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सं0 प्रमुख अभियन्ता/निदेशक(कार्य)/सीडीडब्लयूएम/लोनिवि/2018/5685 दिनांक: 09.08.2018

सेवा में

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3. मुख्य अभियंता (पूर्व), लो.नि.वि, तीसरा तल, बहु–मंजिला भवन, इंद्रप्रस्थ संपदा, नई दिल्ली–02।

विषय:– Technical Paper on "Use of Recycled Asphalt material for sustainable road construction".

A photo copy of the Technical Paper published in the Sept., 2018 edition of Indian Highway on the subject matter is enclosed for information & necessary action. It is concluded in this Paper that the use of Recycled Asphalt Pavement (RAP) in road construction complies with overall objective of sustainable development by careful use of natural resources as large quantities of Recycled Asphalt Pavement materials are produced during highway maintenance and construction. Reclaimed Asphalt Pavement recycling activities reduces the use of virgin aggregate and tackles the issue of material storage and disposal of Reclaimed Asphalt material generated from pavement construction. Further, energy savings can also be done through the use of RAP in roadway construction by reducing processing and transportation of virgin aggregates. It is concluded in this Paper that reclaimed aggregate (100%) and replacing 1.5% of VG30 bitumen (binder) in Bitumen Concrete with CRMB 55 resulted in the increase of Marshall Stability, Flow value and Bulk density of Bituminous Concrete Mix.

On considering the conclusion arrived at by the Research Team, it is found necessary to adopt this technique on all our PWD road projects because it is environmental friendly, economical and fulfills the aspiration of sustainable development. Accordingly, use of pavement milling can be carried out preferably before pavement strengthening to avoid rise in the level of pavement. Use of this milled material also complies with C&D Waste Rules, 2016 and meets with the goal of sustainable development, apart from economical construction (as this saves virgin aggregates and raising of median, foot path and kerb channel).

This issues with the approval of the Engineer-in-Chief, PWD.

संलग्न:– उपरोक्तानुसार।

(संजीव रस्तोगी)
निदेशक (कार्य)

प्रतिलिपि:–

1. प्रधान मुख्य अभियंता (अनुरक्षण), लोनिवि, 12वॉ तल, एम.एस.ओ.भवन, नई दिल्ली को सूचनार्थ हेतु प्रेषित।

