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EXPERIMENTAL INVESTIGATION ON BITUMEN MODIFIED WITH LATEX

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1. INTRODUCTION

India has a road network of over 5,603,293 kilometres (3,481,725 mi) as on 31 March 2016, the second largest road network in the world. It has primarily flexible pavement design which constitutes more than 98% of total road network. Being a vast country, India has widely varying climates, terrains, construction materials and mixed traffic conditions both in terms of loads and volumes. Increased traffic factors are such as heavier loads, higher traffic volume and higher tyre pressure demand higher performance pavements. So to minimize the damage of pavement surface and increase durability of flexible pavement, the conventional bitumen needs to be improved. There are so many modification processes and additives that are currently used in bitumen modifications such as styrene butadiene styrene (SBS), styrene-butadiene rubber (SBR), ethylene vinyl acetate (EVA) and crumb rubber modifier (CRM). Most of the construction materials used for roads are soil, stone aggregate, sand, bitumen, cement etc. The availability of natural materials is declining. Also, cost of extracting good quality of natural material is increasing. To overcome this problem, it is recommended to use alternative materials for highway construction, by which the pollution, disposal problems and cheap materials may be reduced. The need for these solid wastages in India, it is required to test these materials and develop specifications for usage of latex in road construction in which it may lead higher economic returns. The possibility of using these materials should be developed for low volume roads construction in various parts of our country. The necessary specifications should be formulated to maximize the use of solid wastes in different layers of the road pavement. Pavement performance studies are to be done after post construction stage for construction of roads using rubber waste with major advantages: i.e: It will also help to preserve the natural sources of aggregates, and protecting the environment. Rubber is user friendly but not eco-friendly since they are non-biodegradable. The conventional bituminous mix consists of aggregate and 3 to 6 percent bitumen by weight of the aggregate. The latex can be incorporated into bitumen, which is known as modified bitumen are used as a portion of the virgin bitumen. The use of latex in hot bituminous mixes enhances the performance of pavement, protect environment and provide economic and quicker roads.

A. Binder modification

Binder properties may be improved by different process and materials. Binder modification has been driven by the increase in traffic loads, new refining technologies, enhancement in polymer technology, the increasing need to recycle waste material such as plastic bag, plastic bottle, rubber and etc.When we use the bitumen modifier, selected polymer/rubber or a blend of two or more modifier shall have the following properties:

- Compatible with bitumen,
- Resist degration at mixing temperature,
- Capable of being processed by conventional mixing and laying machinery,
- Produce required coating viscosity at application temperature and
- Maintain premium properties during storage, application and in-service.

The polymer and rubber modified bitumen shall be classified into four types as per IS:15462.2004 given below:

a) Type A PMP(P) – Platomeric thermoplastics based,
b) Type B PMB(E) – Elastomeric thermoplastics based,
c) Type C NRMB – Natural rubber and SBR latex based and
d) Type D CRMB – Crumb rubber/treated crumb rubber based.

Type A, Type B and Type C shall be further classified into three grades according to their penetration value and Type D shall be further classified into three grades according to their softening point values as given below:

Grades of Type A PMB(P) : PMB(P) 120, PMB(P) 70 and PMB(P) 40,

Grades of Type B PMB(E) : PMB(E) 120, PMB(E) 70 and PMB(E) 40,

Grades of Type C NRMB : NRMB 120, NRMB 70 and NRMB 40,

Grades of Type D CRMB : CRMB 50, CRMB 55 and CRMB 60.

Note: PMB(P) 120, PMB(E) 120 and NRMB 120 means that corresponding to this grade has penetration value between 90 to 150. PMB(P) 70, PMB(E) 70 and NRMB 70 mean that corresponding to this grade has penetration value between 50 to 90. PMB(P) 40, PMB(E) 40 and NRMB 40 means that corresponding to this grade has penetration value between 30 to 50 and CRMB 50, CRMB 55, CRMB 60 means that corresponding to this grade has softening point value 50^0c, 55^0c and 60^0c minimum respectively.

