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SOLID WASTE MANAGEMENT IN INFRASTRUCTURE DEVELOPMENT WITH SPECIAL REFERENCE TO ROADS AND HIGHWAY PROJECTS IN KERALA

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Abstract: Management of Construction and Demolition Waste (CDW) and plastics are foremost concerns during infrastructure development, including roads and highways. Recycled Asphalt Pavement (RAP) may be effective for the road development and will help manage the bituminous waste included in the hazardous category.

After the 2018 flood, the state of Kerala initiated the rehabilitation and up gradation of Major District Roads (MDR) in various districts with the financial help of KfW Development Bank under the scheme Rebuild Kerala Initiative (RKI). The state identified the damaged roads and developed the DPR under the Kerala State Transport Project (KSTP) supervision. The present study aims to (i) understand the types and amount of various CDW generated in the selected project area (ii) design the asphalt pavement with aggregate-plastic-bitumen mix (iii) prepare mix design for RAP and (iv) application of newly developed mix design in the project road.

The study aims to reuse scarified bituminous material and plastic waste in Highway construction in Kerala and thereby reduce the environmental impact. As we know, Dense Graded Bituminous Macadam (DGBM) is a dense graded premix bituminous mix well compacted to form a high-quality pavement sub-surface course. The DBM consists of a proportioned mixture of coarse aggregate, fine aggregate, Bitumen VG-30 and additionally recycled asphalt pavement (RAP) material to meet the requirements of mix gradation, stability, flow density and voids.

The laboratory determination of the “Job Mix Formula” for Dense Graded Bituminous Macadam will be carried out for the source of bitumen from Bharat Petroleum Corporation Limited (BPCL), aggregate from the local quarry having environmental clearance from the concerned authority, and RAP Material (Scarified Bituminous) of existing road from Rebuilt Kerala Initiative project at Alappuzha and Trivandrum districts of Kerala

RAP Material will be tested for physical properties based on the Trial and Error Method as specified in Section 519 of the MORT&H Specification. Further, a road stretch under reconstruction will be selected and a RAP mix design will be implemented in the Proportion of 80%-20% (80% Conventional Bitumen and 20% RAP).

Even though IRC had already published guidelines (IRC SP 19: 2013) for the use of waste plastic in hot bituminous mixes, the technology continues to receive lukewarm responses from the designers/ contractors. With rapid urbanization, a large quantum of waste plastic is been generated and disposal of waste is a serious problem. Studies have revealed that waste plastics have great potential for use in bituminous construction as its addition in small doses, about 5-10%, by weight of bitumen helps in substantially improving the Marshall stability, strength, fatigue life and other desirable properties of bituminous mix, leading to improved longevity and pavement performance. The use of waste plastic thus contributes to the construction of green roads. The study aims at the use of waste plastic in hot bituminous concrete, thereby trying to re-use the generated waste from Construction in the development of Highways in Kerala.

To bring change and improvement in the current practices of the case area's CDWM, there should be an education, workshop, and training regarding the concept of CDWM, waste management strategies and benefits of BIM in managing CDW to construction project participants. This, in turn, can help the case study's firm and the general public to attain environmental, social and economic benefits from CDWM.

CHAPTER-1
INTRODUCTION

1.1 GENERAL INTRODUCTION

The waste generated during activities such as construction, maintenance, demolition, and deconstruction of buildings and civil work or during natural disasters is defined as construction and demolition waste (CDW) (USEPA, 2016). The average CDW generation is about 1.68 tonnes per person per year which is higher than the municipal solid waste generation, which is estimated at 0.80 tonnes per person per year (Kaza et al., 2018; Hoornweg and Bhada-Tata, 2012). The quantity and composition of CDW vary among regions depending on factors such as population, materials used for the construction, construction activities, etc.

Construction and demolition waste management (CDWM) has become a major environmental concern in major Indian cities. India is generating 150 MT CDW per year which accounts for 35%-40% of the global annual CDW generation (Jain, 2021). The first CDW recycling plant in India was started in 2009 at Burrari and it is estimated that 53 major Indian cities are ready to set up the recycling plant as early as possible, of which 13 are established (CSE, 2020). Furthermore, the report published by the CSE stated that only 1% of the CDW is recycled in India.

1.2 LAWS AND POLICIES FRAMED IN INDIA RELATED TO CDW

1.2.1 Swachh Bharath Mission (SBM)

To accelerate the efforts to achieve universal sanitation coverage, India launched the Swachh Bharath Mission on 2nd October 2014. The programme was initiated by the Ministry of Housing & Urban Affairs (MoUHA) with the motto of "Clean India".

1.2.2 Guidelines on Environmental Management of CDW

The Central Pollution Control Board (CPCB) revised the rules and regulations for CDW management based on the rules published by the Ministry of Environment, Forest, and Climate Change (MoEF & CC). In this, the construction projects which produce more than 20 tons of CDW in a day need to submit the site waste management plan to the local authorities (CPCB, 2017).

1.2.3 Guidelines for Sustainable Habitats (GSH)

The 'guidelines on re-use and recycled CDW' which is published by the Central Public Works Department (CPWD) included the measures and precautions of CDW recycling and the need for reconstruction plans.

1.2.4 Bureau of Indian Standards (BIS)

BIS is the responsible agency for issuing specifications and codes for recycled products. The IS:383 (2016) recommends replacement for 25% of plain cement concrete (PCC), 20% of reinforced cement concrete (RCC), and 100% of lean concrete with recycled aggregates.

1.3 KEY ISSUES OF CDW MANAGEMENT

The following are the major issues faced during the management of CDW (CSE, 2020);

- ❖ Estimation and Characterisation of CDW
- ❖ Difficulties in finding land for collection and recycling
- ❖ Collection and transport of CDW
- ❖ Concerns about business and finance case
- ❖ Involvement of state government agencies
- ❖ Response from the construction industry
- ❖ Pricing of recycled CDW
- ❖ Demolition management
- ❖ Poor monitoring and lack of resources
- ❖ Landfill issues and damaging of crops.

1.4 GENERATION OF CDW IN ROAD CONSTRUCTION PROJECTS

Infrastructure development is the need of time and can't be avoided. However, the generation of CWD in road projects can be minimized and the waste can be recycled.

1.4.1 Source of Construction Waste

The source of construction waste in a road project can be grouped into the following activities;

- Construction process: This includes activities in material cutting, compaction, material mixing, etc.
- Structural works: The activities in formworks, foundation works, and finishing
- Material management: It included activities such as material delivery, movement of material, etc.

1.4.2 Cause of Construction Waste

The major causes of construction waste generation are;

- ❖ Manpower
- ❖ Professional management
- ❖ Design and documentation
- ❖ Quality of materials
- ❖ Work Execution

1.5 DIFFERENT STAGES IN ROAD CONSTRUCTION

Generally, two types of road construction process are available;

1. Flexible pavement (BM/BC)
2. Rigid pavement (Concrete Roads –PQC –White Topping)

Flexible pavement, which is widely used, is composed of different layers such as the surface course of bituminous material, underlying base and subbase course. Statistics show that 95% of the total highways in the world are made of flexible pavement (). Portland cement is used as the binder in case of rigid pavement, whereas bitumen is used as binder in flexible pavement. Asphalt concrete or Bituminous Concrete (BC) is a mixture of aggregates and bitumen.

Bitumen is a viscoelastic complex hydrocarbon, thermoplastic material which is used as the binder in flexible pavement. As per the BIS specifications (IS-73-1992) based on the Viscosity Grade (at 60°C), four grades of bitumen are available.

- VG-10: widely used in spraying applications such as surface dressing and paving in very cold climates.
- VG-20: used for paving in cold climates and high-altitude regions.
- VG-30: Mainly used for constructing extra heavy-duty bitumen pavement.
- VG-40: Used mainly in highly stressed areas like intersections, adjacent to toll booths, truck parking lots etc.

