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INTERPRETATION OF BITUMINOUS MIXES WITH MODIFIED BINDERS

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Abstract — *This report shows research carried out to investigate the effect of mixing process on polypropylene (PP) modified bitumen mixed with well graded fine and coarse aggregates to form modified bituminous concrete mix. There are two mode of mixing, namely dry and wet with different concentration of polymer polypropylene was used with 60/70 pen bitumen, to evaluate the bituminous concrete mix properties. Five percentages of polymer varying from 1% - 5% by the weight of bitumen was used in this study. There are three mixes namely control mix, wet mix and dry mix, were prepared. Engineering properties thus obtained at the calculated optimum bitumen content revealed that wet mixing process is advantageous in comparison to dry mixing as it increases the stiffness of the mixture with the increase in polymer content in the bitumen. The stiffness value for wet mix increases with the increase in polymer content which is advantageous in terms of rutting. 1% of PP dry mix also shows improved stiffness, with the air void content limited to 5.8%. The flow behavior of dry mix does not indicate any major difference with the increase in polymer content revealing that polymer acting as an aggregate only without affecting the viscosity of the binder in the mix. Polypropylene when interact with 60 pen base bitumen, it enhances its performance characteristics which were brought about by altered rheological properties of the modified bitumen.*

Keywords: *- Aggregates, Marshall Flow, Marshall Stability, Polymer Modified bitumen, Polypropylene, Stiffness.*

I. INTRODUCTION

Polypropylene was first polymerized to a crystalline isotactic polymer by G.Natta as well as K.Rehn in March 1954. Bituminous binders were widely used by paving industry

(1) Constantly increase of wheel loads, tire pressure and change in climatic condition very badly affect the performance of bituminous mix pavements. Modification of pure bitumen with synthetic polymer binder is considered as solution to overcome the problems arises because of the increase in wheel load and changing climatic conditions.

(2) Modified polymer is considered as one of the solutions to decrease rutting, improve the life and thermal cracking in the pavement.

(3) Rutting is the most common distress in pavement related to load and temperature associated problem in pavement engineering. Make use of binders modification is taken as a solution in order to improve the rutting problem. Modified polymer is usually used to improve the temperature sensitivity of bitumen by increasing binder stiffness at high service temperatures and reducing the stiffness at low service temperatures. Most commonly used polymer globally includes approximately 15% plastomeric, 75% elastomeric modified binder and remaining 10% belongs to either rubber or other modification.

(4) Thermoplastics when used as modifier alter mechanical properties of the mixture by increasing its mechanical behavior in significant manner.

(5) Polymer whether added directly into the mix (dry mixing) or blending of polymer with bitumen (wet blending) significantly alters the rheological behavior of binder. Bitumen when blended with polymer forms a multiphase system, a phase rich in asphaltenes not absorbed by the polymer.

(6) It enhances the viscosity by the formation of more complex internal structure.

(7) While mixing either using chemical or mechanical method the differences in molecular polarity and weight of base bitumen and polymer has critical affect on compatibility.

(8) Thermoplastic when used as modifier it reduces the deformation under load and gives rigidity to the binder. The affect of this is more acute when the concentration of thermoplastic was kept below 1% by weight of the base bitumen.

(9) It also gives better results in terms of Marshall Stability, fatigue life, resilient modulus and water susceptibility when the concentration of polymer was kept up to 2.5% of thermoplastic when mixed with bitumen even at surrounding temperature increases the viscosity and thus stiffness at service temperature but unfortunately do not show any significant elastic behavior. Thermoplastic morphology is strongly affected deformation and under stress as sliding of chains with respects to entanglements occurs at the nodes. Addition of bitumen become better deformation resistance as the viscosity of blend is enhanced excellently which is observed with increase in softening point and decrease in penetration values. When a compatible base bitumen and polymer are mixed, the polymer strands absorbs part of the low molecular weight oil fraction of the base bitumen and become swell, the swell strands connect together at nodes and form a three dimensional network which significantly affects the mechanical properties of the binders and ultimately the bituminous binder mixes.