Purpose of Bitumen modification:

- To obtain softer blends at low temperature for reducing cracks.
- To increase the stability and strength of mixtures.
- To improve the asphalt cohesive strength in Pavements.
- To improve oxidation and resist aging.
- To reduce costs of pavement.

Advantages of Bitumen modification:

- Lower susceptibility to daily & seasonal temperature variations.
- Higher resistance to deformation at elevated pavement temperature.
- Better age resistance properties, higher fatigue life of mixes.

- Better adhesion between aggregate & binder.
- Prevention of cracking & reflective cracking and
- Overall improved performance in extreme climatic conditions & under heavy traffic condition.

B. Latex

Natural rubber as bio-modifier of bitumen and asphalt mixtures has shown to have some beneficial effects. As initially produced, natural rubber consists of polymers of the organic compound isoprene, with minor impurities of other organic compounds, plus water. Natural rubber can consist of various forms including as latex, which is a sticky, milky colloid; cup lump which is a coagulated latex and ribbed smoke sheet. Natural rubber is used extensively in many products and applications, either alone or in combination with other materials as it has a large stretch ratio and high resilience, and extremely waterproof. Due to these properties together with a chemical composition which can be classified as elastomers, natural rubber modification can improve the performance of conventional asphalt mixtures that are currently faced limitation against increased traffic loading and higher axle loads together with the effect of ageing, moisture, and temperature. Also, the application of natural rubber as part of the construction of asphalt mixture pavement might support the national agenda to boost rubber industry.

Fig.1 Latex sample

2. LITERATURE REVIE

The mixing of natural rubber in asphalt has been testing for many years and it is worthy to improve performance. Moreover, the improvement of asphalt characteristics by utilizing various raw latex i.e. low and high ammonium field latex, cream skim latex, revertex latex, and centrifuged latex had analyzed a long time ago in 1969 [41]. The results revealed that NR as field latex with high ammonium is effective in the reduction of penetration and increasing of softening point against all other forms of NR. The properties of liquid natural rubber (LNR) modified with bitumen was perceived in 1998 by Nair et al, [42] for soft and blown bitumen and results were founded increase in softening point by adding 5 to 10 % LNR and improvement in penetration values as it decreased in both cases, and also shear resistance increased for all cases upon adding of 5 to 10% LNR. Recently, the improvement due to temperature variation has been analyzed mainly in cold conditions where cracks develop and summarized that latex in pavement mainly acts like an elastic band that helps to disintegrate stresses and at the same time also hold asphalt together. Conversely upon changing of rheological properties and flowing of asphalt latex acts as a membrane which boosts the shear strength and resists the flow [12]. Natural rubber built-in elastomers possessions proved that it has potential in enhancing pavement long term performance in asphalt concrete mix and to increase the cohesion and adhesion properties of binder [43]. Natural rubber or generally recognized as field latex comprises 30- 40% rubber and rest is water including a small percentage of impurities. Though NR could not maintain its liquid form too long only last for 3 to 4 hours [21]. Considering this because it is needed to preserve latex for extended time to get benefit from a wide range application of this raw material. Presently, many studies have been conducted on modification of asphalt binder by using preserve NR latex as an enhancer. In additional research have been conducted to analyze the asphalt modification by utilizing field latex, concentrated latex and skim latex and results founded satisfactory upon improvement in softening, high penetration index (PI), high tensional recovery and high tenacity and toughness [16]. Next, a research conducted to summarized the effect of time and temperature on physical properties of modified NR bitumen and revealed that the temperature and blending time should not be more than 150oC and 10 minutes respectively and 9% NRL is maximum useful for improvement [44]. Moreover, the physical properties of bitumen by using deoxidized NR (ENR) have been analyzed and founded that based on softening and penetration values bitumen seems to involve stiffness however the ductile property at the start declined after adding ENR and then starts increasing which indicated the performance improvement. Additionally, the storage stability showed that 6 % ENR is stable for binder use in high temperatures [5]. Apart from rheological properties researchers have conducted studies on performance properties of modified NR bitumen and proved the enhancement of deformation and fatigue resistance of pavement. Furthermore, a study conducted by Khatijah Abu Bakar et al, [45] and reveal that natural latex is best to extend the service life of pavement upon improvement in its flexibility and stability properties. Therefore, it validates asphalt modified with rubbers have more resistance and strength in comparison with conventional asphalt. Next, a study on Hot Mix Asphalt (HMA) to estimate the stripping performance utilizing natural latex as modifiers reveal that on the enhancement of pavement performance and so concluded that NRL is a worthy enhancer for binder properties [43]. The ENR has been used to enhance the performance properties of asphalt concrete and from a study conducted it is revealed that 6% of ENR by weight of bitumen is optimally modified and improved that rutting resistance and also fatigue at a temperature of 30oC [5]. Additionally, Wen et al, [12] found that upon 6% of adding NR latex in asphalt improves the resistance against rutting, thermal cracking and fatigue resistance. Furthermore, krishnapriya et al, [34] revealed that modified rubberized asphalt mix provides a superior result and although not only improves resistance against rut but also upgrade resilient modulus to increase fatigue life.