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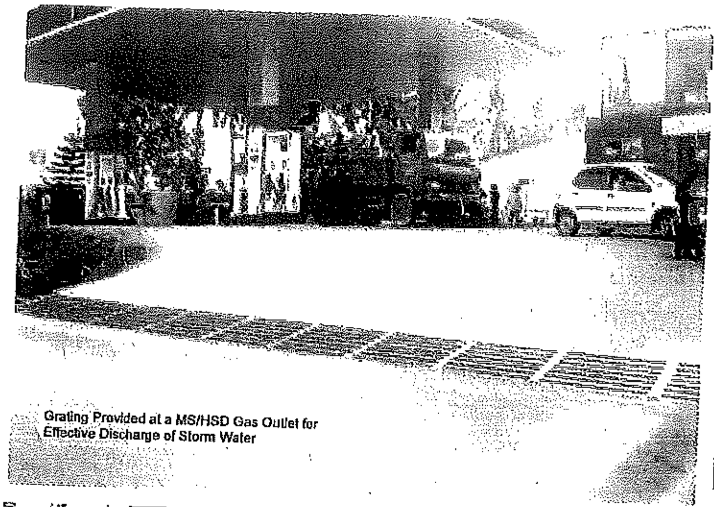
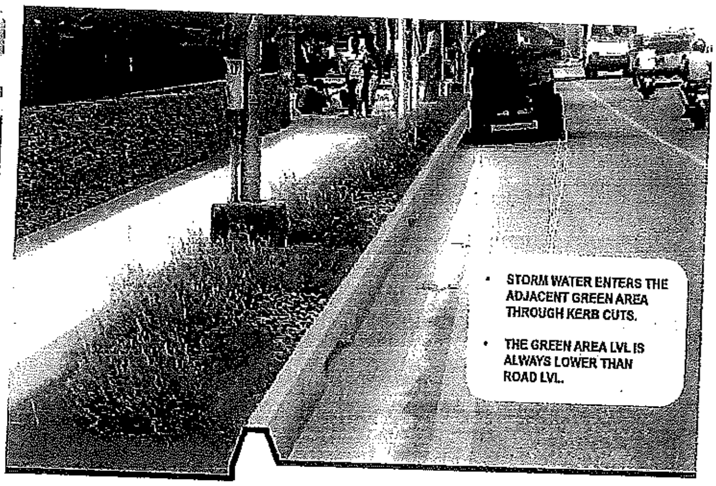
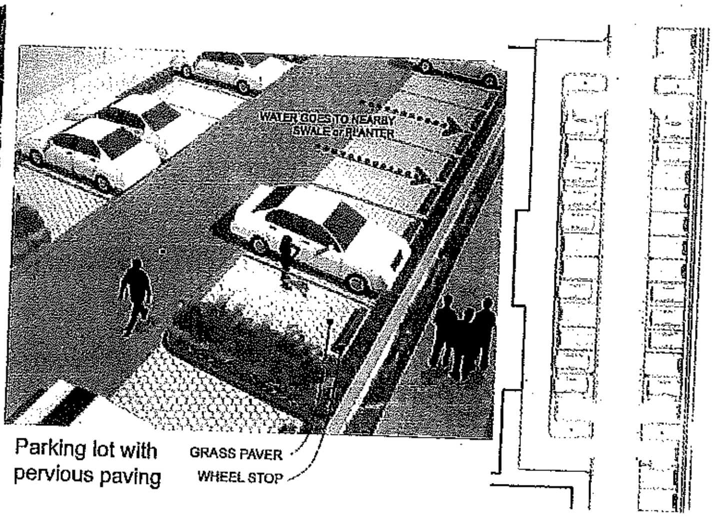


Grating Provided at a MS/HSD Gas Outlet for Effective Discharge of Storm Water



Median Drain



Parking lot with pervious paving

Photographs from IRC:SP:50-2013 "Guidelines on Urban Drainage"

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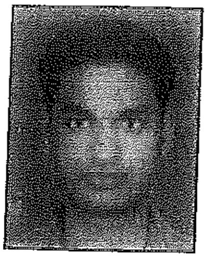
USE OF RECYCLED ASPHALT MATERIAL FOR SUSTAINABLE ROAD CONSTRUCTION


DR. UMESH SHARMA[1], HARISH KUMAR GIRI[2], ANKITA KHATRI[3]

ABSTRACT

The increasing demand from road traffic requires continued construction and improvement of roads in both urban and rural areas. The pavement construction industry is one of the largest economic and material consuming industries in the world. The construction of a new pavement or overlays involves a huge consumption of aggregate and binder. This increasing demand has resulted in growing costs and scarcity of natural materials and increase in construction and demolition wastes, which further causes waste disposal problems. Thus, there is a need to look for alternate pavement design for new construction and maintenance. The use of Reclaimed Asphalt Pavement (RAP) in roadway construction fits with the overall objective of sustainable development by the careful use of natural resources. Large quantities of Reclaimed Asphalt Pavement (RAP) materials are produced during highway maintenance and construction. RAP recycling activates reduces the use of declining virgin aggregates and tackles the issues of material storage and disposal of reclaimed asphalt material generated from pavement construction. Further, energy savings can also be done through the use of RAP in roadway construction by reducing the processing and transport of virgin aggregate. India has very limited experience with recycling and reuse of RAP in various layers of pavement structure. The main objective of the present paper is to evaluate the mechanical properties of reclaimed aggregates so as to analyze the suitability of its usage in flexible pavement. It was observed that the use of reclaimed aggregates (100%) and replacing some percentage of VG30 with CRMB 55 resulted in the increase of Marshall Stability, Flow value and Bulk density of Bituminous Concrete Mix.

