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A Study of Rutting Characteristics of Conventional and Modified Bituminous Concrete Mix

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ABSTRACT:-Rutting is defined as the accumulation of small amounts of unrecoverable strain resulting from applied loads to the pavement. In sort it is a vertical depression observed in road in longitudinal fashion. Due to repeated heavy axle wheel load, on the path of wheel this depression occurs longitudinally. The present investigation is carried out to propose the use of waste plastic and crumb rubber in bituminous mix of flexible pavements in order to improve their performance and also to give a way for safe disposal of plastic wastes and crumb rubber to provide a solution to threat of environmental pollution as well. In this study the dry process is used for waste plastic modified bituminous concrete mix and wet process is used for crumb rubber modified BC mix. The Marshall method of mix design is adopted to find the optimum bitumen content. Rutting in conventional BC mix at optimum binder content and in both modified (crumb rubber and waste plastic) BC mix by adding 10% crumb rubber and 10% waste plastic is determined at 40^0C, 50^0C and 60^0C by passing 2500 number of passes at 0.7 MPatyre pressure. Minimum rutting is observed in waste plastic modified mix.
Effect of variation of binder content on rutting is also studied in conventional and modified mix and it is found that on increasing or decreasing binder content beyond OBC the rut depth always increases.

I. INTRODUCTION

Rutting is the permanent deformation in pavement usually occurring longitudinally along the wheel path. The rutting may partly be caused by deformation in the subgrade and other non-bituminous layers which would reflect to the overlying layers to take a deformed shape.
Development of modified bituminous mix to improve the overall performance of pavements has been the focus of several research efforts made over the past few decades. using crumb rubber (CR) and waste plastic (WP) to improve the performance of bituminous mixes.

1.2 Causes of rutting

Following are the some causes of rutting-
- Heavy traffic volume
- Inadequate compaction of the mix at the surface or in the underlying courses during construction
- Improper gradation of aggregate
- Improper mix design
- Lacking in the stability of mix to support the traffic etc.

1.3 Solutions to prevent rutting

To prevent rutting in bituminous pavements following are some of the solutions-
- Proper gradation of aggregates
- Using appropriate quantity of binder content
- Proper mix design
- By using modifier such as crumb rubber and waste plastic in mix or modified binder in place of conventional bitumen

Rutting resistance potential of any bituminous mix depends on the properties of its constituents. In this study crumb rubber and waste plastic is used to modify constituent's properties. Crumb rubber is the common name used for granulated rubber produced from scrap types. Plastic waste used in this study refers to polybags generally used as carry bags for different grocery items.

Fig1.1 Rutting phenomenon occurrence in bituminous pavement

In this study laboratory evaluation of rutting is done with the help of wheel tracker equipment in which rut depth on specimen is measured simulating field conditions of traffic and environment. Wheel Tracker or Wheel Rut Tester generates rut on a specimen of bituminous mix prepared with the help of Wheel Rut Shaper. Studies shows that wheel tracker devices proved to be most
reliable equipment for rutting measurement in laboratory.

2. OBJECTIVE OF THE STUDY

Following are the objectives of the research work-

- To find out the Marshall stability and other Marshall parameters of conventional Bituminous Concrete (BC) mix & modified BC mix.
- To study the effect of Waste Plastic (WP) & Crumb Rubber (CR) on rutting characteristics of BC mix.
- To study the effect of temperature variation on rutting behaviour of Conventional BC mix and Modified BC mix.
- To study the effect of variation of binder content on rutting characteristics of Conventional BC mix & Modified BC mix.

3 Equipments& Testing of Materials

3.1 Material Used

3.1.1 Aggregates

For the study, crushed coarse aggregate and fine aggregates are selected in required sizes.
For grading of aggregate the specification which is given in MORT&H is taken. There are two gradations given for bituminous concrete layers, grade-I and grade- II. For the present study grading-I (mid point gradation) is selected to carried out different test.Mid-point gradation for Bituminous Concrete (BC) gradation-I is a dense gradation in which nominal aggregate size of 19 mm and layer thickness of 50 mm as per MORT&H guidelines (2013). The aggregate grading is given in Table-3.1

3.1.2 Filler

In the present study cement (passing 0.075 mm sieve) is selected as filler material. The specific gravity of filler is 3.14

3.1.3 Binder

For the bitumen specification as per MORT&H guidelines, it shall be viscosity graded paving bitumen complying with Indian Standard specification for paving bitumen, IS: 73. The type and grade of bitumen to be used would depend upon the climatic conditions and traffic. In the present study VG-30 grade bitumen is used as a binder. When the highest daily mean air temperature is more than 30^0C and lowest daily mean air temperature is more than -10^0C, VG-30 grade bitumen should be used for construction work.