Modification of road pavement with additives has been in practice since many decades ago to increase the performance and to protect the sources of asphalt. Concerning this and due to a declination of oil reserves researchers are interested around the globe in finding substitute pavement binder and modifier.

Furthermore, NR recently expands its applications while attempting a combination with bitumen. The review enlightens the studies conducted for its usage, advancement and the challenges faced on the modification of natural rubber that influence the binder properties. Previously conducted studies on NR modified asphalt has evidenced that it is one of the bio-polymer that can be used as a modifier for pavement performance to mitigate the failures i.e., fatigue, rutting, ageing due to tire stresses or temperature variation. Extensive usage of NR due to its low cost can also enhance the economic growth of industry and simultaneously service life of roads increase with low maintenance cost and will also significantly improve the ride quality. From the review of literature, it has been found that the best size to be used for latex rubber modification can be suggested for commercial production of latex rubber modified bitumen (LRMB). In this study find out the optimum binder content by using Marshall Stability test with various percentages of latex. Therefore, attempts should be made to address some cost effective and more environmentally friendly materials utilising the waste or by product.

3. OBJECTIVE AND METHODOLOGY

A. Objective of the study

The modification of bitumen by adding latex with varying percentages. The objectives of the present study are mentioned below:

1. To modify the bitumen with waste latex rubber and compare with virgin bitumen properties such as Ductility Test, Penetration Test, Softening Point Test and Flash & Fire Point Tests.
2. To find out the bituminous mix optimum bitumen content by using Marshall Stability and flow tests.
3. Based on the optimum bitumen content, to find out the Modified Bituminous mix optimum latex rubber content by using Marshall Stability and flow tests.

B. Methodology

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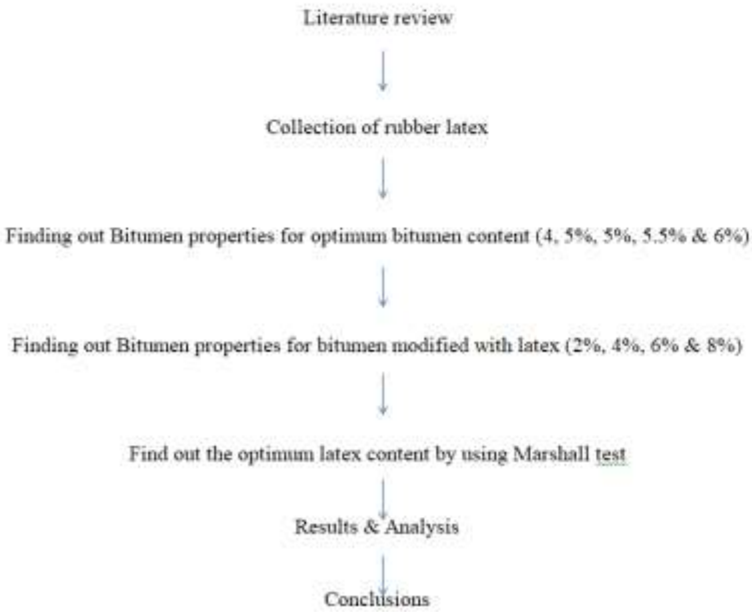