Table No.01: Specification of Viscosity Grade Bitumen as per IS 73:2006

Characteristics	VG-10	VG-20	VG-30	VG-40
Absolute viscosity at 60°C, poises, min	800	1600	2400	3200
Kinematic Viscosity at 135°C, CST, min	250	300	350	400
Flash point C, min	220	220	220	220
Solubility in trichloroethylene, %, min	99.0	99.0	99.0	99.0
Penetration at 25°C	80-100	60-80	50-70	40-60
Softening point, C, min	40	45	47	50
Test on residue from thin film over test / RTFOT				
i. Viscosity ratio at 60°C, max	4.0	4.0	4.0	4.0
ii. Ductility at 25°C, cm, min,	75	50	40	25

A typical cross-section of a flexible pavement consists of the following layers;

1. Surface course: BC
   - the topmost layer of the flexible pavement
   - It withstands maximum stress and wear and tear
   - Made with bitumen bonded with aggregates graded 25 mm -0.75 mm
   - Thickness varies from 25 -50 mm
2. Binder course: DBM
   - the intermediate layer between the surface course and the base course
   - Bitumen-bounded aggregate layer
   - Thickness ranges from 50-100 mm
3. Base Course: WMM
   - Hard crushed aggregates are used in this layer
   - known as the backbone of flexible pavement
   - Thickness ranges from 100-300 mm
4. Sub-base course: GSB
   - provides additional structural support
   - Thickness ranges from 100-300 mm
5. Sub-grade
   - lowest layer of the flexible pavement consisting of a compacted layer of natural soil.

Natural soil layer in uniformly spread and compacted at an optimum moisture content in the preparation of sub-grade course. The sub-base course consists of crushed stones, gravel, and coarse sand. After spreading selected materials over the prepared sub-grade layer, it is compaction will be done by rollers at optimum moisture content.

Hard and crushed aggregates are used as the base course. For this, crushed aggregates are mixed with water in a suitable proportion in a mixing plant to produce a Wet Mix of Macadam (WMM). The prime coat is applied which is a low viscosity cutback bitumen is applied above the base course. The prime coat is commonly prepared by mixing bitumen (80%): kerosene (20%). The prime coat will fill the capillary voids present in the sub-base course and bind the materials into a single unit. In between the binder course and surface course, Tack Coat (an asphaltic emulsion diluted with water) is used.

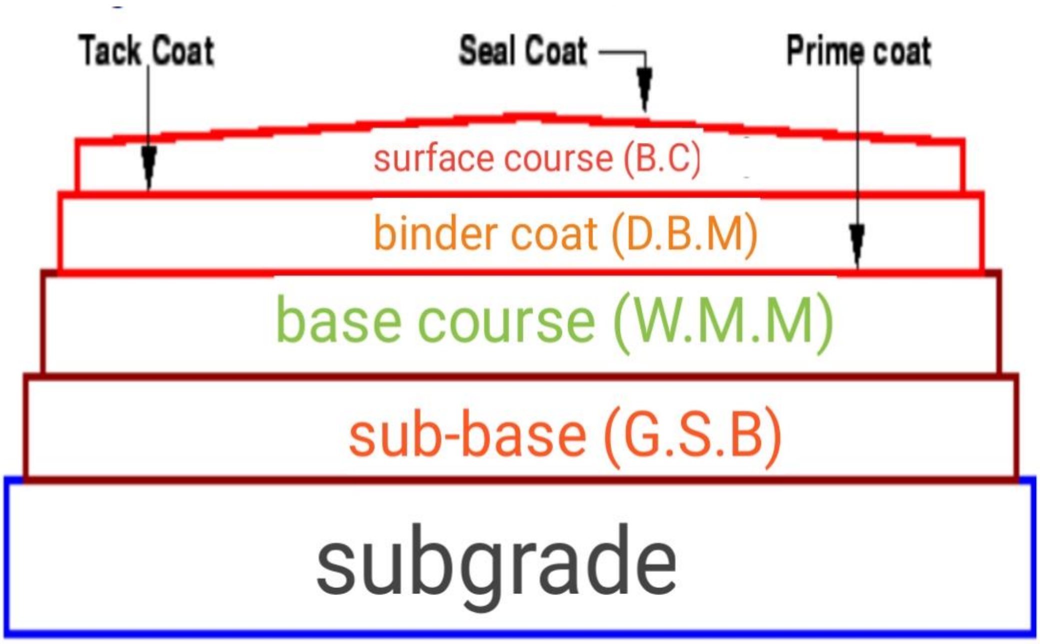


Fig.No.01: Layers of Road Cross Section: Layer by Layer.

The Project can be divided into two phases:

1. Use of 8% Shredded Plastic for BC (VG-30)
2. Use of RAP (20 %) for the DBM.

1.6 RECYCLED ASPHALT PAVEMENT (RAP)

RAP (Reclaimed/Recycled Asphalt Pavement) is used for new road construction and existing road maintenance as sustainable and eco-friendly alternative solution. As of now, no specific criteria, norms, or methods are there in India or other developing countries for identifying recovered asphalt materials. Therefore it is an urgent requirement for classifying the RAP materials that are now accessible for use in road construction. Re-use of RAP Materials can reduce the cost associated with road construction up to 25-30%. Some studies in India reported that new materials were swapped out for RAP in the binder course, but there are undoubtedly many more that are not yet documented. The aim of the current project is to determine the aggregate mix percentage for DBM layers with 20% of RAP in the Climate Resilience Road Construction in the Highways of Kerala.

1.7 REUSE OF PLASTIC WASTE IN BITUMINOUS CONCRETE (BC)

Plastic wastes are of high environmental concern due to their worldwide distribution and adverse impact on the flora and fauna (Sruthy et al., 2016). The re- use of plastic waste in flexible pavements one of the solutions for plastic disposal. Vasudevan R (2007) reveals that the plastic coating can reduce the porosity, absorption of moisture, and improves soundness. Various types of polymers such as polyethene (PE), Polypropene (PP), Polyvinyl chloride (PVC), etc have different advantages and disadvantages in the asphalt binder.

OBJECTIVES OF THE STUDY

The major objectives of the study are;

1. To compare the use of RAP (20%) for the Dence Bituminous Macadam (DBM) with the normal DBM
2. To compare the use of shredded plastic for BC (VG-30) with normal BC.

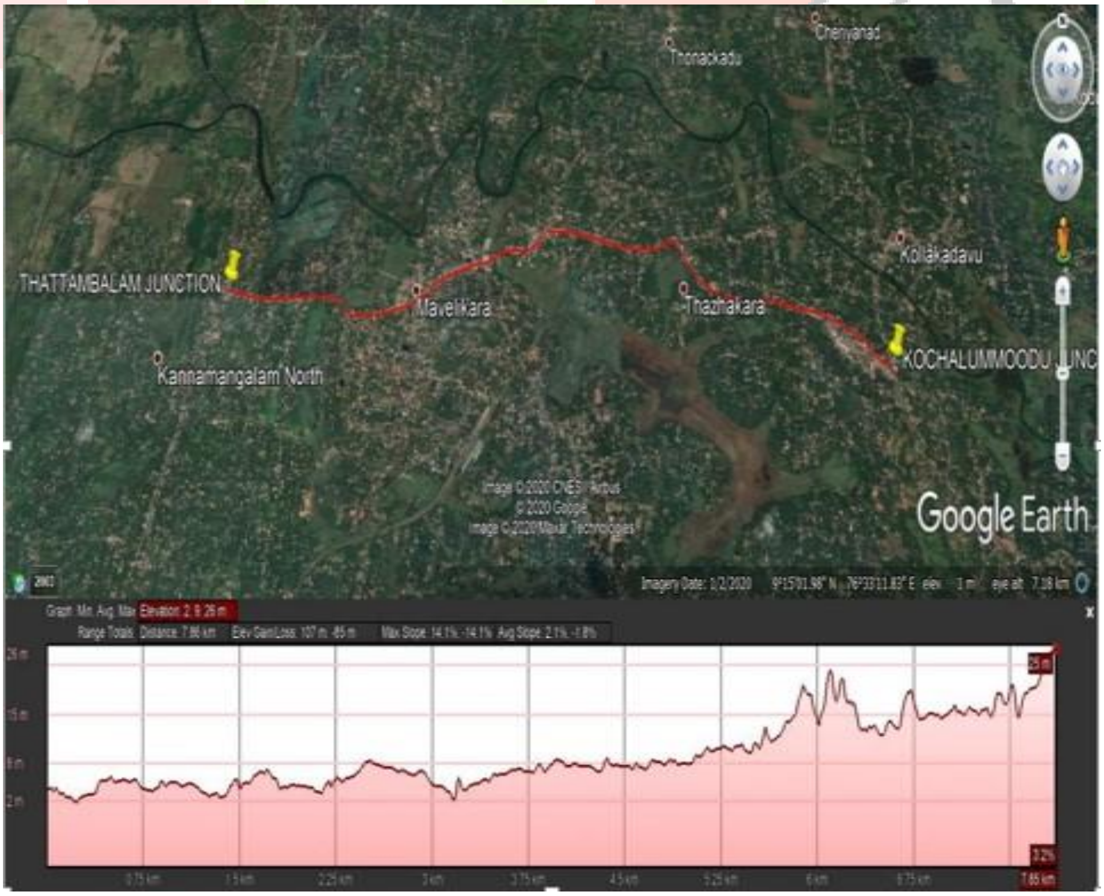
CHAPTER-2
MATERIALS AND METHODS

2.1 Selection of study area

Kerala State Transport Project (KSTP) on behalf of the Government of Kerala (GoK) initiated the rehabilitation and upgradation of two major district roads (MDR) in the Pathanamthitta and Alapuzha districts of Kerala. This project was funded by the KfW Development Bank under the Rebuild Kerala Initiative (RKI). The details of the project roads are given below;