(10) This study focuses on the use of thermoplastic polymer namely polypropylene (PP), as modifying agent for the 60/70 pen base bitumen. The concentration of polymer in the mix was kept till 5% by weight of the bitumen. Different mixing processes namely wet and dry were used in order to compare the obtained resultant engineering properties which in fact used as indicator of mechanical behavior of modified mix. Three mixes namely control mix; dry mix and wet mix were prepared at 170°C in two ways to know the behavior of mix. In wet mix, the polymer was blended separately with bitumen and then added to aggregate. In dry mix, the polymer was added with aggregate and allowed to mix for 15 min before adding bitumen to the mixer. The objective of dry mixing was to overcome the problem of oxidative ageing, storage stability and economy in terms of reducing the cost of blending of bitumen with polymer at blending facility. The different blending process for this reason provides an overview of the effect of mixing processes on the mechanical strength parameter obtained from different modified bituminous mix.

II. LITERATURE REVIEW

"**Plastic Waste Modified Bituminous Surfacing for Rural Roads" by *Dr. P. K. Jain,(2012)* [1]** carried out study which deals with current imperatives for use of plastic waste in bituminous road construction. Are view of the available and usable plastic waste in bituminous road constructions is given. The findings of R & D conducted in India and countries abroad are summarized. The pilot studies/projects done on the use of plastic waste are discussed. It is found that shredded plastic waste of the size 2-8 mm may be incorporated conveniently in bituminous mixes used for road constructions. The optimum dose is 0.4-0.5 % by weight of bituminous mix and 6- 8% by weight of bitumen. Plastic waste may also be used for up gradations of fly ash for its use as fine aggregate and filler in bituminous road construction.

"Effect of Mixing Process on Polypropylene Modified Bituminous Concrete Mix Properties" by *Noor Zainab Habib, Ibrahim Kamaruddin, Madzalan Napiah and Isa Mohd Tan (2011)* [2] In this paper presents a research conducted to investigate the effect of mixing process on polypropylene (PP) modified bitumen mixed with well graded aggregate to form modified bituminous concrete mix. Two mode of mixing, namely dry and wet with different concentration of polymer polypropylene was used with 80/100 pen bitumen, to evaluate the bituminous concrete mix properties. Three percentages of polymer varying from 1-3% by the weight of bitumen was used in this study. Three mixes namely control mix, wet mix and dry mix were prepared. Optimum binder content was calculated considering Marshall Stability, flow, air voids and Marshall Quotient at different bitumen content varying from 4% - 6.5% for control, dry and wet mix.

III. METHODOLOGY

A. Materials

Materials used in this study include 60/70 penetration grade base bitumen taken from Supreme Bituchem India Pvt Ltd at Nagpur. The polymer Polypropylene PP used for modification was supplied by Bajaj Reinforcement at Nagpur, was in fiber form. Crushed aggregates used in this study obtained from MIC Stones, Nagpur.

- **Aggregates**

For preparation of Bituminous Concrete mixes (BC) aggregates as per MORTH grading as given in Table 3.1 respectively, a particular type of binder and fiber in required quantities were mixes as per Marshall Procedure.

"Table 3.1 Showing adopted aggregate gradation for BC (MORTH)"

Sieve size (mm)	Percentage of passing
26.5	100
19	95
9.5	70
4.75	50
2.36	35
0.30	12
0.075	5

- **Coarse Aggregates**

Coarse aggregates consisted of stone chips collected from a local source, up to 4.75 mm IS sieve size. Standard tests were conducted to determine their physical properties of the aggregates.

- **Fine Aggregates**

Fine aggregates consisting of stone crusher dusts were collected from a local crusher with fractions passing 4.75 mm and retained on 0.075 mm IS sieve.

Aggregate passing through 0.075 mm IS sieve is called as filler.

- **Binder**

Here 60/70 penetration grade bitumen is used as binder for preparation of Mix, whose specific gravity was 1.03. Its important property is given in table 3.2

"Table 3.2 Showing properties of Binder (VG30) 60/70 grade"

Property	Test Method	Value
Penetration at 25^0C (mm)	IS : 1203-1978	65
Softening Point (^{0}C)	IS : 1203-1978	48
Specific gravity	IS : 1203-1978	1.03

B. Sample Preparation

Bituminous sample and Marshall Samples were prepared according to the specified IS code and they are as follows:

- **Polymer modified bituminous sample**

Polymer modified bituminous blend was prepared by mixing about 400gm of bitumen with polymer in shear mixer at 120 rpm, while the temperature was kept at 170°C as the melting temperature of polypropylene lies between 130- 170°C. The concentration of PP was kept as 1% - 5% by weight of bitumen. Mixing was continued for 1 hr to produce homogenous mixtures. The modified bitumen was then sealed in containers covered with aluminum foil and stored for further testing and Marshall Sample preparation. Experimental test such as penetration, softening point and viscosity were conducted on the prepared samples. For dry mixing polymer was added directly with aggregate in mixer and was allowed to mix for 15 minutes before addition of bitumen.