3.2 Crumb Rubber & Waste Plastic

3.2.1 Crumb rubber

Crumb rubber usually consists of particles ranging in size from IS 4.75 mm to less than IS 0.075 mm. Crumb rubber used in hot mix asphalt normally has 100 percent of the particles finer than 4.75 mm. Some crumb rubber particles may be as fine as 0.075 mm. The specific gravity of crumb rubber is approximately 1.15, and the product must be free of fabric, wire, or other contaminants. In the present study Crumb rubber passing sieve IS 425μ (- 0.425mm) is used as modifier for BC mix.

Table 3.1- Composition of Bituminous Concrete Pavement layers (Section 500 as per MORT&H guidelines)

Grading	1	Adopted (Mid Point) gradation
Nominal aggregate size	19 mm	19 mm
Layer thickness	50 mm	50 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	Cumulative % by weight of total aggregate passing
45	-	-
37.5	-	-
26.5	100	100
19	90-100	95
13.2	59-79	69
9.5	52-72	62
4.75	35-55	45
2.36	28-44	36
1.18	20-34	27
0.6	15-27	21
0.3	10-20	15
0.15	5-13	9
0.075	2-8	5
Bitumen content, % by mass of total mix	Min 5.2	Min 5.2

3.2.2 Waste Plastic

The processed waste plastic bags (mostly LDPE) from the garbage of local area in the shreddedform are used as modifier for bituminous concrete mix. The size of shredded waste plastic is taken for the present study passing through 4.75 mm IS sieve and retained on 300 μ IS sieve & thickness between 10 μ to 30 μ. The specific gravity of waste plastic is approximately 0.95

3.3 Equipments used

For the present research work following equipments are used in the study-

- Marshall stability testing machine
- Wheel rut shaper
- Wheel rut tester

3.3.1Marshall Stability testing machine

Marshall Stability testing machine is used for find out the stability and flow value of bituminous mix. The machine consists of a motorised loading unit provided with a gear system to lift the base plate upward at the specified rate.

Marshall Stability testing machine and essential accessories consists of the following-

- Compaction Mould Assembly: - This consists of (a) Compaction mould of cylindrical shape of diameter 101.6 mm and height 63.5 mm, a collar extension and a base plate. (b) Compaction hammer of weight 4.5kg which can be lifted and released to obtain 457mm drop.
- Specimen Extractor: - for extruding the compacted specimen from the mould.
- Testing head:- It consists of upper and lower cylindrical segments of test head with an inside radius of curvature of 51 mm. The lower segment is mounted on a base having two vertical guide rods which facilitate insertion in the holes of upper test head.
- Testing Machine: - Capacity of loading machine is 5 tonnes and applying load on specimen at a rate of 50 mm per minute.
- Dial gauge: - fixed to the guide rods of the testing machine serves as flow meter to measure deformation of the specimen during loading.
- Other accessories: - thermostatically controlled water bath, thermometer, mixing devices etc.

Figure 3.1- Marshall Stability Testing Machine

3.3.2 Wheel Rut Shaper

With the help of wheel rut shaper the specimen can be compacted to required density and thickness. Roller (Runner wheel) which is connects with machine compact the specimen up to the required thickness. Before compaction of specimen, heat up the runner wheel to the temperature required for the experiment. Following are the main technical index of the machine-

- Radius of roller- 500 mm
- Width of roller- 300 mm
- Speed of velocity model- 6 times round trip/min
- Pressure of roller- within 20 kN
- Warm-up temperature- 20 to 200 degree

Fig3.2 Wheel Rut Shaper

3.3.3 Wheel Rut Tester

Wheel rut tester is used as to find out rut depth in bituminous concrete mix for different number of passes and for different temperatures under the loading similar to what the pavement surface is applied. Wheel rut tester with the reciprocating motion of loaded wheel on bituminous specimens determines the potential of asphalt pavement rutting. Following are the main technical index of Equipment-