Table No. 02: Details of project roads

Road Name	District	Length (Km)
Thattarambalam-Kochalummood Road	Alappuzha	7.945



2.2 Methodology

2.2.1 Use of RAP (20 %) for DBM.

20% RAP has been added to 80% Conventional Bitumen. This is for complying with the laying temperature of 145°C due to the LEED distance. The Current Hot Mix Plant is 38 km from the site and the temperature at the plant was 154°C upon reaching the site, the minimum term requirement of 145°C was met. The amount of RAP can be increased up to 50 % if we can maintain the laying temperature and the same requires a detailed study. Also, the Lead from the HMP to the site shall be minimized to 15km and in such cases, there could be the possibility of increasing the RAP.

2.2.2 Use of 8% Shredded Plastic for BC (VG-30)

The traffic volume study in the project road is 60 MSA and hence, the maximum permissible limit of plastic is 8%.

2.3 Description of Materials Used

2.3.1 Aggregates were collected from Amity Crusher, Pathanamthitta.

Table No.03: Physical properties of aggregates

Sl. No.	Name of test	Test Method	Test Result	Requirement as per MORTH	Remarks
1	Aggregate impact value	IS: 2386 Part-4	21.97%	Max: 27%	Satisfactory
2	Flakiness & Elongation Index	IS: 2386 Part-1	22.94%	Max: 35%	Satisfactory
3	Coating & stripping of Bitumen aggregate mixture	IS: 6241	98%	Max. 95%	Satisfactory
4	Cleanliness for 3mm down aggregate	IS: 2386 Part-1	0.54	Max 5% passing 0.075 mm sieve	Satisfactory
5	Loss Angeles	IS: 2386 Part-4	22.2	Max 35%	Satisfactory
6	Water Sensitivity	AASHTO 283	93.6	Min. 80%	Satisfactory
7	Plasticity Index	IS: 2720 Part-5	NP	Max. 4%	Satisfactory

2.3.2 VG 30 bitumen was used in this study and was collected from BPCL. It is the popular bitumen used in India which is equivalent to 60/70 penetration grade bitumen. Specific gravity of bitumen is 1.05 and the other properties as per the IS 73-2013 are given below.

Table No.04: Properties of Bitumen VG-30

Sl. No.	Name of test	Test method	Test results	Requirement as per IS: 73	Remarks
1	Specific gravity at 25°C	IS:1202-1978	1.05	Min: 0.99	Satisfactory
2	Penetration at 25°C, mm	IS: 1203-1978	49	Min: 35	Satisfactory
3	Softening point, °C	IS:1205-1978	51	Min: 50	Satisfactory
4	Ductility in CM	IS:1208-1978	90	Min: 25	Satisfactory
5	Viscosity (Absolute), Poise	IS:1208-1978	3490	2400-3600	Satisfactory

2.3.3 Filler: Ordinary Portland Cement (OPC) is collected from a local vendor and rock dust is collected from Amity Crusher, Pathanamthitta.

2.3.4 Plastic Wastes: Polyethylene and polypropylene plastic materials such as carry bags, packaging covers, and bottles were collected from the project camp locations as well as from M/s, Eraviperoor Grama panchayath, Eraviperoor, Thiruvalla.

Table No.05: The summary of BC G-2 mix design details

Bituminous work Item	Paving Bitumen	Hot mix plant bin wise Aggregate proportions				Waste plastic
	VG-30 Grade					
BC-G-II (Without Waste Plastic)	5.52 % by mass of Total mix	HB l (19.0-10 mm)	HB 2 (10-4.00 mm)	HB 3 (4.00 mm down)	Filler (Rock dust)	
		28%	22 %	48 %	2 % of the total mix	NA
BC-G-II (With Waste Plastic, 8 % of Bitumen by weight)	5.52 % by mass of Total mix	28%	22 %	48 %	2 % of the total mix	0.4416%

2.4 Preparation of mix designs

The mix designs of DBM and BC are prepared based on the MoRT&H specifications. The major objective of mix design preparation is to provide sufficient workability to permit easy replacement without segregation, sufficient workability to avoid premature cracking, sufficient strength to resist shear deformation and sufficient flexibility at low temperatures to prevent shrinkage cracks.

2.4.1 Selection of Mix design (DBM Grading -II Mix design with RAP Material)

Dense Bitumen Macadam (DBM) is a pre-mixed bituminous mix which is compacted to form a high-quality pavement sub-surface course. The DBM consist of a proportioned mixture of coarse aggregates, fine aggregates, bitumen VG-30, and recycled asphalt pavement (RAP) to meet the requirements of mix gradation. Scarified material is been collected from the existing pavement to be reconstructed and further taken to the HMP where there is a special type conveyor belt has been installed to maintain the temperature as required in the specification.

Two types of bitumen were selected for the preparation of the mix, i.e.; VG-30 RAP material and the proposed DGBM mix with 20% RAP material. The evaluation of bitumen parameters is given in table 7. JMF/Mix design of Dense graded Bituminous Macadam (DGBM) Grading-2 with RAP (80 % Virgin aggregate & 20 % RAP milling material) material using the input materials of the mix contents are Bitumen VG-30 from M/s Bharath Petroleum Corporation Limited (BPCL), Aggregates from source M/S Amity rock products, Chunkuppara and RAP material from existing site milling material, Coromandel king Cement as a Filler. The relevant test reports enclosed are reviewed per Clause no. 519 of the technical specification of MORT&H, MS-2 & IRC 120 and found in order.

2.4.2 BC with Shredded plastic

Waste plastic have great potential for use in bituminous construction as its addition in small dose (5-10 %) , by weight of bitumen helps in substantially improving the marital stability , strength, fatigue ,life and longevity of the road surface. The bitumen for bituminous mix to be mixed with plastic fibres shall comply with the specifications as per IS 73. The waste plastic shall conform to the size passing 2.36mm sieve and retained on 600 micron sieve. The shredded plastic fibres will be acting as a coating over the aggregates thereby improving the surface property of the aggregates (doubles the binding property of the aggregates). Since the softening point of these plastics varies between 110℃-140℃ and they do not produce any toxic gases while heating, but the softened plastic forms a thin film like structure over aggregates, when it is sprayed on hot aggregate which is heated at 160 ℃. The traffic volume study in the project road is 60 MSA and hence, the maximum permissible limit of plastic is 8%.

Fig. No.03: Hot-Mix Plant (Ammann Appollo, 180 TPH)

CHAPTER-3
RESULTS AND DISCUSSIONS
3.1 BC Mix Design without plastic waste

The BC mix design without plastic waste which is used normally during road construction. The description of materials and mix ratio are given in Table 05.

Table No.06: Description of materials used for BC

Description of material	Mix proportion	Source of material
Hot Bin 1 (19 to 10 mm)	28	Amity Crusher
Hot Bin 2 (10 to 4 mm)	22	Amity Crusher
Hot Bin 3 (4 mm down)	48	Amity Crusher
Filler (Dust)	2	Amity Crusher
Bitumen (VG 30)	5.52	BPCL Kochin

The description test was conducted for the aggregates and the results were shown in table xx.

