Experimental Evaluation on Latex DRC60 Modified Bituminous Concrete Wearing Course

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***Abstract*—Bituminous concrete wearing course is that part of the pavement upon which traffic travels which is likely to undergo early deterioration. This necessitates the need for frequent maintenance andthereby increases the expenditure. Since the problem of deterioration is related to the properties of bituminous concrete mix, researches have been conducted to improve the properties of the mix using additives like nano-materials, marble dust, latex etc. The objective of this study is to modify pure bitumen using latex DRC60 and evaluate the physical properties of the blend so as to determine its optimum content in bitumen. Further Marshall mix design was carried out for bituminous concrete layer using the modified latex-bitumen blend at various binder contents. The specimens were tested for Marshall stability and flow values as well as the density and void calculations. The studies conducted showed that bitumen modified with latex DRC60 had better physical properties and the modified mix had better strength compared to that of conventional bitumen.**

Keywords—bituminous concrete, latex DRC60, Marshall stability, Marshall flow value, density and void analysis

I. INTRODUCTION

Pavement in civil engineering is a durable surfacing of road, airstrip, or similar area whose primary function is to transmit loads to the sub-base and underlying soil. Pavements may be flexible, semi-rigid or rigid. Rigid pavements are made of Portland cement concrete. A flexible pavement structure is typically composed of several layers of materials each receiving loads from the layers above and spreading it to the next layer below. The major disadvantage of flexible pavements over rigid pavements is early deterioration of road surface which can be overcome by improving the physical properties of wearing course. This can be achieved by the use of additives like nanomaterials, latex, marble dust, styrene-butadiene-styrene polymers etc. Conventional bituminous concrete mix using Marshall method has failed rapidly due to heavy traffic and environmental effects. To prevent this deterioration, selection of materials is to be given extra attention and one solution to prepare the bituminous concrete mix using latex as an additive.

II. LITERATURE REVIEW

Conventional bitumen has been modified using addition of various additives since years. Among these studies, theone with the addition of crumb rubber was the earliest. Discarded tyres from vehicles were used to modify the bituminous mixes. They were ground to different sizes and graded like aggregates. For a well graded mix, about 10% crumb rubber in bitumen was found to improve the rutting resistance and while gap graded mixes had longer fatigue life but poor rutting resistance (Palit et al. 2004)[9]. Addition of crumb rubber into bitumen was found to be one way of reducing the quantity of waste generated but even then it was uneconomical considering the costs incurred in grinding and grading of the waste tyres. Thus other additives like latex, nanomaterials etc. came into effect and the studies became prominent.

Bitumen with 7% latex by weight of bitumen exhibited least temperature sensitivity, enhanced fatigue and rutting resistance (Wen et al. 2015)[5]. On the other hand, 4% latex by weight of bitumen was found to be the optimum content by varying the concentration of latex from 0 to 6% (Siswanto 2016)[1]. The rate of deterioration in the modified mixes were decreased since the addition of latex improved the dynamic stability. Moreover the shelf life of the modified mix was improved due to better dispersion of natural rubber latex in bitumen owing to its small particle size (Siswanto 2017)[3]. About 15% natural rubber latex in bitumen obtained lower penetration value as well as reduced penetration index, increased softening point and highest rutting resistance (Bakar et al. 2018)[6].

The mixing variables like mixing time, mixing temperature and mixing speed had influence on the properties of the modified blends so obtained. These variables affect the dispersion of modifiers in bitumen and thus the strength of the mix thus prepared. A mixing time of 60 minutes, mixing temperature of 160°C and a mixing speed of 1270 rpm was found to be the optimum values of mixing variables (Shaffie et al. 2018)[8]. Later studies were conducted with a combination of additives in bitumen. The optimum content of crumb rubber-HDPE mixture in bitumen was 8% while it was 6% for crumb rubber-LDPE mixture (Ghorpade and Desai 2018)[7].

The objectives of this study include:

- Finding the optimum latex content and binder content in the mix
- Evaluating the changes in unit weight and voids
- Determination of Marshall stability
- Determination of Marshall flow value

III. METHODOLOGY

A. Material Selection and Testing

1) *Aggregates:* Aggregates suitable for the mix design were selected by testing the various physical properties of the aggregates. These tests for determination of properties were conducted according to the procedures and limits specified in Indian Standard codes. The properties of aggregates tested include:

a) *Strength (IS 2386-1963 Part IV):* It is tested on aggregates of size between 12.5mm and 10mm. The test was done for crushing value using the compression testing machine at the rate of 4 tonnes per minute

b) *Toughness (IS 2386-1963Part IV):* It was also done on aggregates of size between 12.5 and 10mm, using the impact testing apparatus.