- **Marshall Samples**

All Marshall Samples were prepared according to IS: 2386 (P IV). Standard size 10.16 cm diameter and 6.35 cm high samples were prepared by using compaction pedestal and hammer is used to compact a specimen by 4.54 kg weight with 45.7 cm height of fall. For Marshall Sample preparation, 1200gms of well graded aggregate according to MORTH specification was blended with bitumen at varying bitumen percentage between 3.5% - 6.5%, in order to get the optimum bitumen content for a mix. Three different types of Marshall Samples were prepared namely control mix prepared with virgin bitumen, wet polymer modified Marshall Samples using polymer modified bitumen with varying polymer concentration between 1% - 5% by weight of bitumen, where blending of PMB was done before mixing with aggregates and dry blend modified Marshall Samples, prepared by adding polymer (1% - 5% by weight of bitumen) directly with the aggregates before adding bitumen. Engineering properties calculated at optimum binder content for all three types of mixes, were then compared with IS: 1203-1978 standard values.

IV. LABORATORY INVESTIGATION

A. Penetration Test (IS: 1203-1978)

The penetration test is widely used for classifying the bituminous materials in to different grades. It determines the hardness of these materials by measuring the depth in tenths of a millimeter to which a standard needle will penetrate vertically under specified condition of standard load, time and temperature, which are100g, 5 second and 25^0C respectively.

"Figure 4.1 Photographs of Penetration Test Apparatus"

- **Apparatus**

- Container- A flat bottomed cylindrical metallic container 55 mm in diameter and 35 mm or 57 mm in ht.
- Needle- A straight, highly polished cylindrical hard steel needle with conical end. Needle is provided with a shank appropriately 3 mm in diameter into which it is immovably fixed.

- Water Bath- A water bath is maintained at 25 + 1 °C containing not less than 10 liters of water, the sample is immersed to depth not less than 100 mm from top and supported on a perforated shelf not less than 50 mm from the bottom of the bath.
- Penetrometer- It is an apparatus which allows the needle to penetrate without appreciable friction. It is accurately calibrated to yield results in hundreds of centimeters "These days automatic penetrometers (eclectically operated) are also available.
- Transfer Tray- A small tray which can keep the container fully immersed in water.
- Heating stove to heat and soften the bitumen.
- Stop watch

➢ **Test Procedure**

The bitumen is heated to 75^0 C to 100^0 C above the above the approximate temp at which bitumen softens. The sample material is thoroughly stirred to make it homogeneous and free from air bubbles and water. The sample containers are cooled in atmosphere of temperature not lower than 13°C for one hour. Then they are placed in temperature controlled water bath at a temperature of 25°C for a Period of one hour. The sample is immersed to depth less than 100 mm from the supported, perforated shelf not less than 50 mm from the bottom of the bath.

The weight of needle, shaft and additional weight are checked. The total weight of this assembly should be 100 g. using the adjusting screw, the needle assembly is lowered and the tip of the needle is made to just touch the top surface of the sample. The needle assembly is clamped in this position. The contact of the tip of the needle is checked using the mirror placed on the rear of the needle. The initial reading of the penetrometer dial is either adjusted to zero or the initial reading is noted. Then the needle is released by pressing a button and a stop watch is started. The needle is released exactly for a period of 5.0 seconds. At least 3 measurements are made on this sample by testing at distance of not less than 100 mm apart. The test is to be repeated for 1% - 5% of Polypropylene.

B. Marshall Test

Marshall Mix design is a standard laboratory method, which is adopted worldwide for determining and reporting the strength and flow characteristics of bituminous paving mixes. We will carry out three different bituminous mix concrete sample namely control, wet and dry mix. This test method is widely accepted because of its simplicity and low of cost. Considering various advantages of the Marshall method it was decided to use this method to study various Marshall Characteristics such as Marshall Stability, flow value, stiffness, air voids etc.