Table No.07: Description of test for aggregates

Sl. No.	Description of tests	Obtained results	Specification	Remarks
1	**Optimum binder content by mass of total mix (%)**	5.52	5.40 minimum	as per MoRT&H Table 500-17
2	**Fines to Bitumen ratio**	1.02	0.6-1.2	as per MoRT&H 505.3
3	**Bulk Density of Mix (GMB)**	2.454		as per MoRT&H clause 507.3.5
4	**Air Voids (VA) %**	3.85	3-5	as per MoRT&H Table 500-11
5	**Voids in mineral aggregates**	12.36	Minimum 12	as per MoRT&H Table 500-12
6	**Voids filled with bitumen**	68.84	65-75	as per MoRT&H Table 500-11
7	**Marshell stability of the mix in Kn at 60°C**	16.1	Minimum 9 Kn	as per MoRT&H Table 500-11
8	**Flow (mm)**	3.1	2 to 4	as per MoRT&H Table 500-11
9	**Retained stability after 24 Hrs at 60 in water**	94.62	Minimum 80%	as per MoRT&H Table 500-8
10	**Retained coating on aggregate %**	Above 95%	Minimum 95%	as per MoRT&H Table 500-8

Table No.08: Summary of BC design mix

Composition of Bituminous Concrete (Table 500-17)	
Grading	2
Nominal aggregate size	13.2 mm
Layer thickness	30-40 mm

Table No.09: Mixing and laying temperature of BC Mix (MoRT&H Table 500-2)

Sl. No.	Description	Temperature in °C
1	Bitumen Temperature	150-165
2	Aggregate Temperature	150-170
3	Mixing Temperature	150-165
4	Laying Temperature	Min 140
5	Rolling Temperature	Min 90 (After Rolling)

Table No.10: Summary of Bituminous Concrete Design Mix

Test	Specification	Method Test	Results as per MTC
Penetration	45 Min	IS 1201	68
Softening point	Min 47	IS 1206-2	50
Ductility test for residue after TFOT	Min 40	IS 1206-3	90
Flash point test	Min 220	IS 1448 P:69	>220
Absolute viscosity	Min 2400, Max 3600	IS 1216	2600
Kinematic viscosity	Min 350	IS 1205	445
Solubility in TCE	Min 99	IS 1208	99.7

Table No.11: Physical requirements of course & fine aggregates

Property	Test	Specification	Method of test	Results
Cleanliness	Grain size analysis	Max 5%	IS 2386 part 1	0.58
Particle shape	Combined flakiness & Elongation	Max 35%	IS 2386 part 1	22.50%
Strength	Aggregate Impact value	Max 24%	IS 2386 part 4	23.21%
Durability	Magnesium Sulphate	Max 12%	IS 2386 part 5	3.41%
	Sodium Sulphate			1.16%
Water absorption	Water Absorption	Max 2%	IS 2386 part 3	0.058% for 19-10 mm
				1.01% for 10-4 mm
				1.45% for 4mm down
Stripping	Coating and stripping value	Min 95%	IS 6241	98%
PI	LL&PI	<4	IS 2386 part 5	Non plastic
Sand equivalent	Sand equivalent test	>50	IS 2720 part 37	82

Fig.No.04: Extraction test for bitumen

Fig.No.05: GMM test for bitumen

Fig.No.06: Preparation of mould for martial test

Fig.No.07: Martial Mould

Marshall Test

The Martial Test measures the load and flow rate of asphalt samples. The Martial test is conducted in 2 stages:

1. Specimen Preparation.
2. Specimen Testing.

Sl No	Bitumen % (Pb)	Wt in Air (gm)	Wt in Water (gm)	SSD Wt in Air (gm)	Volume (CC)	Bulk Density (Gmb)	GMM	Air Voids (%)	VMA (%)	VFB (%)	Proving Ring Reading (Div)	Stability (KN)	Correction factor (vol)	Correct Stability (KN)	Flow (mm)
								3-5	Min 12	65-75				Min 9KN	2-4
1	5.00	1260.0	743	1261.0	518.0	2.432	2.574	5.47	12.63	56.68	200	14.82	0.96	14.23	1.7
2		1259.5	742	1260.0	518.0	2.431					200	14.82	1.00	14.82	1.8
3		1259.0	743	1260.0	517.0	2.435					205	15.19	0.96	14.58	1.7
						2.433								14.5	1.7
1	5.25	1262.0	746.0	1263.0	517.0	2.441	2.563	4.70	12.50	62.43	210	15.56	1.00	15.56	2.5
2		1262.5	746.0	1263.0	517.0	2.442					215	15.93	1.00	15.93	2.5
3		1262.0	747.0	1263.0	516.0	2.446					205	15.19	1.00	15.19	2.4
Average						2.443								15.6	2.5
1	5.50	1265.5	750.0	1266.0	516.0	2.453	2.553	3.89	12.35	68.49	215	15.93	1.00	15.93	3.1
2		1265.0	751.0	1266.0	515.0	2.456					215	15.93	1.00	15.93	3.1
3		1265.0	750.0	1266.0	516.0	2.452					215	15.93	1.00	15.93	3.2
3						2.454								15.9	3.1
1	5.75	1268.5	750.0	1269.5	519.5	2.442	2.543	3.97	13.01	69.45	220	16.30	0.96	15.65	3.9
2		1268.0	749.0	1269.0	520.0	2.438					215	15.93	0.96	15.29	4.0
3		1269.0	751.0	1270.0	519.0	2.445					220	16.30	0.96	15.65	4.1
Average						2.442								15.5	4.0
1	6.00	1271.0	751.0	1272.0	521.0	2.440	2.533	3.81	13.44	71.64	205	15.19	0.96	14.58	4.9
2		1271.5	750.0	1272.5	522.5	2.433					210	15.56	0.96	14.94	4.6
3		1271.0	750.0	1272.0	522.0	2.435					210	15.56	0.96	14.94	4.5
Average						2.436								14.8	4.7

Fig:No.08: Martial Test Results for Normal Bituminous Concrete.

3.2 BC with plastic waste

Table No.12: Description of materials for BC with plastic

Description of material	Mix proportion	Source of material
Hot Bin 1 (19 to 10 mm)	28	Amity Crusher
Hot Bin 2 (10 to 4 mm)	22	Amity Crusher
Hot Bin 3 (4 mm down)	48	Amity Crusher
Filler (Dust)	2	Amity Crusher
Bitumen (VG 30)	5.52	BPCL Kochin
Plastic waste (8% of Bitumen by weight)	0.4416	Eraviperoor Gramapanchayathh

Table No.13: Description of test for aggregates: BC with plastic

Sl. No.	Description of tests	Obtained results	Specification	Remarks
1	Optimum binder content by mass of total mix (%)	5.52	5.40 minimum	as per MoRT&H Table 500-17
2	Fines to Bitumen ratio	1.02	0.6-1.2	as per MoRT&H 505.3
3	Bulk Density of Mix (GMB)	2.46		as per MoRT&H clause 507.3.5
4	Air Voids (VA) %	3.86	3-5	as per MoRT&H Table 500-11
5	Voids in mineral aggregates	12.16	Minimum 12	as per MoRT&H Table 500-12
6	Voids filled with bitumen	68.25	65-75	as per MoRT&H Table 500-11
7	Marshell stability of the mix in Kn at 60 C	16.2	Minimum 9 Kn	as per MoRT&H Table 500-11
8	Flow (mm)	3.2	2 to 4	as per MoRT&H Table 500-11
9	Retained stability after 24 Hrs at 60 in water	95.42	Minimum 80%	as per MoRT&H Table 500-8
10	Retained coating on aggregate %	Above 95%	Minimum 95%	as per MoRT&H Table 500-8

Table No.14: Mixing and laying temperature of BC Mix (MoRT&H Table 500-2)

Sl. No.	Description	Temperature in °C
1	Bitumen Temperature	150-165
2	Aggregate Temperature	150-170
3	Mixing Temperature	150-165
4	Laying Temperature	Min 140
5	Rolling Temperature	Min 90 (After Rolling)