c) *Particle shape (IS 2386-1963 Part I):* To determine the shape of aggregates, the flakiness index (FI) and elongation index (EI_c) were calculated using the thickness and length gauge respectively. Later combined elongation and flakiness index ($FI + EL_c$) was also calculated. In addition to this angularity of aggregates were also tested.

d) *Specific gravity (IS 2386-1963 Part III):* The specific gravity of the coarse aggregate was conducted wire basket and that of the fine aggregate was found using a pycnometer.

e) *Gradation and size (IS 2386-1963 Part I):* This was done by sieve analysis using the IS sieves for both coarse and fine aggregates.

2) *Bitumen:* The base bitumen chosen was of VG30. Preliminary tests were conducted on bitumen to determine its properties and analyse its performance. The tests conducted were:

a) *Penetration test:* the bitumen was poured into a container which was then placed under the penetrometer after giving a water bath at 25°C. The needle was then released for 5 seconds.

b) *Softening point test:* This was determined using the ring and ball apparatus. The temperature at which the softened bitumen together with steel ball touches the metal plate below is recorded as the softening point of bitumen.

c) *Specific gravity test:* This was done using pycnometer.

d) *Ductility test*: The ductility value is measured as the distance in centimetres to which the bitumen specimen of standard size can be stretched just before the tread breaks.

The samples tested for the properties mentioned above are as shown in fig. 1. below.

Fig. 1. Samples for testing bitumen

B. Latex-Bitumen Blend Preparation

The latex-bitumen blends were prepared by heating the bitumen to a pouring consistency in a pan at 135 to 140°C. Later, accurately measured quantity of DRC-60 latex was added at different percentages; 0%, 2%, 4%, 6%, 8% and 9%. The blends were then tested for penetration, softening point, specific gravity and ductility. The percentage of latex by weight of bitumen in the latex-bitumen blend which yield better results in these tests were fixed to be the optimum value. Further the results obtained were compared to the test results for pure bitumen.

C. Marshall Mix Proportioning and Design

Three categories of aggregate samples A, B and C were proportioned to prepare Marshall specimens. These samples were sieved and batched as per MORTH specification for BC grading II shown in TABLE I using trial and error method.

TABLE I. MORTH SPECIFICATION FOR BC GRADING II

Sieve Size	% Passing
12mm	100
10mm	80-100
4.75mm	55-75
2.36mm	35-50
1.18mm	28-34
0.6mm	18-29
0.3mm	13-23
0.15mm	6-8
0.075mm	4-10

The proportion of aggregates were fixed using the following equations (1) and (2).

$$P = Aa + Bb + Cc \ldots \quad (1)$$

$$a + b + c + \ldots = 1.00 \quad (2)$$

About 1200g of this batched aggregate was heated to 175 to 190°C. The bitumen was heated in parallel to a pouring temperature of 140°C to which measured amount of latex was added. The blend was then stirred thoroughly, poured onto the heated aggregate and evenly mixed as shown in fig. 2. The mix is placed in a preheated mould and compacted by a rammer with 75 blows on either side. The bitumen content was varied in the next trial by +0.5% and the above procedure was repeated from 5.0% to 7.0% of total mixture weight. Three specimens were prepared for each latex-bitumen content. Four levels of latex content were investigated in this study, at 0%, 2%, 4% and 6% latex by weight of bitumen respectively. The Marshall stability and flow value of the modified mixes were then studied in comparison with those made with pure bitumen using Marshall apparatus. Further density and void calculations were also conducted.

Fig. 2. Mix preparation

IV. RESULTS AND DISCUSSIONS

A. Results of Tests on Aggregates

The aggregates were tested for strength, toughness, specific gravity, particle shape, size and distribution. The results obtained as shown in TABLE II conformed with the IS specifications.

TABLE II. TEST RESULTS ON AGGREGATES

Tests	Results
Crushing value	27%
Impact value	22%
Specific gravity of coarse aggregate	2.625
Specific gravity of fine aggregate	2.625
Flakiness index	22.44%
Elongation index	23.72%
Combined flakiness and elongation index	29.14%
Angularity	8
Sieve analysis	Well graded

B. Results of Tests on Bitumen

Tests conducted on pure bitumen yielded the following results as in TABLE III.

TABLE III. TEST RESULTS ON BITUMEN

Tests	Results
Penetration	65
Softening point	60°C
Specific gravity	1.061
Ductility	45 cm

C. Tests on Latex-Bitumen Blend

The tests conducted on the latex-bitumen blend obtained the following results shown in TABLE IV.