- Pressure wheel speed: 42±1 time/min (single way)
- Moulds size: 300x300x50mm(standard),here the moulds height can be in a range between 30-100mm
- Displacement measuring range: 0-30mm
- Displacement measuring precision: less than ±0.005mm
- Testing time of rutting wheel: 60 minute
- Adjusted range of the controlled temperature: 40-60°C

Fig 3.3 Wheel Rut Tester

3.4 Tests on Aggregates and Bitumen

In order to find out the properties of aggregates some tests are performed in the laboratory such as Impact test, Abrasion test, Shape test, Specific gravity and water absorption test and for bitumen Ductility test, Penetration test, Specific gravity test, &Softening point tests are performed. The results obtained after test are tabulated in Table 3.2 and Table 3.3

Table 3.2- Properties of Aggregates

Sr. No.	Properties	Obtained Results	Range of Values as per IS/MORT&H Specifications
1.	Aggregate Impact Value, %	9.5%	Max 24%
2.	Los Angeles Abrasion Value, %	13%	Max 30%
3.	Combined Flakiness & Elongation Index, %	22%	Max 35%
4.	Specific gravity	2.8	2.5 to 3.2
5.	Water absorption,%	0.6%	Max 2%

Table 3.3- Properties of Bitumen

Sr. No.	Properties	Obtained Results	Test Method
1.	Penetration, at 25^0C (0.1mm)	67	IS:1203-1978
2.	Softening point (R&B), ^{0}C	50	IS:1205-1978
3.	Ductility (cm)	75.8	IS:1208-1978
4.	Specific gravity	1.01	IS:1202-1978

3.5 Properties of crumb rubber modified bitumen

For modified bituminous mix the crumb rubber and waste plastics are used as modifier. For mixing Crumb rubber the wet process (i.e. crumb rubber is added to the bitumen before mixing it with aggregate) & for waste plastic dry process (i.e. shredded waste plastic is added to the aggregate before mixing it with bitumen) is adopted.

3.5.1 Preparation of Crumb Rubber Modified Bitumen- For preparation of Crumb Rubber modifiedbitumen, VG-30 grade normal bitumen is heated to a temperature of 160°C before the addition of crumbrubber. After the bitumen is heated up to the required temperature the crumb rubber is mixed with bitumen. The blend is mixed at low speed for about 5 min. After thisthe mixture is heated to 175°C and agitated vigorously for about30 to 40 minute using a mechanical stirrer or mixer which is operated at 500 rpm. Blendingtemperature is maintained between 175 and 180°C. The properties of crumb rubber modified bitumen is given in Table 3.4

Table 3.4- Properties of CR Modified Bitumen

Sr. No.	Properties	Obtained Results		
		CR-5	CR-10	CR-15
1.	Penetration, at 25^0C (0.1mm)	52	48	45
2.	Softening point (R&B), ^{0}C	58	62	65
3.	Ductility (cm)	60	57	56
4.	Specific gravity	1.02	1.02	1.02
5.	Elastic Recovery at 15^0C, %	59	66	64

Where CR-5, CR-10, CR-15 represents crumb rubber contents 5%, 10%, 15% (by weight of bitumen) respectively which are mixed with bitumen.

3.5.2 Properties of Waste Plastic coated aggregates

For adding waste plastic in the mix, dry process is used. In dry process plastic is added to hot aggregates (at 180^0C) and mixed thoroughly. Waste plastic gets coated on the surface of aggregates uniformly. Then bitumen is added to the waste plastic coated aggregates and mixed to get a uniform modified BC mix. The properties of waste plastic coated aggregates are given in Table 3.5

Table 3.5- Properties of WP coated Aggregates

Sr. No.	Properties	Obtained Results		
		WP-5	WP-10	WP-15
1.	Aggregate Impact Value, %	8.3	8.0	8.2
2.	Los Angeles Abrasion value, %	11.3	11.2	11.5

II. METHODOLOGY & MIX DESIGN

4.1 Methodology

The present study is focused on the rutting characteristics of 50 mm thick conventional and modified bituminous concrete mix using optimum binder content &to find out the rut depth for different variables like number of passes, temperature, and binder content for bituminous concrete mixes. The BC mix design details obtained like Stability, flow, VMA, VFB and Vv for conventional and modified BC mix are