"Figure 4.2 Photographs of Marshall Stability Test Apparatus"

➢ **Apparatus**

- Marshall Stability testing machine
- Cylindrical mould – 10 cm. diameter and 7.5 cm. height
- Rammer – 4.5 kg. weight with free fall of 45.7 cm
- Compacting Machine
- Oven
- Thermometer
- IS Sieves

➢ **Test Procedure**

In the Marshall Test method of mix design three compacted samples are prepared for each binder content. At least four binder contents are to be tested to get the optimum binder content. All the compacted specimens are subject to the following tests:
· Bulk density determination.
· Stability and flow test.
· Density and voids analysis.

V. RESULTS AND ANALYSIS

A. Penetration Results

Penetration test was conducted with different percentages of PP as 0%, 1%, 2%, 3%, 4%, 5% and 6% are tabulated in the following tables.

"Table 5.1 Showing Penetration value for 0% PP"

Sl. No.	Dial Reading (in mm)		Penetration (in mm)	Average Penetration in mm
	Initial	Final		
1	300	367	67	65
2	290	353	63	
3	320	385	65	

"Table 5.2 Showing Penetration value for 1% PP"

Sl. No.	Dial Reading (in mm)		Penetration (in mm)	Average Penetration in mm
	Initial	Final		
1	100	132	32	32
2	160	193	33	
3	220	251	31	

"Table 5.3 Showing Penetration value for 2% PP"

Sl. No.	Dial Reading (in mm)		Penetration (in mm)	Average Penetration in mm
	Initial	Final		
1	200	228	28	29
2	190	221	31	
3	140	168	28	

"Table 5.4 Showing Penetration value for 3% PP"

Sl. No.	Dial Reading (in mm)		Penetration (in mm)	Average Penetration in mm
	Initial	Final		
1	90	117	27	27
2	150	178	28	
3	200	226	26	

"Table 5.5 Showing Penetration value for 4% PP"

Sl. No.	Dial Reading (in mm)		Penetration (in mm)	Average Penetration in mm
	Initial	Final		
1	120	145	25	26
2	150	176	26	
3	180	207	27	

"Table 5.6 Showing Penetration value for 5% PP"

Sl. No.	Dial Reading (in mm)		Penetration (in mm)	Average Penetration in mm
	Initial	Final		
1	50	76	26	25
2	80	104	24	
3	110	135	25	

From the above tables for virgin bitumen and PP modified bitumen, there is a sharp decrease in the penetration value of 65 dmm for virgin bitumen to 32 dmm for 1% PP concentration shows that increase in the hardness of the PMB was because of the use of the high molecular weight polymer PP with melt flow Index of 8g/10 min, enhances the hardness of PMB. It is obvious from the observation that thermoplastics influence more on the penetration with the increase in the viscosity of the bitumen as can be observed by the decrease in the value of penetration with the increase in concentration of polymer. The melting temperature of PP is 170°C, thus it absorbs some oil from the bitumen and releases low molecular weight fraction into the bitumen which increases the viscosity of the PMB. The hardening of the bitumen can be beneficial as it increases the stiffness of the material, thus the load spreading capabilities of the structure but also can lead to fretting or cracking.

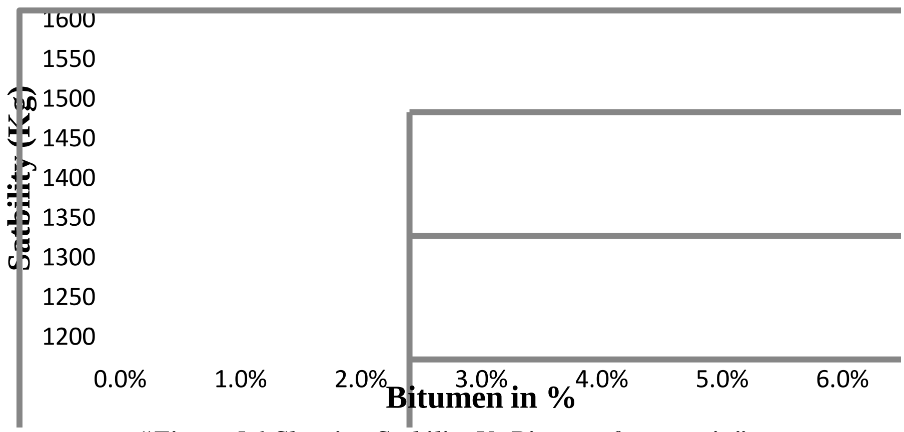
B. Marshall Test Results

Marshall Test was conducted for various mixes as control, dry and wet mixes are tabulated in the following tables.