TABLE IV. TEST RESULTS ON LATEX-BITUMEN BLEND

% of latex in bitumen	**0**	**2**	**4**	**6**	**8**
Penetration	65	61	60	58	54
Softening point (°C)	60	61.8	62.9	63.05	65.65
Specific gravity	1.06	1.11	1.12	1.16	1.28
Ductility	45	34	39.1	46	52

It can be inferred from the table that for the blend with 8% latex by weight of bitumen, all the properties were improved compared to the base bitumen. Further a trial blend of 9% latex by weight of bitumen was also prepared for testing. However, this blend prepared resulted in a thick blend with reduced workability. Increasing the percentage of latex in bitumen gradually reduced the workability. Hence, the blend with 9% of latex content was discarded and further tests were not conducted on the same. Thus 8% of latex by weight of bitumen was selected to be the optimum latex content in the modified blend.

D. Results of Mix Proportioning

Bituminous concrete mix design was carried out for both the base bitumen and the bitumen modified with an optimum latex content of 8%. The aggregates were proportioned and batched as shown in TABLE V and VI.

TABLE V. PROPORTIONING OF AGGREGATES

Sample	**Sample A**	**Sample B**	**Sample C**	**Total**
Sample proportion	62.11	11.92	25.97	100.00

TABLE VI. BATCHING OF AGGREGATES

Sieve size (mm)	% passing of			Total	Limit
	Sample A	Sample B	Sample C		
12.5	62.11	11.92	25.97	100.00	100.00
10	61.96	11.92	25.97	99.85	80-100
4.75	39.16	11.92	23.79	74.87	55-75
2.36	17.20	11.72	21.60	50.00	35-50
1.18	0.68	9.46	20.15	30.28	28-34
0.60	0.45	7.54	16.24	24.24	18-29
0.30	0.38	5.73	8.34	14.45	13-23
0.15	0.30	2.36	3.34	6.01	6-8
0.075	0.22	1.31	5.03	6.56	4-10

The proportioning was in agreement with the MORTH specification. Hence, it was fixed that for the preparation of Marshall mix specimens, out of a total of 1200g aggregates, about 62% will be Sample A, 12% will be Sample B and 26% will be Sample C.

The weight of materials to be selected for the bituminous mixes were as shown in TABLE VII and VIII. Three samples were prepared for various binder contents from 5% to 7% and were then tested in the Marshall apparatus for stability and flow value. Further, density and void calculations were done. The results thus obtained for the mixes with base bitumen and modified bitumen were then compared to determine the optimum binder content for the modified mix.

TABLE VII. WEIGHT OF MATERIALS TO BE USED FOR THE PURE BITUMINOUS MIX

Binder Content (%)	5	5.5	6	6.5	7
Sample A (g)	745.32	745.32	745.32	745.32	745.32
Sample B (g)	143.04	143.04	143.04	143.04	143.04
Sample C (g)	311.64	311.64	311.64	311.64	311.64
Bitumen (g)	60	66	72	78	84
Latex (g)	0	0	0	0	0

TABLE VIII. WEIGHT OF MATERIALS TO BE USED FOR 8% LATEX MODIFIED BITUMINOUS MIX

Binder Content (%)	5	5.5	6	6.5	7
Sample A (g)	745.32	745.32	745.32	745.32	745.32
Sample B (g)	143.04	143.04	143.04	143.04	143.04
Sample C (g)	311.64	311.64	311.64	311.64	311.64
Bitumen (g)	55.55	61.11	66.67	72.22	77.78
Latex (g)	4.44	4.89	5.33	5.78	6.22

E. Results of Tests on Bituminous Concrete Mixes

The maximum load which each of the specimen of different binder content at 0% and 8% latex-bitumen blend could withstand were determined along with the deformation occurred at that time. The theoretical specific gravity (G_t) and bulk specific gravity (G_m) for the specimens were calculated. These values were then used to calculate the volumetric parameters of specimens like percentage of air voids (V_v) and percentage volume of bitumen (V_b). The results obtained are as shown in TABLE IX and X below.