4. EXPERIMENTAL INVESTIGATIONS

The experimental works carried out in this present investigation. This experimental work has been divided into two parts. First part deals with the experiments carried out on the aggregates, bitumen and modified latex rubber. Second part deals with the experiments carried out on the Marshall stability and Marshall Flow.

A. Materials used

Aggregates: The grades of aggregates and their quantities to be used for preparing Marshall Samples were graded as per Ministry of Road Transport and Highways (2001) given in Table.1. The BC mix with smaller aggregate in the other way having relatively higher bitumen contents, which not only impart high flexibility but also increase their durability.

Coarse Aggregates: The Coarse aggregates consisted of stone chips, up to 4.75 mm IS sieve size. Its specific gravity was found as 2.67. Standard tests were conducted to determine their physical properties as summarized in Table.2.

Fine Aggregates: The Fine aggregates, consisting of stone crusher dusts with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Its specific gravity was found to be 2.61.

Filler: The aggregate passing through 0.075 mm IS sieve is called as filler. Here Portland cement (Grade 53) was used as filler material. Its specific gravity was found to be 3.1.

Table.1 MORTH gradation for BC (NMAS 13 mm)

IS Sieve (mm)	Percent Passing	
	Specification Grading	Grading adopted
19	100	100

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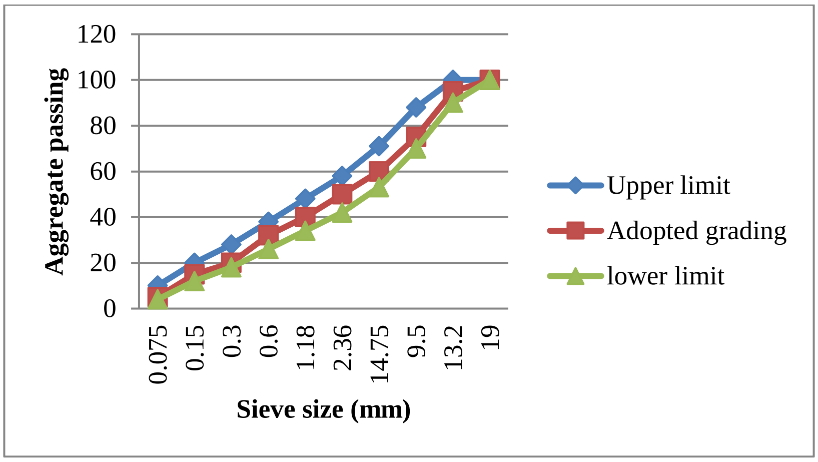
13.2	90-100	95
9.5	70-88	75
4.75	53-71	60
2.36	42-58	50
1.18	34-48	40
0.600	26-38	32
0.300	18-28	20
0.150	12-20	15
0.075(filler)	4-10	5
Binder Content % by weight	5-7	5.5 & 6.0



Graph.1 Aggregate gradation curve for BC

Table.2 Physical properties of aggregates

Property	Method of Test	Specification	Test Result
Aggregate Impact Value (%)	IS: 2386 (Part-IV)	Max 24%	17.13%
Aggregate Crushing Value (%)		Max 35%	18.80%
Los Angeles Abrasion Value (%)		Max 30%	24.31%
Combined Flakiness and Elongation Indices (%)	IS: 2386 (Part-I)	Max 35%	16.18%
Coating of Bitumen Aggregate Mix	(IS:6241)	Minimum Retained Coating 95%	98%
Water Absorption (%)	(IS:2386 Part III)	Max 2%	0.15%

Latex: The latex rubber used in Bitumen Tests and preparing Marshall Samples for optimum latex content for BC mixes. The Specific gravity was found to be 1.10.