After the study of different literatures, the following methodology is adopted step by step for the further study-

- Selection of Aggregate and Binder
- Testing of materials used in the study
- Mix design of bituminous mix
- Preparation and testing of Marshall Specimens
- Preparation and testing of Rutting Specimens
- Analysis of results obtained from Marshall test and Rutting test

4.2 Mix Design of Bituminous Mixes

Following steps are followed for a design of a bituminous mix by Marshall method-

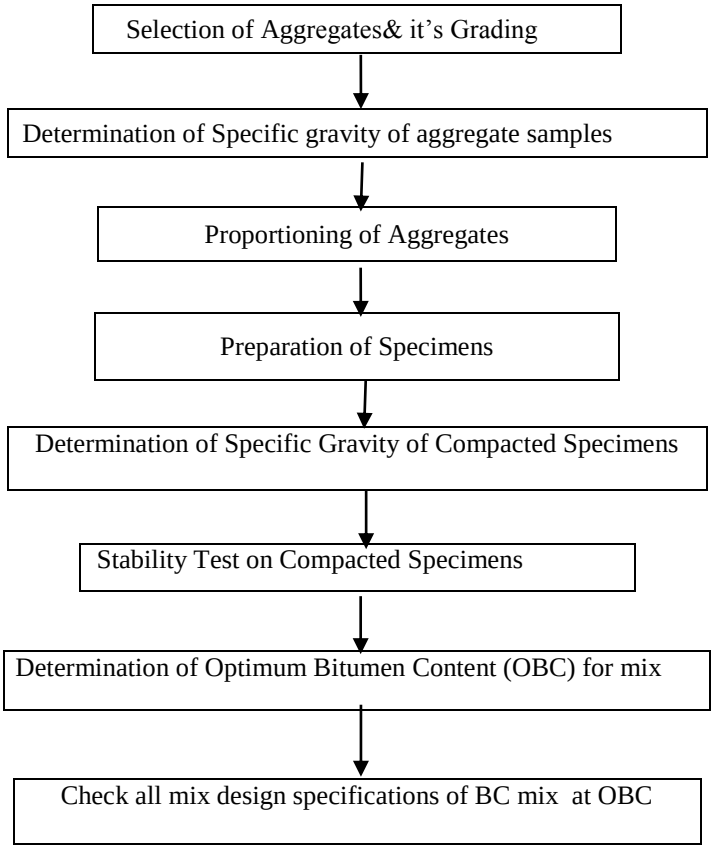

Figure 4.1 Flow chart for mix design

Table 4.1- Mix design specifications for BC according to MORT&H

Properties	Specifications
Marshall Stability value, kN (minimum)	9.0 (For VG grade) 12.0 (For Modified Bitumen)*
Marshall flow value, mm	2-4 (For VG grade) 2.5-4 (For Modified Bitumen)*
Air voids in mix ,Vv %	3-5
Voids Filled with Bitumen, VFB %	65-75
Voids in Mineral Aggregates, VMA %	12-14

*on considering hot climate

4.3 Procedure for Sample preparation

For the present study specimens are prepared for Marshall Test and Rutting test. For each type of bituminous mixes samples are prepared by varying binder contents in five different contents 5%, 5.25%, 5.5%, 5.75% and 6% (by weight of total mix) for both conventional and modified mix. For the preparation of conventional mix plane bitumen,VG-30 grade used as a binder& for modified mix binder content includes both bitumen content and modifier content. There are the some details related to modified mix given below in table.

Type of modified mix	**Method/Process used**	**% Waste Plastic or %Crumb Rubber (by weight of bitumen)**
Crumb rubber modified mix	Wet Process	5%
		10%
		15%
Waste plastic modified mix	Dry Process	5%
		10%
		15%

4.3.1 Preparation of specimen for Marshall Stability test-

- Weigh the aggregates and filler (approximately 1200 g) & mix it properly and heated to a temperature of 175^0C to 190^0C.
- The bitumen is also heated to a temperature of 120^0C to 165^0C.
- Add the weighed quantity of heated bitumen to the heated aggregate and the mixture is thoroughly mixed at the specified mixing temperature. The recommended mixing temperature for VG 30 grade bitumen is about 160^0C.
- For Modified Bituminous concrete mix Crumb rubber mixed by wet process and shredded Waste Plastics are mixed by dry process.
- After mixing thoroughly, the bituminous mix may be allowed to slightly cool down to recommended compacting temperature. The recommended compacting temperature is about 150^0C for VG 30 grade bitumen.
- Prepared mixture transferred in the mould & compacted by hammer, by applying 75 blows on either side.
- After the compaction, the specimen with the mould is allowed to cool down to the room temperature.
- After this the test specimen is carefully extruded from the mould and determined the volumetric properties and stability value of the samples.

