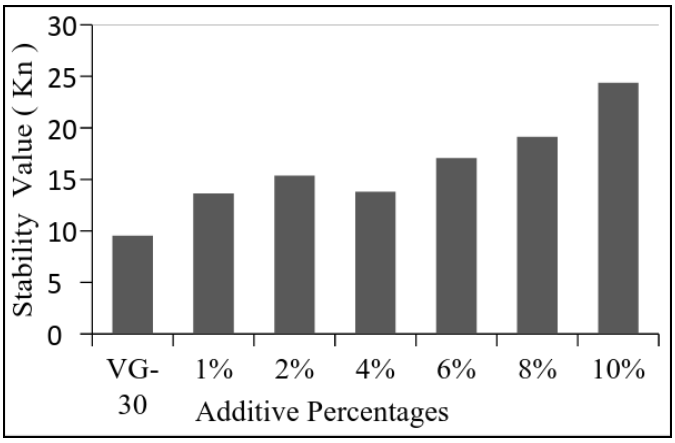


Chart 8- Dry Process of Bituminous Mix Design



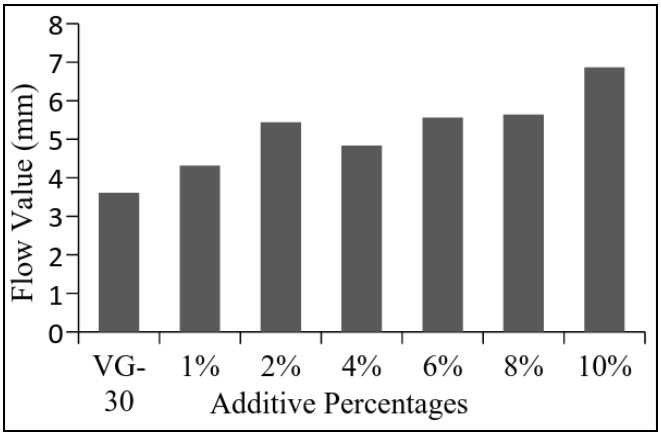


Chart 9- Wet Process of Bituminous Mix Design

8. ECONOMY OF THE PROCESS

Dry Process of Bituminous mix design is most cost efficient to utilize industrial PP plastic waste than Wet Process. For 1 km patch of Two Lanes Highway following results are obtained.

Table -9: Statistical Material Cost Analysis and Savings

Materials	Conventional Bitumen	Dry Process	Wet Process
Bitumen	84.86 T	77.15 T	81.62 T
Cost	28,85,240	26,23,100	27,75,080
Net Saving of Bitumen	-	7.71 T	3.24 T
PP Waste	-	6.17 T	3.26 T
Cost	-	92,250	48,900
Total Cost for 1km road	43,53,507	41,83,617	42,92,247
Net Saving	-	1,69,890	61,260
Carbon credit achieve on avoiding burning of plastic	-	6 T	3 T

9. CONCLUSION

Polymer coating derivate the voids which prevent the moisture absorption and oxidation of bitumen by entrapped air. It has resulted in no pothole formation. Following are some points which are drawn from the study: (ref. IS 73:2013 Table No. 1 Requirements of paving bitumen)

1. Specific Gravity of standard aggregate increases from 2.85 to 2.916 for 6% PP waste and 3.071 for 10% PP waste.
2. Water Absorption reduces to nil for 10% PP and 1.13% for 13% PP waste with respect to standard specimen.
3. Aggregate Impact value of standard specimen was 9.37%. It reduced to 2.43% for 6% PP waste and 1.40% for 10% PP waste. Hence toughness of aggregate increases to face the impacts. The roads can sustain heavy traffic and show better durability.
4. As per MORTH recommendations minimum Stripping value for aggregates is 95%, experimental result for standard specimen is 95.23%. The stripping value varies from 95.60% for 8% PP waste and 95.70% for 10% PP waste. Hence as we increase in the amount of PP waste in standard specimen Stripping value goes on increasing with positive results.
5. As per IS specifications for Softening temperature of standard specimen is minimum 47^0C, while test results for 2% PP waste gives 50.75^0C and 4% PP waste gives 60.75^0C. In India, maximum temperature is up to 50˚C hence, it finalizes that up to 4% PP waste is allowed.
6. As per IS specifications for Ductile nature of bitumen, permissible limit is minimum 40 cm for VG-30 grade. Lab experiment result shows 58.3 cm for 6% PP waste and 41 cm for 6% PP waste. As amount of % PP waste increases, ductility of standard specimen affected and goes on decreasing suddenly.
7. By MORTH limits for Bituminous Mix Design and IRC:SP:98-2013 Guidelines for the use of waste plastic in hot bituminous mixes in wearing course , Dry process of mix design gives most satisfactory results within permissible limits.
8. Marshall Stability Test result helps to integrate the stability of mix as well as flow as per IRC: SP: 98-2013. Increase in stability shows that increase in Strength as well as Durability of mix. Also, dry process utilizes huge amount of PP waste not only gives eco friendly method of disposal but also achieve sustainable growth.
9. Cost analysis on the basis of material cost suggests that Dry process of mix design directly reduces the processing cost more than1 lakh rupees. Almost 6 T of PP waste directly utilize with net saving of 7 T of bitumen of cost 2,38,840.

In brief, Dry process not only helps to save natural resources but also reduce the non-biodegradable PP waste by around 4% by using wet process and 8% by using dry process. Disposal methods like incineration and land filling are totally avoided and ultimately develop a technology, which is eco-friendly. This increases the strength and performance of road.

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