TABLE IX. TEST RESULTS OF PURE BITUMINOUS MIX

Binder Content (%)	5	5.5	6	6.5	7
Marshall stability (kN)	17.55	18.90	20.18	20.79	18.96
Marshall flow (mm)	6.70	5.32	5.85	5.60	6.00
G_t	2.45	2.43	2.42	2.40	2.39
G_m	2.33	2.34	2.35	2.32	2.30
V_v (%)	4.65	4.02	2.60	3.56	3.77

TABLE X. TEST RESULTS OF 8% LATEX MODIFIED BITUMINOUS MIX

Binder content(%)	5	5.5	6	6.5	7
Marshall stability (kN)	17.68	21.02	19.57	18.79	15.52
Marshall flow (mm)	6.00	5.05	6.15	6.15	6.90
G_t	2.500	2.489	2.478	2.467	2.456
G_m	2.423	2.433	2.418	2.397	2.378
V_v (%)	3.071	2.253	2.387	2.836	3.178

These test results were analysed graphically for Marshall stability, flow value bulk specific gravity and percentage air voids in order to compare the variation in properties of latex modified mix with that of pure bituminous mix. For this, graphs were plotted with Marshall stability, flow value, bulk specific gravity and percentage air voids against binder content as shown in fig. 3.to 7.

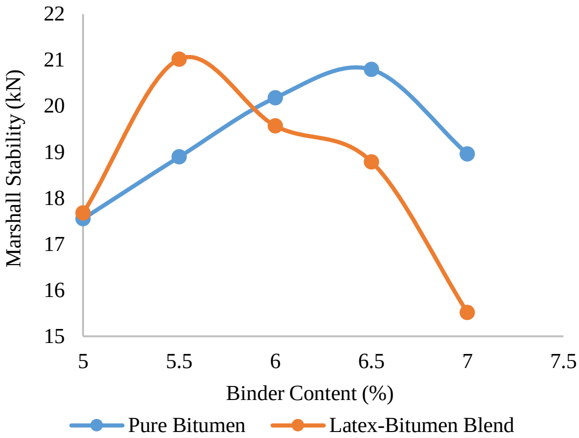

Fig. 3. Marshall stabilityvs binder content for latex-bitumen blends

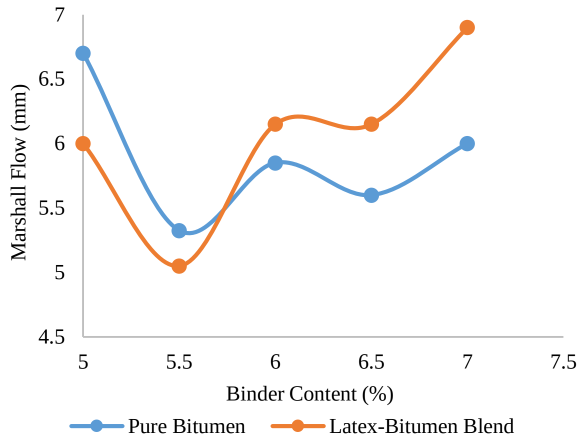

Fig. 4. Marshall flow vs binder content for latex-bitumen blends

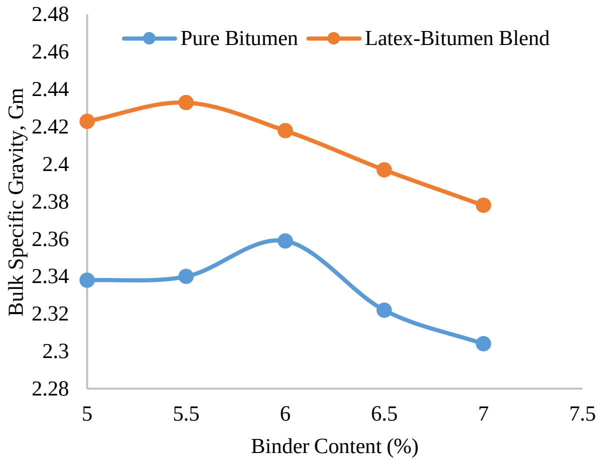

Fig. 5. Bulk specific gravity vs binder content latex-bitumen blends

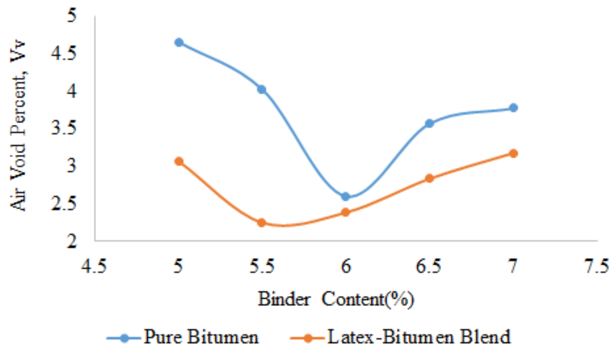

Fig. 6.Air void percent vs binder content for latex-bitumen blends

It was observed that the peak values of Marshall stability, bulk specific gravity and the minimum value of Marshall flow was around 6 to 6.5% of binder content for specimen with pure bitumen and was around 5 to 6% of binder content for specimens with 8% latex content. On an average, the optimum binder content for pure bitumen specimens was fixed as 6.14% and that of 8% latex-bitumen blend was 5.55%. For the purpose of study, specimens with 7% latex-bitumen blend were also prepared for different binder contents and all the above parameters were studied. But the results obtained were poor compared to the specimens of 8% latex-bitumen blend. Hence, a binder content of 5.55% with 8% latex in bitumen was found to the best mix.