Figure4.2 Marshall specimen

Figure4.3 Marshall Stability Testing

4.3.2 Preparation of specimen for rutting test

For the rutting test the dimension of specimens is 300mmx300mmx50mm. Plain bitumen of VG-30 grade and crumb rubber &shredded waste plastics are used for the study. The specimens are prepared for both type of mix i.e. conventional and modified.

- Take the different size of aggregates according to grading & mix the aggregate with filler properly and weigh accurately for each specimen.
- Take all the weighed aggregates into the pan and heat the aggregates up to 175^0C - 190^0C. Bitumen is also heated to a temperature of 120^0C to 165^0C.
- Add binder to the aggregate and mix it properly. The mixing temperature should be between 150ºC to160ºC.
- For Modified bituminous concrete mix Crumb rubbers are mixed by wet process and shredded Waste Plastics are mixed by dry process.
- After this the prepared mix should be filled in the rut mould when the temperature of the mix is between 120ºC to 145ºC.
- Compact the mix at a constant rate of loading using Wheel Rut shaper up to a required thickness of 50 mm & desired density of the mix.
- Cure the specimen in air for 24 hours.
- Perform the test to find out the rut depth, in wheel rut testing machine by applying0.7 MPa tyre pressure.

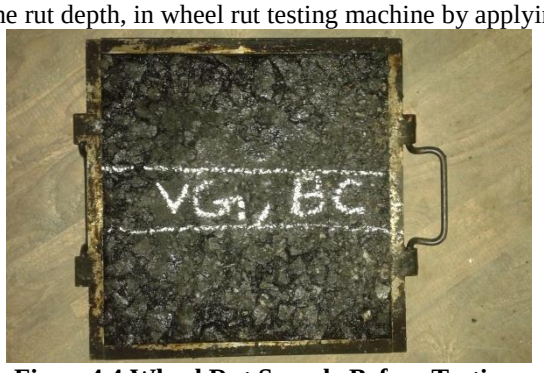

Figure4.4 Wheel Rut Sample Before Testing

Figurte4.5 Wheel Rut Sample After Testing

III. PERFORMANCE EVALUATION TESTS

Following two tests are performed in the laboratory –

- Marshall Stability test
- Wheel rut test considering different variables like temperature, binder content, type of mix.

5.1 Marshall Stability Test

In Marshall Method of mix design VG-30 grade bitumen is used to find the optimum bitumen content (OBC) in conventional and modified mix. The Marshall Specimens are prepared at bitumen content ranging from 5% to 6% with an increment of 0.25% by weight of total mix. For modified mix, waste plastic content is 5%, 10% and 15% & crumb rubber content is 5%, 10% and 15% by weight of bitumen used. The different volumetric properties like air voids (Vv), VMA, VFB and Marshall Stability value & flow value are determined for both conventional and modified mix

Table5.1 Maximum Marshall stability for conventional and modified bitumen mixes

Types of Bitumen mixes	Maximum stability For grading-I
VG30	14.27
5% CRMB	15.1
10% CRMB	16.3
15% CRMB	14.82
5% WP	14.96
10% WP	17.47
15% WP	15.15

Table5.2 Maximum Density for conventional and modified bitumen mixes

Types of Bitumen mixes	Maximum DensityG_m(g/cc)
VG30	2.462
5% CRMB	2.470
10% CRMB	2.472
15% CRMB	2.466
5% WP	2.468
10% WP	2.474
15% WP	2.468

5.2 Selection of crumb rubber and waste plastic content for rutting test

After the study of volumetric properties, stability & flow value of crumb rubber modified BC mix at 5%, 10% & 15% crumb rubber content, it is observed that the modified mix containing 10% crumb rubber gives the better result in view of stability, flow value and other volumetric properties like density, % voids etc. as

compare to other modified BC mix which containing 5% and 15% crumb rubber. So 10% crumb rubber content is considered for the study of rutting characteristics of crumb rubber modified BC mix.Similarly for waste plastic modified BC mix at 5%, 10% & 15% waste plastic content, it is observed that the modified mix containing 10% waste plastic gives the better results in view of stability, flow value and other volumetric properties as compare to other modified BC mix which containing 5% and 15% waste plastic.