1. INTRODUCTION

Construction of roads involves huge outlay of investment and mainly sixty percent of the highway project cost is associated with the road construction. A precise engineering design may save considerable investment and ensure reliable performance of the road network. In India almost ninety percent road network is occupied by asphalt pavement only which are constructed and maintained by using naturally available road aggregates and bitumen[1]. The increasing demand for road construction has further resulted in growing costs and scarcity of these natural materials. Hence, there is a requirement to look for alternate pavement designs for new construction and maintenance works. Nowadays, the construction industries are emphasizing on materials conservation, reuse and recycling in order to move towards better environmental quality and sustainable development. The use of recycled materials in pavement has become an increasingly widespread practice in recent years. The recycling of existing asphalt pavement materials produces new pavement with considerable savings in material, money and energy. Aggregates and binder from old asphalt pavements are still valuable even though these pavements have reached the end of their service life.

In India, most of the roads are asphalt surfaced pavements[2]. These roads are periodically maintained by resurfacing. Large quantities of Reclaimed Asphalt Pavement (RAP) materials are produced during the maintenance and construction operations[3]. Reclaimed asphalt pavement is a method by which asphalt pavements are constructed using reclaimed or recycled materials obtained from existing pavements. The use of RAP is gradually gaining popularity with the development in technology[4]. Earlier pavements were scarified by excavators which gave huge blocks of RAP materials. Therefore, it was difficult to use

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RAP materials in the construction of new pavements. Now with the latest development in technology, milling machines have been made available in the market which cut the pavement to desired thickness thereby making the use of RAP materials much easier. The asphalt milling machine also known as pavement planer or pavement recycler is a construction machine used to remove asphalt pavement or asphalt concrete from roadways. The milled surface is accomplished by bringing a rotating mandrel or "head" into contact with the pavement at an exact depth or slope. The mandrel has hundreds of hardened spikes or teeth on its surface, which bite and cut away at the roadway's surface. The surface material that is removed is normally fed by conveyor into a dump truck or semi-trailer, but can be left in place to be removed or recycled later. A water spray system provides cooling for the mandrel, as well as dust management[5]. In the present work is to determine and compare the physical and Marshall Properties of virgin aggregates, recycled aggregates and to assess the suitability of usage of RAP in flexible pavement design.

2. MATERIALS AND METHODS

2.1 Virgin Aggregates

The coarse aggregates are crushed by utilizing crusher to get varying size of aggregates from 19 mm and retained on a 2.36 mm sieve while fine aggregate should comprise 100% of fine crushed sand passing the 2.36 mm sieve and retained on 0.075 mm sieve.

2.2 Recycled Aggregates

The main source of recycled aggregates is demolished flexible pavement removed by milling process and it should free from any other contaminants. Aggregates are collected from demolition site in front of Punjab Engineering College (Deemed to be University), Sector-12, Chandigarh. The aggregates are crushed manually with hammer and the reclaimed materials (aggregates and bitumen) are separated out with bitumen/centrifugal extractor by using benzene. The usage of recycled aggregates (100%) was decided based on physical/mechanical test of recycled aggregates as compared to virgin aggregates as per MoRT&H Specification. The aggregates are sieved through 25 mm, 19 mm, 10 mm, 4.75 mm, 2.36 mm, 425 micron and 75 micron IS sieves for proper gradation.

2.3 Bitumen (VG 30)

Bitumen is the byproduct of petroleum and its grading depends upon its penetration value and viscosity grade for different climatic factor and nature of duty. It has excellent adhesive and bonding properties with aggregates, excellent waterproofing properties, resistance to acids and alkali as well.