Table No.15: Summary of Bituminous Concrete Design Mix

Test	Specification	Method Test	Results as per MTC
Penetration	45 Min	IS 1201	68
Softening point	Min 47	IS 1206-2	50
Ductility test for residue after TFOT	Min 40	IS 1206-3	90
Flash point test	Min 220	IS 1448 P:69	>220
Absolute viscosity	Min 2400, Max 3600	IS 1216	2600
Kinematic viscosity	Min 350	IS 1205	445
Solubility in TCE	Min 99	IS 1208	99.7

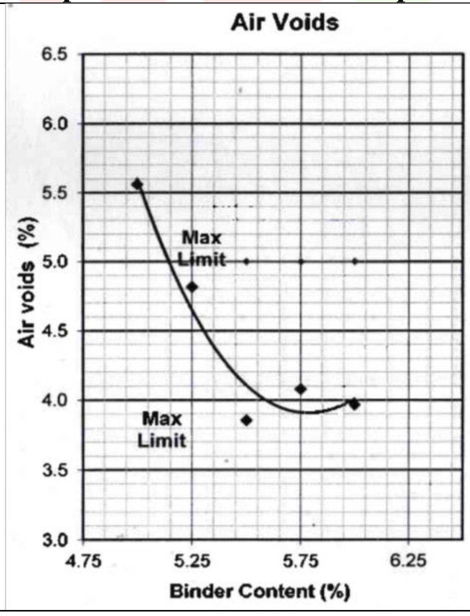
Marshall Test

Sl No	Bitumen % (Pb)	Wt in Air (gm)	Wt in Water (gm)	SSD Wt in Air (gm)	Volume (CC)	Bulk Density (Gmb)	GMM	Air Voids (%)	VMA (%)	VFB (%)	Proving Ring Reading (Div)	Stability (KN)	Correction factor (vol)	Correct Stability (KN)	Flow (mm)
								3-5	Min 12	65-75				Min 9KN	2-4
1	5.00	1260.0	744	1261.0	517.0	2.437	2.580	5.56	12.50	55.52	205	15.19	0.96	14.58	1.7
2		1259.0	743	1260.0	517.0	2.435					200	14.82	1.00	14.82	1.8
3		1260.0	744	1261.0	517.0	2.437					205	15.19	0.96	14.58	1.8
						2.436								14.7	1.8
1	5.25	1261.0	747.0	1262.0	515.0	2.449	2.569	4.82	12.40	61.17	210	15.56	1.00	15.56	2.4
2		1262.5	747.0	1263.0	516.0	2.447					215	15.93	1.00	15.93	2.5
3		1262.0	746.0	1263.0	517.0	2.441					210	15.56	1.00	15.56	2.4
Average						2.446								15.7	2.4
1	5.50	1265.0	751.0	1266.0	515.0	2.456	2.559	3.86	12.11	68.16	215	15.93	1.00	15.93	3.2
2		1264.0	752.0	1265.0	513.0	2.464					215	15.93	1.00	15.93	3.1
3		1265.0	752.0	1266.0	514.0	2.461					220	16.30	1.00	16.30	3.2
2						2.460								16.1	3.2
1	5.75	1268.5	751.0	1269.5	518.5	2.446	2.549	4.08	12.90	68.37	220	16.30	0.96	15.65	4.0
2		1268.0	750.0	1269.0	519.0	2.443					215	15.93	0.96	15.29	4.0
3		1269.0	751.0	1270.0	519.0	2.445					220	16.30	0.96	15.65	4.1
Average						2.445								15.5	4.0
1	6.00	1271.0	751.0	1272.0	521.0	2.440	2.538	3.97	13.38	70.34	210	15.56	0.96	14.94	4.9
2		1271.5	750.0	1272.5	522.5	2.433					210	15.56	0.96	14.94	4.7
3		1271.0	751.0	1272.0	521.0	2.440					210	15.56	0.96	14.94	4.6
Average						2.438								14.9	4.7

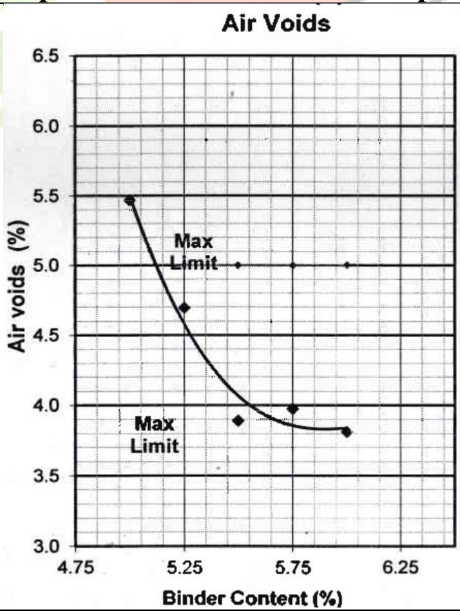
Fig.No.09 : Martial Test Results of BC Mix with 8% Plastic Fibres.

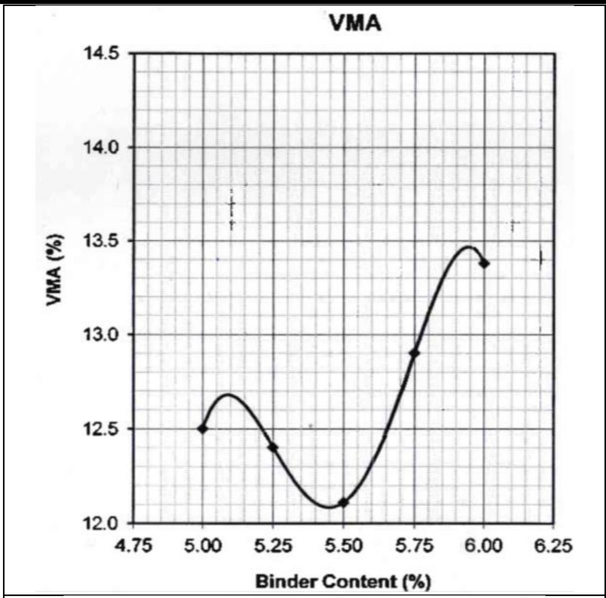
Comparison of various test parameters of BC with and without plastic