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Binder: The Bitumen used in preparing Marshall Samples was of 80/100 penetration grade. The Specific gravity was 1.01. Its important properties are given in table.3.

Table.3 Properties of Binder

Property	Method of Test	Test Result
Specific gravity	IS : 1202-1978	1.01
Penetration at 25°C (cm)	IS : 1203-1978	81
Softening Point (°C)	IS : 1205-1978	48
Ductility (cm)	IS : 1208-1978	68
Flash Point (°C)	IS : 1209-1978	180
Fire Point (°C)	IS : 1209-1978	188

B. Tests for Bitumen

The addition of latex to the bitumen with varying percentages i.e.: 0%, 2%, 4%, 6%, & 8%. After addition of latex rubber to bitumen, to prepare the samples for required test. The bitumen test as follows:

- Penetration Test [IS: 1203-1978]
- Softening Point Test [IS: 1205-1978]
- Ductility Test [IS: 1208-1978]
- Flash Point and Fire Point [IS: 1209-1981]

Fig.2 bitumen

Table.4 Test results of Bitumen with Latex

S. No	Latex (%)	Penetration (mm)	Softening Point (°C)	Ductility (cm)	Flash Point (°C)	Fire Point (°C)
1	0	83	52	85	290	305
2	2	76	58	89	301	322
3	4	72	63	90	308	330
4	6	65	65	94	310	332
5	8	62	70	96	315	347

C. Sample Preparation

Marshall Sampling Mould:

The specifications of the Marshall sampling mould and hammer are given in table 4.3.

Table.5 Dimensions of Marshall Sampling mould & hammer

APPARATUS	VALUE	WORKING TOLERANCE
MOULD		
Average internal diameter (mm)	101.2	±0.5
HAMMER		
Mass (kg)	4.535	±0.02
Drop Height (mm)	457	±1.0
Foot diameter (mm)	98.5	±0.5

Mixing Procedure:

The mixing of ingredients was done as per the following procedure (STP 204-8).

1. Required quantities of coarse aggregate, fine aggregate & mineral fillers were taken in an iron pan.
2. This was kept in an oven at temperature 160^0c for 10min. This is because the aggregate and bitumen are to be mixed in heated state so preheating is required.
3. The bitumen was also heated up to its melting point prior to the mixing.
4. The required amount of Latex rubber was weighed and kept in a separate container.
5. The aggregates in the pan were heated on a controlled gas stove for a few minutes maintaining the above temperature.
6. The Latex rubber was added to the bitumen and it was mixed for 5 minutes.
7. For BC: Now bitumen (60, 66, 72 gms), i.e. 5.0%, 5.5%, 6.0% was added to this mix and the whole mix was stirred uniformly and homogenously. This was continued for 10-20 minutes till they were properly mixed which was evident from the uniform colour throughout the mix.
8. Then the mix was transferred to a casting mould.

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9. This mix was then compacted by the Marshall Hammer. The specification of this hammer, the height of release etc. are given in Table 5.
10. 75 no. of blows were given per each side of the sample so subtotal of 150 no. of blows was given per sample.
11. Then these samples with moulds were kept separately and marked.
12. Keep at for 24hours for drying.
13. Based on the point 7, there different percentages of bitumen used for optimum binder content determination for BC mixes.
14. The optimum bitumen or binder content used for latex modified bituminous mixes i.e.; 2, 4, 6, 8% of latex replacing with virgin bitumen and prepare the modified bituminous mix samples for testing. For casting and drying same procedure followed.