2.4 Crumb Rubber Modified Bitumen

Crumb Rubber Modified Bitumen (CRMB 55) is a hydrocarbon binder obtained through physical and chemical interaction of crumb rubber (produced by recycling of used tyres) with bitumen and some specific additives which are available in market (Source: Indian Oil, Panipat Refinery). It is a unique kind of bitumen whose properties are enhanced by mixing it with crumb rubber and special additives as per the provisions of IRC:SP:53-2002 and IS 15462: 2004. CRMB 55 is prescribed for moderate climatic regions and was procured from the local sources.

2.5 Mineral Fillers

Mineral fillers have substantial influence over the properties mix design. The utilization of hydrated lime is encouraged because of its very good anti-stripping and anti-oxidant properties. In the present work lime and sand are used as fillers for bituminous mix specimen.

2.6 Marshall Method of Mix Design

Marshall Stability Test of a mix is characterized as maximum load carried by a compacted specimen at a standard test temperature at 60°C. The flow value is the deformation the Marshall Test specimen under goes during the loading up to the maximum load in 0.01 mm units. The Marshall Stability Test is relevant for hot mix design using bitumen and aggregate with maximum size of 26.5 mm.

2.7 Aggregate Gradation

The aggregate gradation (Grading-I) for bituminous concrete mix in the present study is adopted as per MoRT&H (Vth revision) specifications and is shown in **Table 6**. The **Fig. 1** shows the gradation curve of both virgin and recycled aggregates.

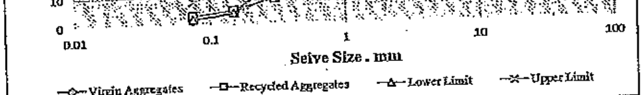

Fig. 1 Gradation Curve of Virgin Aggregate and Recycled Aggregate

3. RESULTS AND DISCUSSIONS

3.1 Physical Properties of Aggregates, Bitumen and Crumb Rubber Modified Bitumen

Test results of virgin aggregates and recycled aggregates for bituminous concrete as per Indian Standard are shown in Table 1.

The test results of Bitumen (VG 30) as per Indian Standard are shown in Table 2.

The test results of Crumb Rubber Modified Bitumen (CRMB 55) as per Indian Standards are shown in Table 3.

The test results shows the Specific Gravity of Fillers are shown in Table 4.

Test results of shows the properties of Extracted Bitumen from RAP are shown in Table 5.

Table 1 Test Results of Virgin Aggregates and Recycled Aggregates

Test	Test Results		MORT&H.(V[th] Revision)[6]
	Virgin Aggregates	Recycled Aggregates (100%)	
Aggregate Impact value (%)	19.82	21.45	Max 30%
Grain size analysis (%)	3.0	4.0	Max 5% passing 0.075 mm IS sieve
Los Angeles abrasion value (%)	23.62	25.56	Max 40%
Flakiness and Elongation index (%)	21.2	23.25	Max 35%
Aggregate crushing value (%)	20.34	20.34	Max 30%
Water absorption (%)	0.37	0.35	Max 2%
Aggregate Specific Gravity			
□ Coarse Aggregates	2.67		Min 2.5
□ Fine Aggregates	2.6	2.66	
□ Filler	2.3	2.66	
Stripping Value (%)	99.7	99.52	Min. Retained Coating 95%

Table 2 Test Results of Bitumen

Test	Test Results	IS73:2013
Penetration at 25°C, 100 g, 5 seconds, 0.1 mm, Min.	66	45
Softening point (R&B), °C, Min.	52	47
Ductility test at 27°C, cm	87	Min. 75
Specific gravity	1.02	Min. 0.99
Flash point, °C, Min.	273	Min 220
Fire point, °C, Min.	292	Min 220
Kinematic viscosity at 135°C,cSt, Min.	458	Min 350
Absolute viscosity at 60°C, Poises	3086	2400-3600

Table 3 Test Results of CRMB 55

Test	Test results	IS:15462-2004
Penetration at 25°C, 100gm, 5 seconds, 0.1mm	52	Max 60
Softening point (R&B), °C	51	Min 55
Flash point, °C	256	Min 220
Fire point, °C	275	Min 220
Elastic recovery of half thread in Ductilometer at 15°C, percent, minimum	55	Min 50
Elastic recovery of half thread in Ductilometer at 25°C, percent, minimum	43	Min 35