V. SUMMARY AND CONCLUSIONS

In this study, the performance of latex DRC60 modified bituminous concrete wearing course was studied. The properties of base materials were first studied and then the optimum content of latex DRC60 to be added to modify the bitumen was estimated, which was found to be 8% by weight of bitumen. The bituminous concrete mix proportioning was done and the Marshall specimens were prepared with 0% and 8% latex-bitumen blends for a binder content of 5, 5.5, 6, 6.5 and 7%. On testing the specimens it was found that the addition of latex DRC60 could improve the strength of the mix as well as reduce the deformations.

Each of the preliminary tests conducted to determine the properties of aggregates and bitumen suggests their suitability to be used in the wearing course of pavement. The tests conducted on bitumen modified with 0, 2, 4, 6 and 8% latex revealed that

- The penetration of bitumen decreases, while the softening point, ductility and specific gravity increases with increase in latex content.
- The optimum values for the tests were obtained for 8% latex in bitumen. A trial blend of 9% latex was prepared and discarded since the workability offered was poor.
- The lower penetration value and higher ductility and softening point suggested that the blend could be used in warmer regions.

With this 8% latex modified bitumen, mix proportioning was done which satisfied the MORTH specifications. The samples with pure bitumen and modified bitumen were prepared, tested and compared for Marshall stability and flow value as well as for density and void analysis which showed that

- The peak of Marshall stability and bulk specific gravity and the valley of Marshall flow value were obtained at lower binder contents for samples of modified bitumen compared to samples of pure bitumen.
- The optimum binder content for modified bituminous mix was thus found to be 5.55% while it was 6.14% for pure bituminous mix.
- This suggested that the desired strength and durability is obtained with modified bituminous mix and that it can reduce about 16% of bitumen in the mix compared to pure bituminous mix.
- Trial mix specimens prepared for 7% latex in bitumen was discarded as it obtained poor results.

Thus, a bituminous mix with 8% latex by weight of bitumen at 5.55% binder content was fixed to be the optimum mix.

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REFERENCES

[1] Siswanto, H., (2016), “Improving the physical properties of asphalt concrete bearing course using latex DRC60”, Journal of American Institute of Physics.

[2] Siswanto, H., (2017), “Improving water resistance of asphalt concrete wearing course using latex-bitumen binder” MATEC Web of Conferences 97.

[3] Siswanto, H., (2017), “The effect of latex on permanent deformation of asphalt concrete wearing course”, Journal of Procedia Engineering, Vol. 171, pp.1390-1394.

[4] S.K. Khanna, C.E.G. Justo and A. Veeraragavan. Highway Engineering, Khanna publishers, 10th edition, 2015.

[5] Wen, Y., Zhao, K., Wang, Y., and Sumalee, A., (2015). “The use of natural rubber latex as a renewable and sustainable modifier of asphalt binder”. International Journal of Pavement Engineering.Vol.18, No.6.

[6] Bakar, S.K.A., Abdulah, M.E., Kamal, M.M., Rahman, R.A., Hadithon, K.A., Buhari, R., and Tajudin, S.A.A., (2018). “Evaluating the rheological properties of waste natural rubber latex modified binder”. E3S Web of Conferences 34, 01037 (2018).

[7] Ghorpade, M.R., and Desai, D.B., (2018). “A study of enhancement of bituminous mix by use of modifiers”. Imperial Journal of Interdisiplinary Researches (IJIR), Vol. 4, No.1, pp. 341-347.

[8] Shaffie, E., Arshad, A.K., Alisibramulisi, A., and Ahmad, J., (2018). “Mixing variables on physical properties of modified bitumen using natural rubber latex.” International Journal of Civil Engineering and Technology (IJCIET), Vol.9, No.7, pp. 1812-1821.

[9] Palit, S. K., Pandey, B., and Reddy, K. S., (2004). “Laboratory evaluation of crumb rubber modified asphalt mixes.” Journal of Materials in Civil Engineering, Vol.16, No.1, pp. 45-53.