Calculations involved:

The Latex rubber content was varied from 2 to 8 % and for each Latex rubber content, 3samples were prepared. The coarse aggregate was gravel, 5 per cent by mass of total aggregate of Portland cement (OPC 53) was added and the percentage of fine aggregate reduced accordingly. The Plasticity Index requirement shall not apply if filter is cement.

Total weight of sample = 1200 gm

Bitumen Contents for BC = 5%, 5.5%, 6%

<u>Example calculations for BC 5.5 %:</u>

Weight of aggregate (with filler) = 1200 - 66 =1134 gm

Weight of aggregate (without filler) = 1134 – 56.7 = 1077.3 gm

The samples were named, the weight of Latex rubber, aggregate and cement for each sample calculated and shown in Table 6 below.

Fig.3 Fried aggregates

Fig.4 Uniform colour throughout the mix

Fig.5 Marshall moulds for OBC determination

Fig.6 Closer view of a marshall sample

Table.6 Amounts of raw materials

Bitumen (%)	Latex (%)	Weight of bitumen (gm)	Weight of Latex (gm)	Weight of Aggregate (gm)	Weight of Cement (gm)
5.0	0	60	0	1083	57
	2	58.8	1.2		
	4	57.6	2.4		
	6	56.4	3.6		

	8	55.2	4.8		
5.5	0	66	0	1077.3	56.7
	2	64.68	1.32		
	4	63.36	2.64		
	6	62.04	3.96		
	8	60.72	5.28		
6.0	0	72	0	1071.6	56.4
	2	70.56	1.44		
	4	69.12	2.88		
	6	67.68	4.32		
	8	66.24	5.76		

D. Marshall testing

The Marshall test was done as procedure outlined in ASTM D6927 – 06.

Marshall Stability Value:

It is defined as the maximum load at which the specimen fails under the application of the vertical load. It is the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute (2 inches/minute). Generally, the load was increased until it reached the maximum & then when the load just began to reduce, the loading was stopped and the maximum load was recorded by the proving ring.

Fig.7 Marshall Stability test setup

Marshall Flow Value:

It is defined as the deformation undergone by the specimen at the maximum load where the failure occurs. During the loading, an attached dial gauge measures the specimen's plastic flow as a result of the loading.

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The flow value was recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load was recorded.

5. ANALYSIS OF RESULTS

A. Optimum binder content

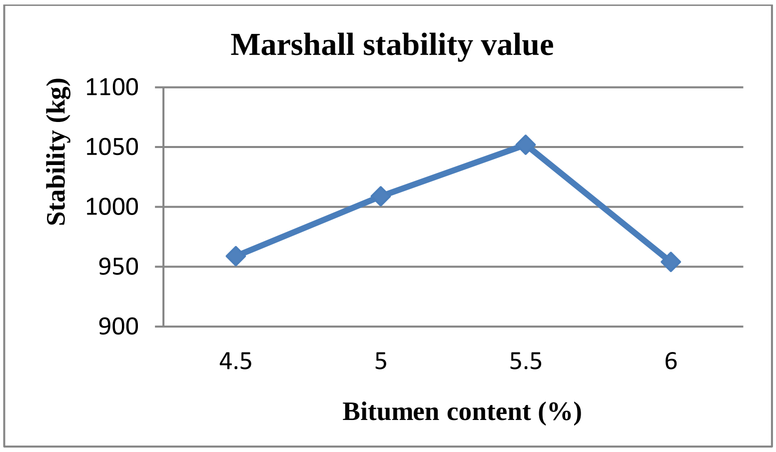
2 curves were plotted. i.e.:

- Marshall Stability Value vs. bitumen Content
- Marshall Flow Value vs. bitumen Content

For each % of Bitumen, 3 samples of BC have been tested. So the average value of the 3 was taken. The mean values are shown in Table 7.