Table 4 Test Results of Fillers

Filler	Specific Gravity
Lime	2.18
Sand	2.30

Table 5 Test results of Extracted Bitumen from RAP

Name of the Property	Value Obtained	Method of Testing
Penetration at 25°C, 100 g, 5 seconds, 0.1 mm	20	IS :1203-1978
Softening point (R&B), °C	77	IS :1205-1978
Ductility test at 27°C, cm	57	IS :1208-1978
Flash point, °C	288	IS :1209-1978
Fire point, °C	305	IS :1209-1978
Specific gravity	1.04	IS :1202-1978

Table 6 Gradation of Aggregates for Bituminous Concrete (Grading-I)

Sieve Size (mm)	Obtained Gradation		% Passing Required
	Virgin Aggregates	Recycled Aggregates	
26.5	100	100	100
20	92.5	88	100
13.2	74.41	64	79 -100
9.5	63.6	55	59-79
4.75	38.12	33	35-55
2.36	29.8	26	28-44
1.18	22.8	19	20-34
0.6	20.33	11	15-27
0.3	14.9	9	10-20
0.15	4.68	5	4-13
0.075	1.75	3	2-8

3.2 Marshall Properties of Conventional Bituminous Concrete (BC) Grade I Mix Design using Virgin Aggregates

Marshall Samples are prepared by varying percentage of bitumen VG 30. Stability flow analysis, density and volumetric analysis is carried out for the prepared Marshall samples with varying bitumen content from 4.5 % to 6.5 % are shown in **Table 7**. The obtained test results are plotted graphically and are shown in **Fig. 2**.

Table 7 Marshall Properties of Conventional Bituminous Concrete Mix

Bitumen (%)	Marshall Stability (kN)	Flow (mm)	Air Voids (%) Va	Voids Filled with Bitumen (%) VFB	Voids in Mineral Aggregate (%) VMA	Bulk Density (g/cc)
4.5	12.20	2.4	5.6	65.52	16.51	2.38
5.0	14.65	2.8	4.5	73.41	16.78	2.41
5.5	16.55	3.1	4.0	77.25	17.62	2.53
5.65	16.75	3.4	3.9	77.35	17.69	2.55
6.0	15.10	4.4	3.1	81.56	17.87	2.42
6.5	13.33	4.8	2.3	86.77	17.98	2.47

From the test results the following observations are made:-

- The stability value increases when bitumen content is increased from 4.5% to 5.5 % and then it decreases from 6.0% to 6.5% bitumen content. Maximum value of stability is found to be 16.75 kN at 5.65% bitumen content.
- Flow value increases with the increase in bitumen content from 4.5% to 6.5% and the value is found to be 3.4 mm at 5.65% bitumen content, the criteria of 2 mm to 4 mm for BC (Grade I) are almost satisfied.
- The air voids decreases continuously from 4.5% to 6.5% bitumen content. The air voids achieved in total mix is 3.9 % at 5.65% bitumen content.
- The percentage of voids filled with bitumen increases continuously from 4.5% to 6.5% bitumen content the value of VFB is found to be 77.35% at 5.65% bitumen content.
- Void in mineral aggregates decreases from 4.5% to 5.5% and then increases from 6.0% to 6.5% bitumen content. The value of VMA is found to be 17.69% at 5.65% bitumen content.

- Bulk Density value decreases from 4.5% to 5.0% and then increases from 5.5% to 6.5% bitumen content. The value of bulk density is found to be 2.55 g/cc at 5.65% bitumen content.

Optimum Binder Content is found to be 5.65% by weight of aggregate in conventional bituminous concrete mix.