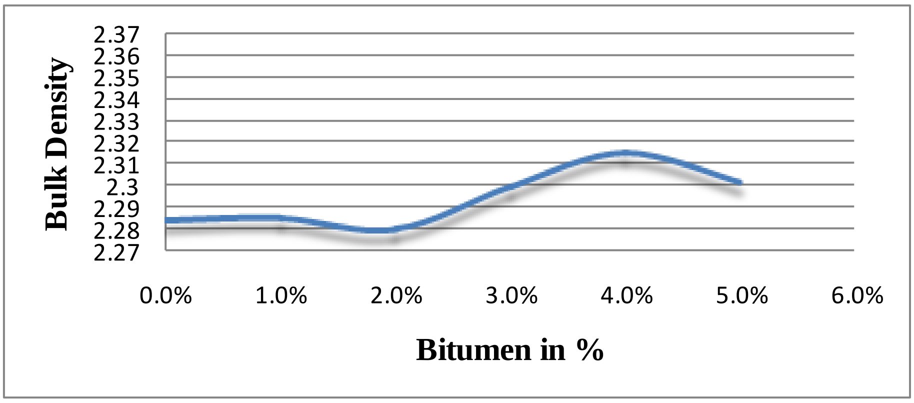
"Table 5.7 Showing Marshall Sample for Wet modified bitumen"

PP %	specific gravity of Aggregate (Gt)	specific gravity of bitumen (Gb)	Volume of air Void (Vv%)	Volume of bitumen (Vb %)	Void in mineral Aggregate (VMA=Vv +Vb)	Void filled with bitumen (VFB)	Stability Value, kg	Flow Value in 0.25mm	Stiffness
Control Mix	2.43	2.284	6.00	11.776	17.770	66.27	1231	2.40	5.12
1% PP Wet mix	2.43	2.285	5.96	11.763	17.723	66.37	1272	2.52	5.04
2% PP Wet mix	2.42	2.280	5.78	11.858	17.638	67.23	1291	2.89	4.46
3% PP Wet mix	2.41	2.300	4.56	11.715	16.275	71.98	1300	2.97	4.37
4% PP Wet	2.41	2.315	3.94	11.581	15.52	74.61	1552	2.95	5.26

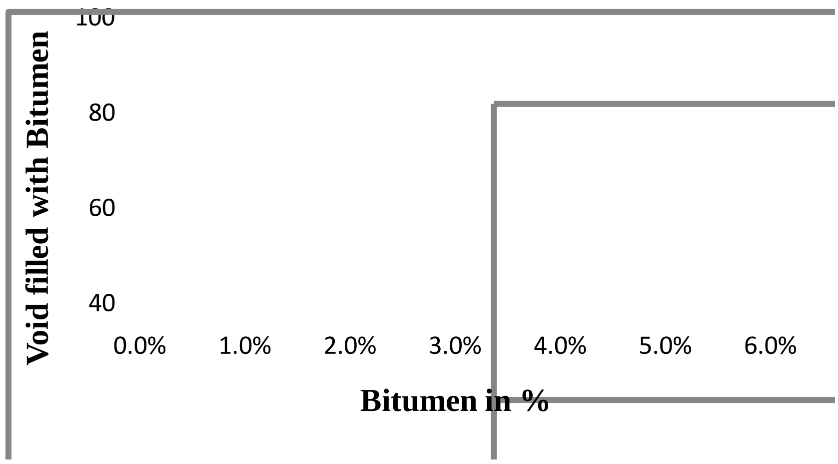
mix									
5% PP Wet mix	2.40	2.302	4.08	11.592	15.672	73.96	1413	2.90	4.87