So 10% waste plastic content is considered for the study of rutting characteristics of waste plastic modified BC mix

5.3 Wheel Rut Test

Rutting characteristics is studied using Wheel Rut testing machine. The stress that the wheel applied on the specimen is 0.7MPa.The slabs are compacted with wheel rut shaper machine to achieve a compaction level of required density& 50 mm thickness in the mix. The slab is subjected to reciprocating load repetitions for 2500 wheel passes and the depression on the surface of specimen is observed. The variables considered are the temperature (40^0C to 60^0C), type of mix (conventional and modified), number of passes of tyre and binder content.

Figure 5.1 - Wheel rut testing machine with specimen

5.3.1 Effect of temperature and type of mix on Rutting

Rut depth increases with, on increasing temperature for all type of mix. The maximum rut depth is observed in conventional mix and minimum for waste plastic modified mix. The rut depths for different bituminous mixes are tabulated in Table-

Table5.3 Rutting test results in Bituminous Concrete mix at varying temperatures for VG30

Rut Depth at Optimum Bitumen content(OBC)			
Number of Passes	Conventional mix		
	Rut Depth (mm)		
	40^0C	50^0C	60^0C
0	0	0	0
500	1.1	1.55	2.7
1000	1.72	2.08	3.29
1500	2.14	2.67	3.73
2000	2.56	3.1	4.23
2500	2.861	3.686	4.831

Table5.4 Rutting test results in Bituminous Concrete mix at varying temperatures for 10%CRMM

Rut Depth at Optimum Bitumen content(OBC)			
Number of Passes	Crumb Rubber (10% CR) modified mix		
	Rut Depth (mm)		
	40^0C	50^0C	60^0C
0	0	0	0
500	1.0	1.3	2.36
1000	1.4	1.76	2.93
1500	1.8	2.17	3.19
2000	2.1	2.58	3.37
2500	2.45	3.026	3.805

Table5.5 Rutting test results in Bituminous Concrete mix at varying temperatures for 10%WPMM

Rut Depth at Optimum Bitumen content(OBC)			
Number of Passes	Waste Plastic (10% WP) modified mix		
	Rut Depth (mm)		
	40^0C	50^0C	60^0C
0	0	0	0
500	0.9	1.02	1.25
1000	1.25	1.34	1.7
1500	1.51	1.72	2.0
2000	1.77	2.02	2.35
2500	1.915	2.33	2.827

5.3.2 Effect of variation of binder content on Rutting

For the present study binder content is varied from 5% to 6% with 0.25 %increment (by weight of the total mix) while preparing the samples. Rutting is also affected by the variation of binder content. The effect of binder content is measured by varying the binder content above and below from OBC (5.5% OBC is considered for all type of BC mix). In the present work rut depths are measured for 2500 number of wheel passes at 40ºC temperature for all type of mixes using wheel rut testing machine. Relative rutting test results measured at 40ºC are given in Table 5.6

From the Table 5.6 it is concluded that the on increasing or decreasing binder content beyond OBC rut depth always increases. With decrease in binder content from OBC, all the mixes have resulted in increase in rutting but less compared to rutting observed for Binder Content above OBC. Generally when binder content decreases from OBC, bituminous mixes will have higher air voids as compare to mix corresponding to OBC and low air voids for higher binder content. At lower air voids, bitumen acts as lubricant and during the compaction some content of bitumen may be comes out on the surface of mix due to low air voids which finally shows the higher rutting as compare to mix corresponding to OBC, thereby more rutting at higher binder contents. Mixes prepared using waste plastic have resulted in less rutting at all binder contents (lower and higher from OBC) and showed less effect even beyondOBC compared to other mixes.