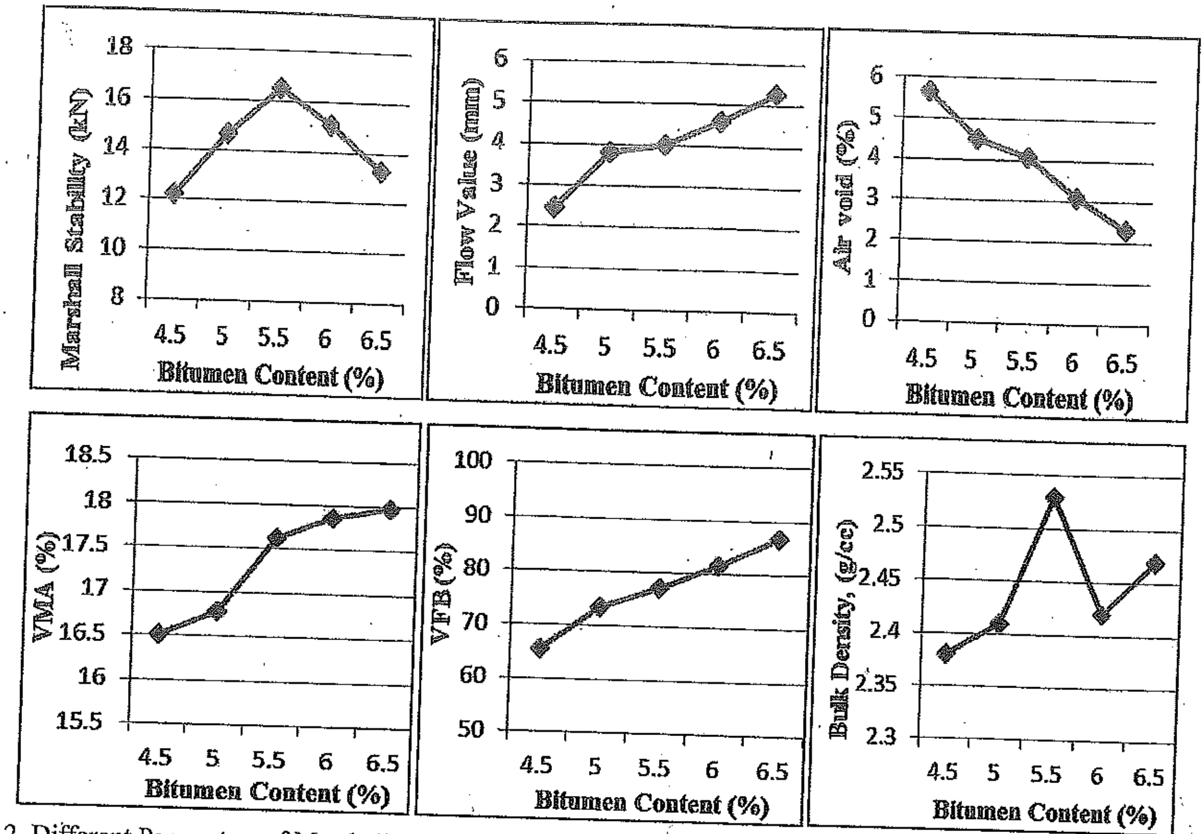

Fig. 2 Different Parameters of Marshall Stability Test on Conventional Bituminous Concrete using Virgin Aggregates

3.3 Marshall Properties of Rubber Modified Bituminous Concrete (BC) Grade I Mix Design using Recycled Aggregates

Marshall method for rubber modified bituminous concrete mix design is carried out by using recycled aggregate and by replacing bitumen with CRMB 55 at optimum binder content. The same optimum binder content i.e. 5.65% of conventional bituminous concrete mix is used for evaluating the effect of adding or replacing of different percentage of crumb rubber modified bitumen in VG30 on strength and flow characteristics of mixes.

Initially, CRMB has been added with percentage of +1.0% and +0.5% without replacing bitumen. After that the varying percentage of -0.5%, -1.0%, -1.5% and -2.0% of VG30 has been replaced with the same percentage of CRMB 55 by weight of the total mix at optimum binder content i.e. at 5.65%. The outputs of stability-flow, density and volumetric analysis are shown in **Table 8**. The obtained test results are plotted graphically and are shown in **Fig. 3**.