Table.7 Data for plotting curves of BC (optimum binder content)

Bitumen (%)	Marshall stability (KN)	Average Marshall stability (Kg)	Marshall flow (mm)	Average Marshall flow (mm)
4.5	966	959	2.3	2.16
	951		2.1	
	960		2.1	
5	1009	1009	2.4	2.4
	1013		2.5	
	1006		2.3	
5.5	1048	**1052**	3	3.2
	1052		3.2	
	1057		3.5	
6.0	944	945	3.7	3.8
	942		3.8	
	950		4	



Graph.2 Marshall Stability Value vs. Bitumen Content

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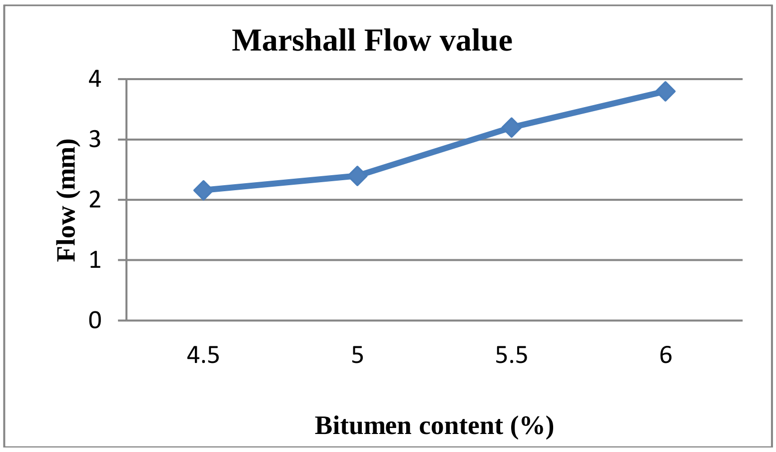


Graph.3 Marshall Flow Value vs. Bitumen Content

B. Optimum Latex content

2 curves were plotted. i.e.:

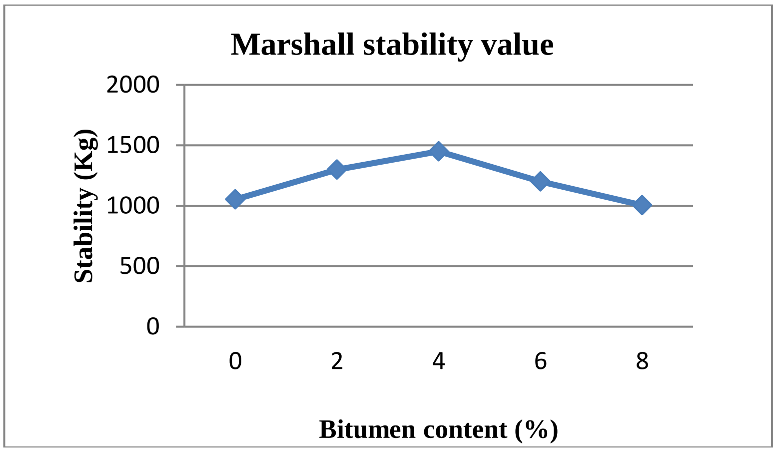
- Marshall Stability Value vs. bitumen Content
- Marshall Flow Value vs. bitumen Content

For each % of Latex rubber, 3 samples of BC have been tested. So the average value of the 3 was taken. The mean values are shown in Table 8.

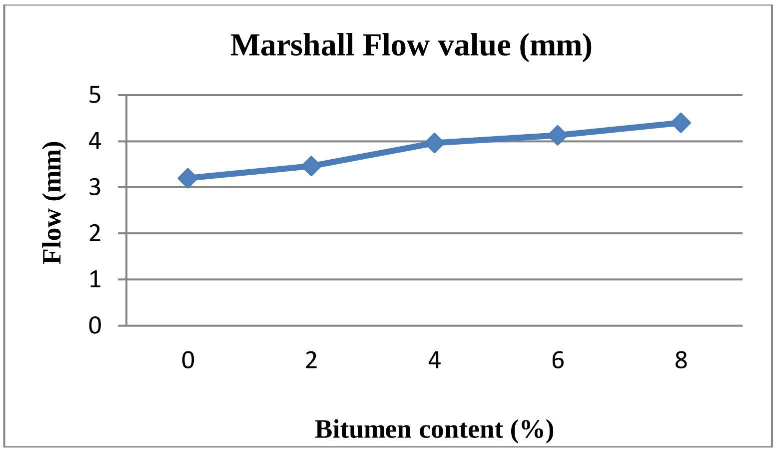
Table.8 Data for plotting curves of BC (optimum latex content)