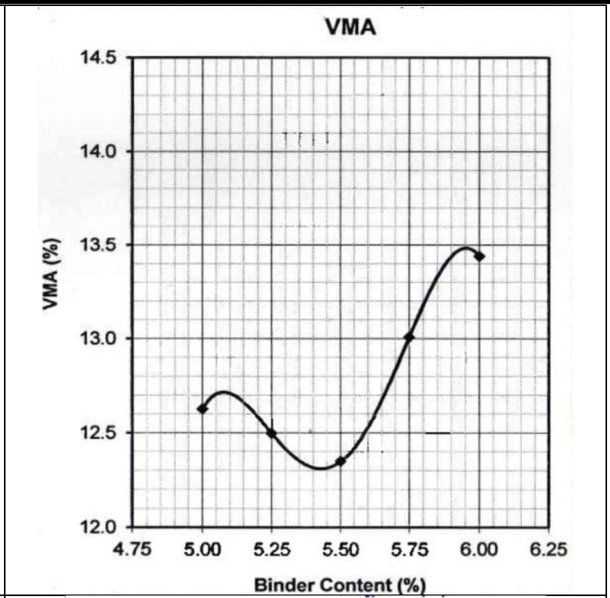
Test parameters for BC with plastic

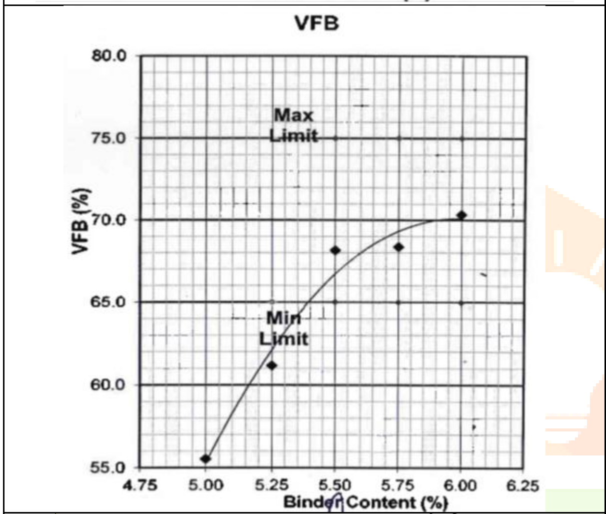


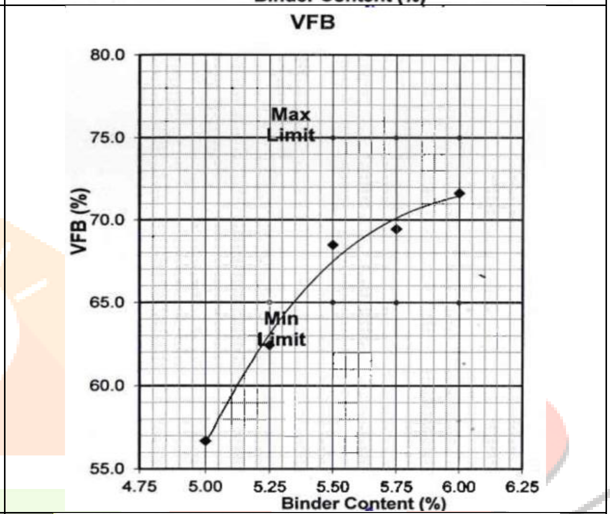
Test parameters for BC without plastic

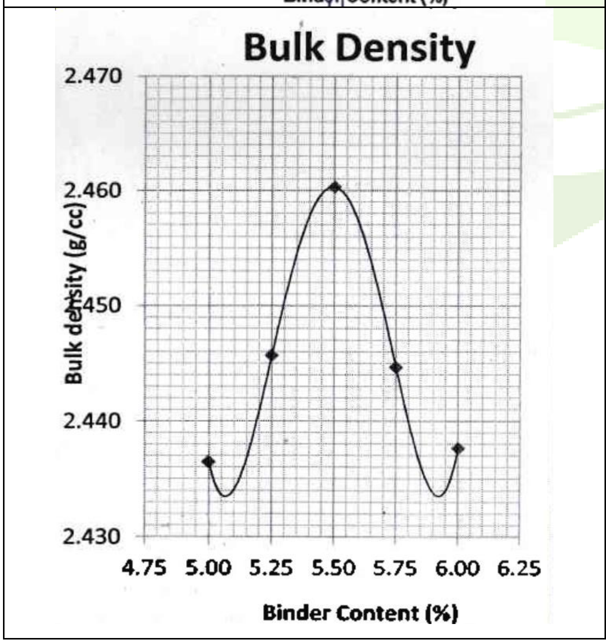


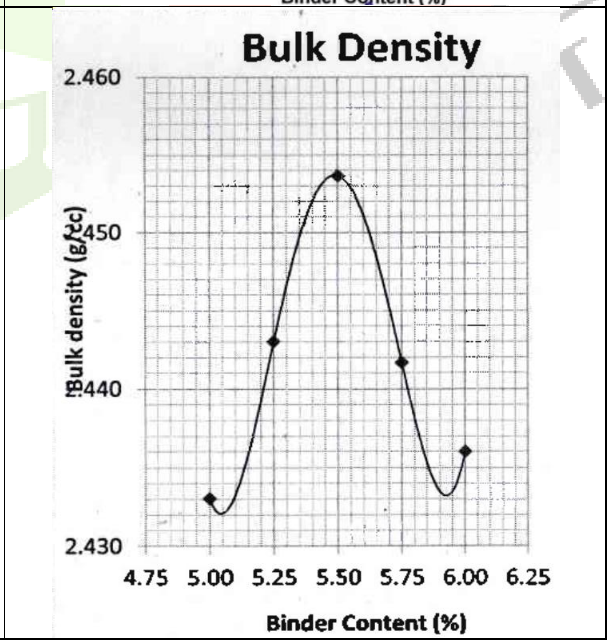

VMA
VMA (%)
Binder Content (%)

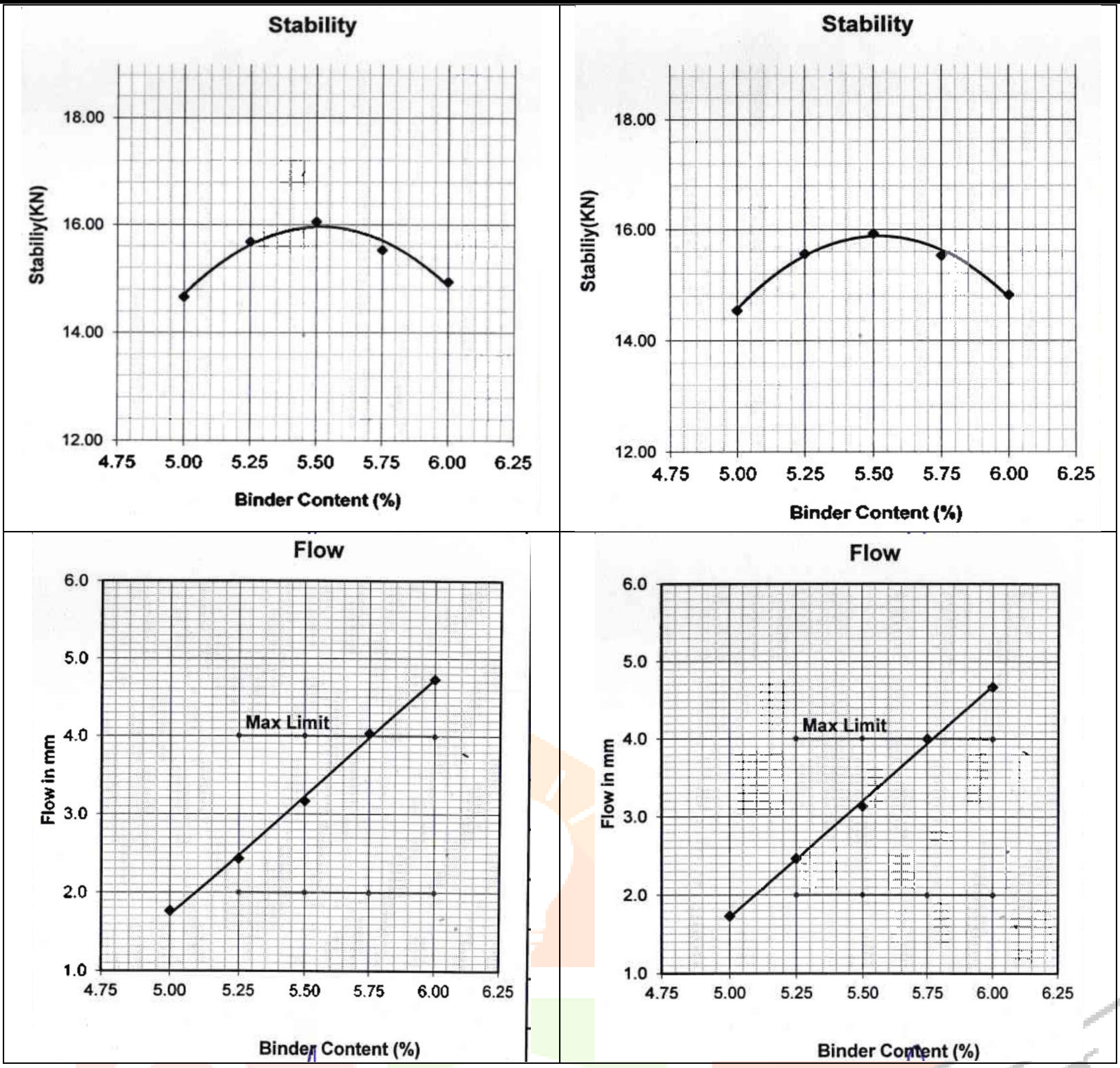

VMA
VMA (%)
Binder Content (%)


VFB
VFB (%)
Max Limit
Min Limit
Binder Content (%)


VFB
VFB (%)
Max Limit
Min Limit
Binder Content (%)


Bulk Density
Bulk density (g/cc)
Binder Content (%)


Bulk Density
Bulk density (g/cc)
Binder Content (%)



Marshall Stability Values

Marshall Stability analysis showed that upon the use of plastic fibres, the properties of Bitmunious coarse like the Air Voids, Voids in mineral aggregates (VMA) and Voids filled with bitumen (VFB), Bulk density, Stability and flow value are within the standard limits as per the specification and standards. Also, there are a few parameters that have shown tremendous improvements like:

- There has been an increase in the melting point of bitumen upon the addition of plastic fibre.
- Air voids get reduced due to the addition of plastic fibre.
- Use of Plastic makes the road retain its flexibility during winter resulting in long life of the pavement.
- Also, it can be concluded that upon laying of bitumen mix prepared using treated binder could withstand adverse soaking conditions under water for a longer duration. Due to the adverse rain in Kerala, it is an added advantage.