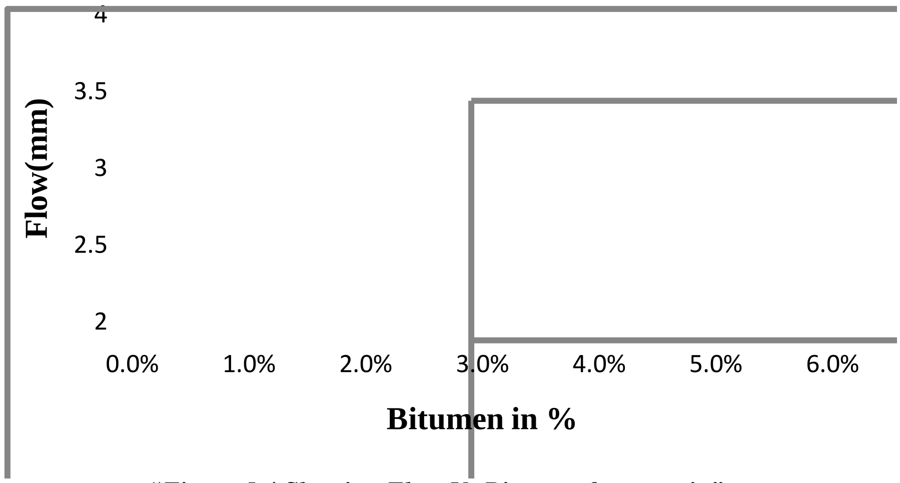
"Figure 5.1 Showing Stability Vs Bitumen for wet mix"



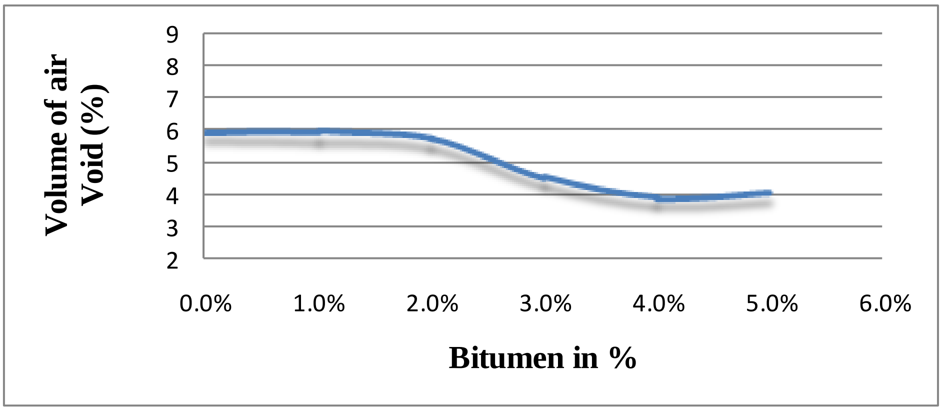
"Figure 5.2 Showing Bulk density Vs Bitumen for wet mix"



"Figure 5.3 Showing Void filled with bitumen Vs Bitumen for wet mix"



"Figure 5.4 Showing Flow Vs Bitumen for wet mix"



"Figure 5.5 Showing Volume of air void Vs Bitumen for wet mix"

Mixes with the higher internal resistance offers resistance to densification as observed for wet PP modified samples except for 5% PP wet mix which is almost equal to plain mix. The results revealed that for wet blend samples binder acts as lubricating agent allowing sliding of aggregates with each other thus enhancing the elastic and plastic properties of the bituminous concrete mixture. The Mixes upto 4% shows better performances and beyond 5% PP wet mix samples decreases in flow was observed which may be due to agglomeration of polymer resisting the sliding past of particles as observed from the test results. High stiffness values indicate a mix with a greater ability to spread the applied load and resistance to creep deformation. The characteristic would be beneficial in enhancing creep modulus of the mix which can be taken upto 4%.

VI. CONCLUSIONS

From this study following conclusions have been drawn

1. It was found that mixing processes used for manufacturing of polymer modified bituminous concrete has profound effect on the engineering properties.
2. Plain and modified wet bituminous mixtures meet the requirement of MORTH specification.
3. The methodology of binder used for wet mix as observed by penetration tests revealed that increase in polymer content decreases the penetration of the modified binder.
4. Binder theology significantly affects the stiffness, flow and density of the wet bituminous mix.
5. Softening temperature are least affected by thermoplastic modification thus considered a positive point considering the application side.
6. 4% PP modified wet bituminous mixture shows promising performance in terms density, stability and stiffness in comparison to 1, 2, 3 and 5% wet bituminous mixture.

A. **FUTURE SCOPE**

The present study can be explained on following points:

1. To study detailed laboratory investigation to find whether the use of polypropylene material in bituminous concrete will be viable to use or not in terms of suitability, economically and environmentally.
2. To study the basic physical and mechanical properties of polypropylene in order to contribute a better knowledge of its properties.
3. To study the effect on Marshall Stability of bituminous mix with the addition of polypropylene.
4. To reduce the bitumen content by the addition of polypropylene in bituminous mix.

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