Table 8 Marshall Properties of Rubber Modified Bituminous Concrete Mix using Recycled Aggregates

CRMB 55 at OBC (%)	Marshall Stability (kN)	Flow (mm)	Total Air Voids (%) Va	Voids Filled with Bitumen (%) VFB	Voids in Mineral Aggregate (%) VMA	Bulk Density (g/cc)
+1.0	11.88	5.5	3.3	65.20	18.30	2.64
+0.5	13.20	4.4	4.0	71.42	17.50	2.51
-0.5	14.78	3.4	4.1	75.66	17.0	2.44
-1.0	16.10	3.6	4.0	78.20	17.10	2.48
-1.5	17.50	3.8	3.6	82.50	17.40	2.66
-2.0	14.92	5.3	3.4	76.62	17.70	2.23

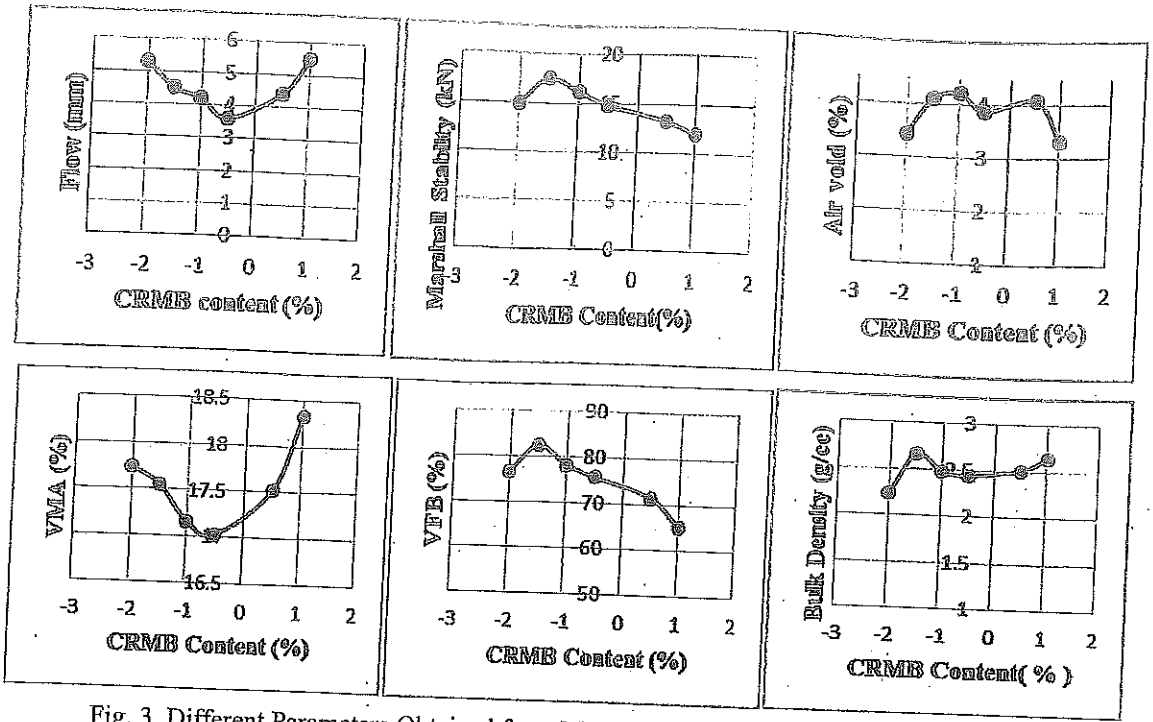

Fig. 3 Different Parameters Obtained from Marshall Stability Test on Rubber Modified Bituminous Concrete Mix Using Recycled Aggregates