3.3 Comparison between BC with and without plastic

1. Plastic-Coated Aggregate for asphalt pavement helps with the reuse of plastic waste and improves the strength and durability of the pavement.

2. An attempt was made to use plastic waste like LDPE (Low density Poly Ethylene) e.g.: milk packets. Water bottles to coat the aggregate in the bituminous mix and properties such as density, stability, flow and air voids are investigated and found that found that the properties are enhanced. Since the softening point of plastic

varies between 110℃-140℃, they do not produce any toxic gases while heated, and instead forms a thin film-like structure over aggregates when it is sprayed on hot aggregate which is heated at 160 ℃.

3. There has been an improvement in the binding properties and stability value with the plastic coated aggregate bituminous mix and the method is eco-friendly and economical.

4. The melting point of bitumen get increased with the use of plastic.

5. The optimum bitumen content of BC is attained at 6% addition of waste plastic to the mix the optimum plastic content comes at 7-8%, and after that, the value of stability decreases.

6. The Environmental pollution could be limited to a level due to this process/

7. The Marshall Stability value had increased after the addition of plastic content up to 8 % by weight of bitumen.

8. Waste plastic when used as a modifier for the bituminous concrete mix gets coated over the aggregates of the mixture and reduces porosity, absorption of moisture and improves the binding property of the mix.

9. The Optimum Bitumen Content (OBC) was found to be 5% by weight of aggregates and the Optimum Plastic Content (OPC) to be added as a modifier was found to be 8 % by weight of Optimum Bitumen Content of the mix.

10. In terms of Martial Stability Value and indirect tensile stress, the results of the wet mix and the dry mix were compared and result had shown that there is tremendous improvement in the performance by addition of 8% plastic fibre onto the mix.

11. A slight decrease in air voids of dry mix as compared to wet mix were noticed and the variation is within the permissible range. No appreciable changes were noticed in terms of VFB parameters (Voids filled with Bitumen).

12. The Marshall Stability value increases with plastic content up to 8 % and thereafter decreases. Hence the use of a higher percentage of waste plastic/ polythene is not preferable as of the current situation. The volumetric and Marshall properties of conventional and modified bituminous concrete mixes almost satisfied the requirement as per MORTH and IRC: 111-2009/IRC: SP 98 -2013 specifications. This concluded that plastic waste blended with bituminous concrete mix is a better choice for flexible pavement construction.

Fig.No.10: Lying of trial patch

Fig.No.11: BC with 8% Plastic Fibre laying for 2.5 km stretch

3.4 DBM with RAP

Source of Aggregates

Source of bitumen was BPCL, aggregate obtained from Amity Crusher, Konni, and RAP materials were collected from the existing project road.

Table No. 16: Physical requirements of aggregates as per Table 500-8 of MoRT&H

Sl. No.	Name of test	Test method	Test results	Requirement as per MORT&H	Remarks
1	Aggregate impact value	IS:2386 Part-4	21.97	Max: 27%	Satisfactory
2	Flakiness & Elongation Index	IS:2386 Part-1	22.94	Max: 35%	Satisfactory
3	Coating & and stripping of bitumen aggregate mixture	IS:6241	98%	Max: 95%	Satisfactory
4	Cleanliness for 3mm down aggregate	IS:2386 Part-1	0.54	Max.5%	Satisfactory
5	Loss Angeles	IS:2386 Part-4	22.2	Max:35%	Satisfactory
6	Water sensitivity	AASHTO 283	93.6	Min: 80%	Satisfactory
7	Plasticity index	IS: 2720 Part-5	NP	Max: 4%	Satisfactory

Test report of Bitumen VG-30

The bitumen VG-30 from BPCL having a specific gravity of 1.05 is used for the preparation of the mix-design. The test results of VG-30 are given below;

Table No.17: Test report for VG-30

Sl.No.	Name of test	Test method	Test results	Requirements as per IS:73	Remarks
1	Specific gravity at 25°C	IS:1202-1978	1.05	Min 0.99	Satisfactory
2	Penetration at 25°C, mm	IS:1203-1978	49	Min: 35	Satisfactory
3	Softening point	IS:1205-1978	51	Min: 50	Satisfactory
4	Ductility in CM	IS:1208-1978	90	Min: 25	Satisfactory
5	Viscosity, Poise	IS:1208-1978	3490	2400-3600	Satisfactory

Test results of VG-30, Extracted RAP, and proposed mix are listed below (Table 17);

Absolute viscosity of RAP extracted bitumen at 60°C: 41721 poise.

Bitumen content in the RAP sample: 2,80%

VG-30 and extracted bitumen from DBM+20% RAP sample

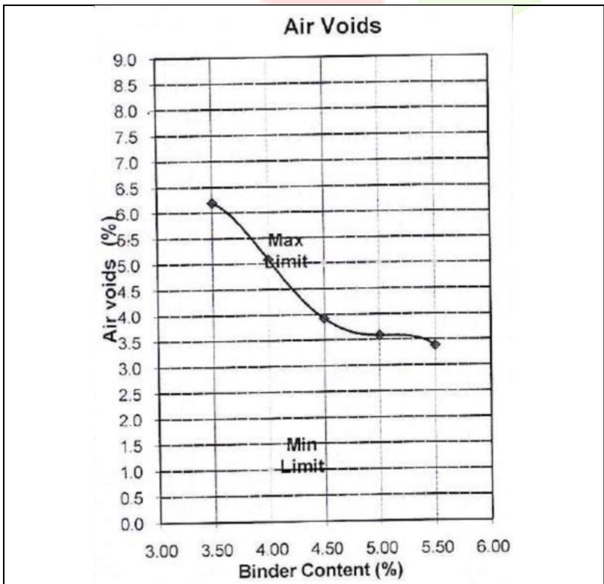
Table No.18: Test results of VG-30, Extracted RAP, and proposed mix

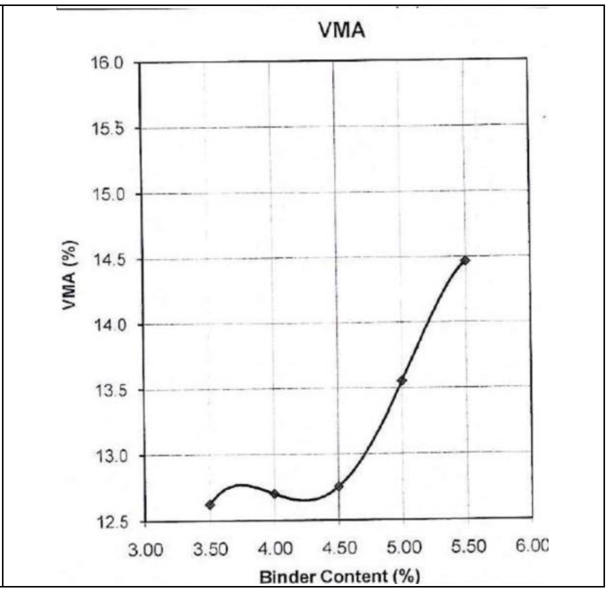
Sl. No.	Tests	Bitumen type		
		VG-30	Extracted from DBM+20% RAP	
1	Binder content (%)		4.63	Minimum penetration value 39
2	Penetration at 25°C, 100g, 5s, 0.1mm	46	41	
3	Absolute viscosity at 60c, poise	3490	3570	
4	Brookfield viscosity at 135c	620	752	
5	Softening point, °C	49	51.2	

As per MORT&H section 519, Table 400-48, the minimum penetration value of recycled mix is 39 for VG-30 as a new binder. The resulting value of bitumen extracted from DBM with 20% RAP is 41.