Latex (%)	Bitumen (%)	Marshall stability (KN)	Average Marshall stability (Kg)	Marshall flow (mm)	Average Marshall flow (mm)
0	100	1048	1052	3	3.20
		1052		3.2	
		1057		3.5	
2	98	1302	1305	3.4	3.46
		1305		3.4	
		1308		3.6	
4	96	1450	1450	3.8	3.96
		1447		4.1	
		1453		4	
6	94	1200	1200	4.2	4.13
		1195		4.1	
		1206		4.1	

8	92	1012	1004	4.5	4.4
		997		4.3	
		1003		4.4	



Graph.4 Marshall Stability Value vs. bitumen Content



Graph.5 Marshall Flow Value vs. Bitumen Content

C. Analysis

Bitumen modified with latex:

The Bitumen has added with latex with various percentages 0, 2, 4, 6, 8%, the bitumen properties was mentioned below;

- The penetration value was decreasing with increasing latex content by the replacement in the bitumen. Hence the modified bitumen was hardened when latex added.
- The Softening point value was increasing with increasing latex content by the replacement in the bitumen. Hence the modified bitumen was hardened.

- The ductility value was increasing with increasing latex content by the replacement in the bitumen. Hence the modified bitumen had elastic properties.
- The Flash & Fire point value was increasing with increasing latex content by the replacement in the bitumen. Hence the modified bitumen resistance up to 340^0.

Finding Optimum Bitumen Content:

The value of Bitumen content at which the sample has maximum Marshall Stability Value and minimum Marshall Flow Value is called as Optimum Bitumen Content.

BC: From the Graph 2 & 3, we got the Optimum Bitumen Content as 5.5% and also from Graph 4 & 5, we got the Optimum latex rubber Content as 4%.

6. CONCLUSIONS

The test results of Coarse aggregate, the crushing value (%) was 20.31, impact value (%) was 12 and water absorption value (%) was;

1. The properties of plain bitumen and plastic modified bitumen, by increasing of plastic content the penetration value was decreased from 83mm to 62mm, softening point value was increased from 52°C to 70°C, ductility value was decreased from 85cm to 96cm, flash point value was increased from 290°C to 315°C and fire point value was increased from 305°C to 347°C.
2. The optimum bitumen content was 5.5% gives highest Marshall Stability value 1052kg as compare to 4.5%, 5%, 5.5% and 6%.
3. The addition of 4% of latex content for BC was determined to be the most suitable content, yielding much better test results than unmodified bitumen and the other mixtures. The use of latex rubber will also prevent the accumulation of this waste material in the environment.it can be observed that the BC sample prepared using 4% give the highest stability value of 1450 kg, minimum flow value of 3.96mm. The increment of stability value with latex modified bituminous mix as compare to the conventional bituminous mix was 37.83%.

Considering these factors we can assure that we can obtain a more stable and durable mix for the pavements by binder modifications. This small investigation not only utilizes beneficially, the waste non-degradable Latex rubber but also provides us an improved pavement with better strength.

SCOPE FOR FURTHER STUDIES

Few aspects can be included for the extension of the present study, and they are as follows.

- The other performance test can be conducted to assess the fatigue behavior of the mix and Void analysis.
- The present study can be extended to different fillers with latex modified bitumen.
- The study can be extended to use of natural fibres and synthetic fibres.

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