From the test results the following observations are made:-

- The stability value decreases on adding CRMB from +0.5% to +1.0% by weight of total mix in bitumen and increases on replacing CRMB from -0.5% to -1.5% by weight of total mix and then decreases rapidly for -2.0% replacement of bitumen by CRMB at OBC. Maximum value of stability is found to be 17.50 kN at -1.5% replacement of bitumen with CRMB.
- Flow criteria of 2 mm to 4 mm for rubber modified mix are almost satisfied at -0.5%, -1.0% and -1.5%. The higher flow value is found at -2.0%, +0.5% and +1.0%.
- The air voids decreases from +0.5% to +0.1% and -0.50% to -2.0% of CRMB content. The air voids is found to be 3.6% of the total mix at -1.5% replacement of binder content.
- The percentage of voids filled with bitumen increases continuously from +1.0% to - 1.5% and then decreases for -2.0% replacement of binder content. The value of VFB is found to be 82.50% of the total mix.
- Void in mineral aggregates decreases from +1.0% to -0.5% and then increases up to 2.0% replacement of binder content. The value of VMA is found to be 17.40% of the total mix. The density increases from +0.5% to +0.1% of CRMB content and -0.5% to -1.5% replacement of bitumen with CRMB. The maximum value of bulk density is found to be 2.66 g/cc at -1.5% and then decreases at -2.0% replacement of binder content.

Considering the criteria of maximum stability, maximum density and keeping flow value within the limits, -1.5% replacement of VG30 with CRMB 55 at OBC i.e. at 5.65% is considered as the most optimum replacement.

3.4 Comparisons of Mixes

A. Comparison of Conventional Bituminous Concrete Mix & Recycled Asphaltic Mix is shown in **Table 9.**

Table 9 Comparisons of Conventional Mix & Recycled Asphaltic Mix at same OBC

Properties	Conventional mix	Recycled Asphaltic Mix
Marshall stability (kN)	16.75	17.50
Flow (mm)	3.4	3.8
Air voids (%)Va	3.9	3.6
Voids filled with bitumen (%) VFB	77.35	82.50
Voids in mineral aggregate (%) VMA	17.69	17.40
Bulk density, (g/cc)	2.47	2.66

- Considering the criteria of maximum stability, maximum density and keeping flow value within limits replacing -1.5% of bitumen with CRMB at OBC and it is found out to be the most optimum binder replacement in Recycled Asphaltic Mix.
- The stability value of Recycled Asphaltic Mix increases by 4.55% with the replacement of 1.5% bitumen by CRMB at OBC as compared to Conventional Bituminous Concrete.
- The density of Recycled Asphaltic Mix increases by 4.31% with the replacement of 1.5% bitumen by CRMB at OBC as compared to Conventional Bituminous Concrete.
- CRMB mixtures have better adhesion than the mixed prepared with conventional bitumen. Mixture prepared with the combination blend has improved adhesion as compared to the mixture developed with conventional mix.
- The use of rubber modified bitumen needs to be encourage in maintenance treatments for extension in life of renewals. The renewal cycle of bituminous concrete with modified bitumen may be taken as 1.5 times of the conventional bitumen.

4. CONCLUSIONS

This study essentially deals with the need to sustain the roads with recycled asphalt materials such as by using 100% recycled aggregates in HMA mixtures for both construction and maintenance. On comparing the obtained results, it is found that the stability value of recycled asphaltic mix is higher than the stability value of conventional bituminous mix. The recycled asphaltic mixes are expected to be more durable, less susceptible to moisture in actual field condition with enhanced properties. CRMB enhanced the properties of the mix as the Inter-molecular bonding between bitumen and crumb rubber coated aggregate enhance strength and thus upgrades the quality of bituminous concrete mixes. Therefore, as a result the use of 100% reclaimed aggregates and replacing some percentage of VG30 with CRMB 55 at same OBC there is an increase in the values of Marshall Stability, Flow value and Bulk density in bituminous concrete mix. Thus, the performance based analysis carried out can be implemented in road construction and can be beneficial in reducing the load on mining of stones and will solve the problem of overlay.

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