Table5.6 Rutting test with different type of mix and Binder content

Type of Bituminous Concrete Mix	Rutting (mm) in mixes with Binder content (%)				
	5	5.25	5.5	5.75	6
Conventional Mix	3.415	3.334	2.861	3.594	4.262
CR Modified mix	3.217	2.538	2.45	2.726	3.234
WP Modified mix	2.4	2.131	1.915	2.337	2.63

IV. RESULTS AND DISCUSSIONS

The results of the study are discussed below-

- Aggregate coated with waste plastic (5%, 10% and 15% respectively) showed improvement in physical properties: Aggregate Impact Value (AIV) by 12.6%, 15.8% & 13.7% respectively and Los Angeles Abrasion Value (LAAV) by 13%, 13.8% & 11.5% respectively.
- The maximum stability is obtained for conventional mix is 14.27kN and for crumb rubber modified mix maximum stability is obtained 16.3kN (at 10% CR content) which is 1.14 times higher than conventional mix and for waste plastic modified mix maximum stability is obtained 17.47kN (at 10% WP content) which 1.22 times higher than conventional mix.
- Flow value & volumetric properties of the conventional and modified BC mix are within the limits as specified in the MoRT&H-2013 and IRC SP: 53-2010.
- Optimum Bitumen Content (OBC) for conventional and modified mix obtained is 5.4% (conventional mix), 5.45% (10% CR modified mix) & 5.44% (10%WP modified mix). The Marshall characteristics at OBC are given in table 6.1 All the results are within limits as specified in MORT&H.

Properties	Conventional mix	Modified mix	
		10 % Crumb Rubber	10 % Waste Plastic
Stability	13.8	16.2	17.4
Flow	3.2	2.95	2.9
Density	2.459	2.472	2.473
% Voids	4.2	3.8	3.5

- Modified mixes containing crumb rubber & waste plastics are less susceptible to deformation as compared to conventional mix. On considering 50^0C temperature, for crumb rubber modified mix the rut depth at 50^0C is 3.026 mm which is 17.9% less from conventional mix & for waste plastic modified mix the rut depth at 50^0C is 2.33 mm which is 36.8% less from conventional mix.
- For varying temperature (40^0C to 60^0C) the rut depth changes for conventional mix from 2.861mm to 4.831mm (i.e. 69% increment) and for CR modified mix rut depth increases from 2.45mm to 3.805mm (i.e. 55% increment) & for WP modified mix rut depth increases from 1.915mm to 2.827mm (i.e. 47.6% increment).
- For 2500 number of passes at particular temperature (say 40^0C) rut depth for conventional mix is 2.861 mm and for crumb rubber modified mix the rut depth is 2.45 mm which is 14% less from conventional mix & for waste plastic modified mix the rut depth is 1.915 mm which is 33% less from conventional mix.
- Rut depth increases for all type of mix if binder content increases or decreases from OBC. For conventional mix at OBC the rut depth is 2.861 and for binder content 5.75% rut depth is 3.594mm & for

5.25% rut depth is 3.334mm.Similarly for crumb rubber modified mix& waste plastic modified mix rut depth increases when binder content increases or decreases beyond OBC.

V. CONCLUSIONS

- Coating of waste plastic on aggregate improves the Aggregate Impact Value up to by 15.8% & Los Angeles Abrasion Value up to by 13.8% of aggregate and mixing of crumb rubber with bitumen also improves the properties like Penetration, Softening point & Ductility of bitumen.
- For modified mix the maximum Marshall Stability value is obtained for the mix with 10% of crumb rubber & 10% of waste plastic content. The stability increased by 14% for crumb rubber modified mix and 22% for the waste plastic modified mix as compared to the conventional BC mix.
- On comparing the Marshall parameters such as flow value, density, air voids for different content of crumb rubber(5%, 10%, and 15%),&different content of waste plastics (5%, 10%, and 15%), modified mix containing 10% crumb rubber and 10% waste plastic gives improved results of Marshall parameters.
- Comparing all the three types of BC mixes conventional mix, crumb rubber modified mix & waste plastic modified mix, the waste plastic modified BC mix showed maximum resistance to rutting for a particular temperature and for different number of wheel passes.
- On increasing the temperature from 40^0C to 60^0C the rut depth increases but the crumb rubber modified mix & waste plastic modified mix showed lower temperature susceptibility by 31% and 54% respectively as compared to conventional mix.
- From the study conducted on different mixes, it can be concluded that binder content limit beyond optimum has effect on rutting. However, waste plastic modified mix appears to perform better compared to other bituminous mixes even at both lower and higher binder contents of the range considered.

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