Table No.19: Marshall properties of DBM

Sl.No.	Bitumen content (%)	Bulk density (g/cc)	Gmm	Air voids (%)	VMA	VFB	Stability (Kn)	Flow (mm)
1	3.5	2.431	2.592	6.20	12.62	50.90	11.36	1.73
2	4	2.442	2.572	5.08	12.70	60.03	13.09	2.43
3	4.5	2.453	2.553	3.92	12.75	69.30	13.65	3.13
4	5	2.443	2.534	3.58	13.55	73.60	12.84	3.57
5	5.5	2.430	2.515	3.38	14.46	76.66	11.73	3.93





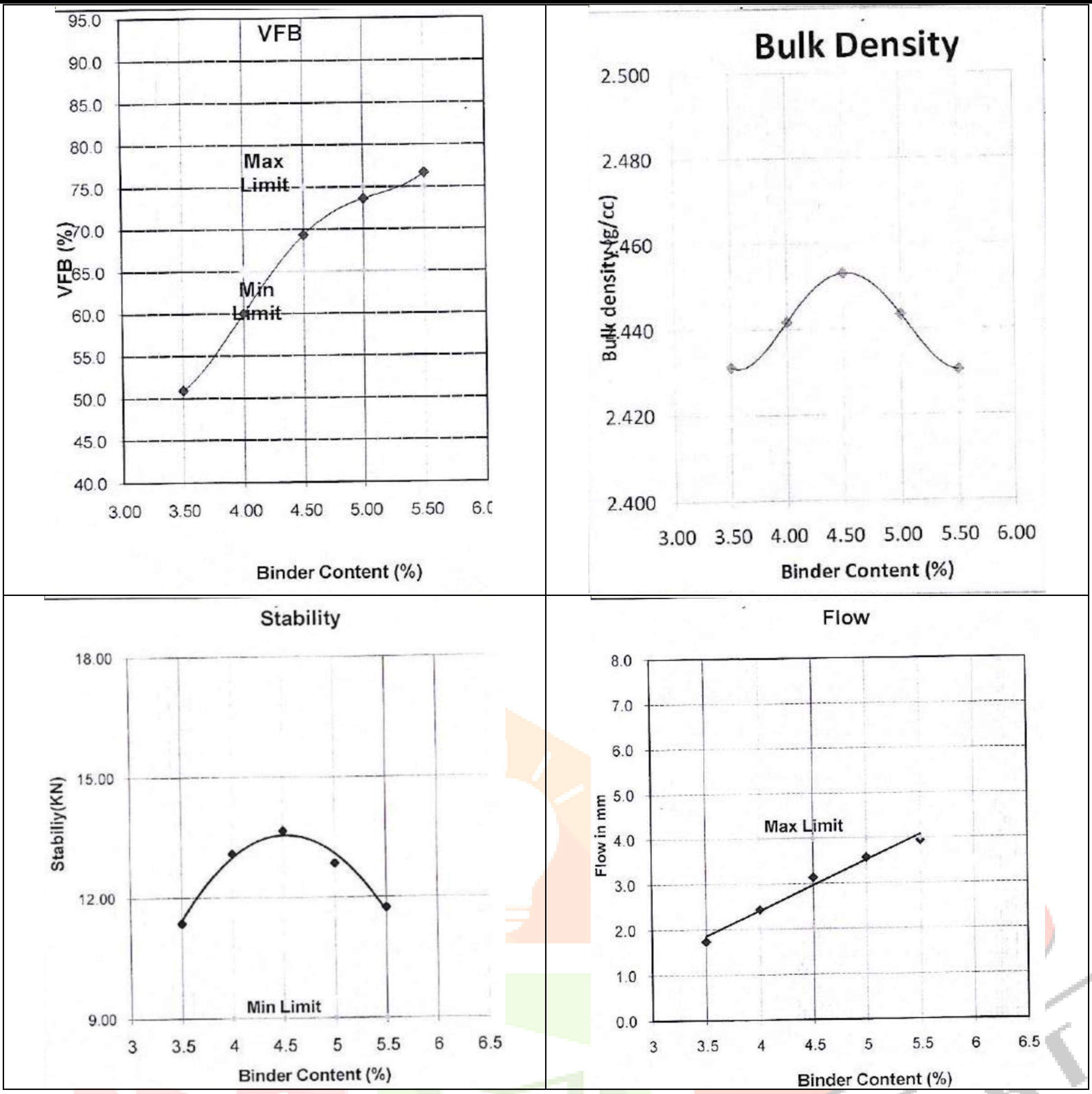


Fig.No. 12: Test results for DBM with 20% RAP

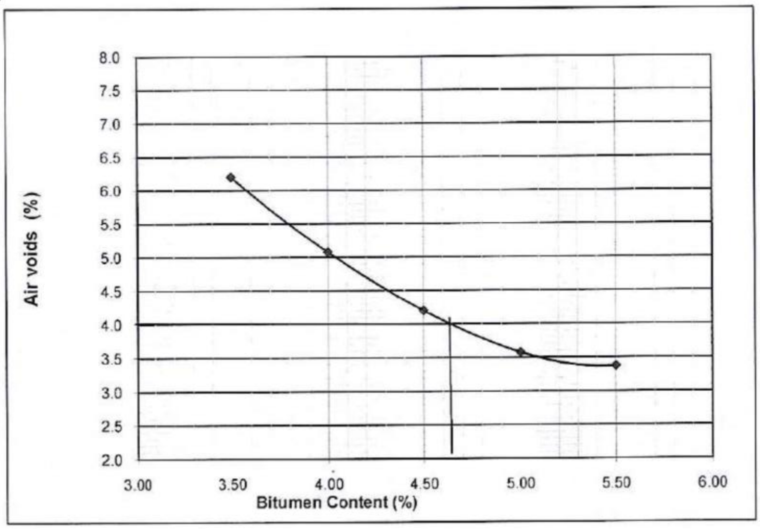


Fig.13: Optimum bitumen content is 4.63%.

The use of (Reclaimed Asphalt Pavement) material in construction of new Pavement (Dense Bituminous Macadam Grade – II) will considerably reduce the use of fresh aggregate in the construction. This also overcomes the shortage of aggregates and quarries in the state. The use of RAP The design requirement as per the Marshall Mix method is satisfied while using the RAP. The standard technical specifications followed for implementing the mix designs are MORT&H 519 & IRC 120

The following points suggest the generalized benefits:

1. Reuse and Conservation of non-renewable energy sources
2. Reduced landfilling and preserve the environment.
3. Improved pavement smooth and sustainable infrastructure development.
4. Cost saving over conventional methods
5. Improvement physical properties by modification of existing aggregate gradation and asphalt binder properties.
6. Avoids further crushing of aggregate particles from the quarry/crusher.
7. The processing of RAP is economical.
8. Millings in huge quantities from major road projects are likely to have a steady gradation and asphalt content and can be re-used in the form of RAP at more areas.
9. Reduction in overall dust generation due to less use of the crusher unit.
10. Using different-sized RAP stockpiles provides greater flexibility in developing mixed designs

Fig.No. 14: DBM with 20% RAP laying at Site

CHAPTER-4
CONCLUSION

Management of solid waste is one of the major issues faced by developing countries and among those waste, plastic has an important role. Plastic pollution is a threat to the earth and it affects all flora and fauna. So, proper management of waste generated in any field can reduce the environmental impact and this will ensure sustainable development in the world.

The main focus of this study is to reuse the generated asphalt and plastic waste in the newly constructed flexible road. The findings revealed that the addition of plastic waste into the bitumen concrete (BC) enhances the Marshall stability values. This helps in the improvement of the strength characteristics of the mix and improved mix density.

The asphalt waste generated during the demolition of existing roads normally turns into a waste hill in a dumping yard. But, as part of the study, the asphalt waste was reused with the DBM and this increased the stability of the road and reduced the quantity of asphalt waste generated in the project area.

"Aim is to have a Sustainable Infrastructure development throughout the Nation ".

CHAPTER-5
DIRECTIONS FOR FUTURE WORK

In the present study, various tests were carried out for 20% RAP materials only. However, various other percentages must be evaluated such as;

- To know the realistic results and performance accurately, 100 % RAP material is to be re-used.
- Binders may be changed and tests can be done.
- Semi Field Track Test Studies need to be carried out to validate the performance of RAP Mixes.

For Plastic Fibre with BC, the maximum percentage that can be added as of now is 8% because martial stability properties increase up to 8% and further decrease. Further studies need to be initiated to increase the plastic content above 15 %.

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