

# *Global Road Infratech Summit & Expo (GRIS-2026)*

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## Developing a Standard Operating Procedure Based on Field Learning on Use of Reclaimed Asphalt Pavement (RAP) in Bituminous Mix – DBM-II: A Case Study

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# What is RAP?

**Reclaimed Asphalt Pavement (RAP)** is the term given to removed and/or reprocessed pavement materials containing asphalt and aggregates.

These materials are generated when asphalt pavements are removed for-

- Reconstruction
- Resurfacing

RAP can be used in highway construction with following options,

- Hot Mix Asphalt (Central Processing Facility)
- Hot Mix Asphalt (In-Place Recycling) - HIPR
- Cold Mix Asphalt (Central Processing Facility) -CCPR
- Cold Mix Asphalt (In-Place Recycling) - CIPR
- Granular Base Aggregate
- Stabilized Base Aggregate
- Embankment or Fill

Asphalt pavement is generally removed-

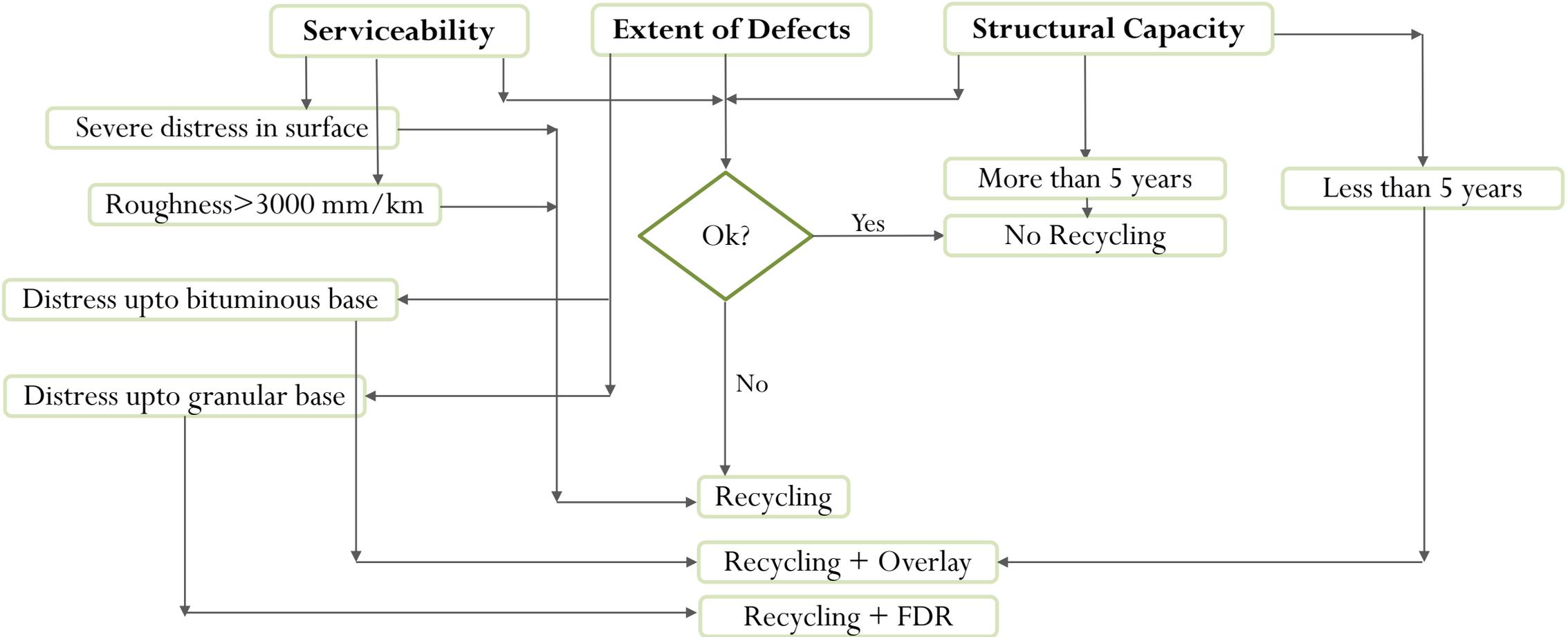
- By Milling: Removal of the pavement surface using a milling machine, which can remove up to 50 mm (2 in) thickness in a single pass.
- By Full-depth removal: It involves ripping and breaking the pavement using a rhino horn on a bulldozer and/or pneumatic pavement breakers.



*Cube Tech has extensive experience in working with **Reclaimed Asphalt Pavement (RAP)** materials. Over the years, the company has developed an experience-based **Standard Operating Procedure (SOP)** covering all stages—from **mix design to implementation**.*

*With multiple assignments across **different zones of India**, Cube Tech's team has successfully implemented RAP in various projects since 2018, ensuring **optimal performance and sustainability** in road construction.*

# Decision Making Tree



# Methodology for Utilization of RAP in Bituminous Mixes

Selection of Project & Source Finalization

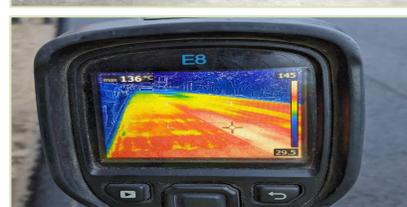
Collection of RAP Samples

Selection of virgin materials –Aggregates, Filler & Binder

Mix Design with RAP samples and find the suitability of RAP & % RAP adoption

Hot Mix Production

Field Execution & Quality Control

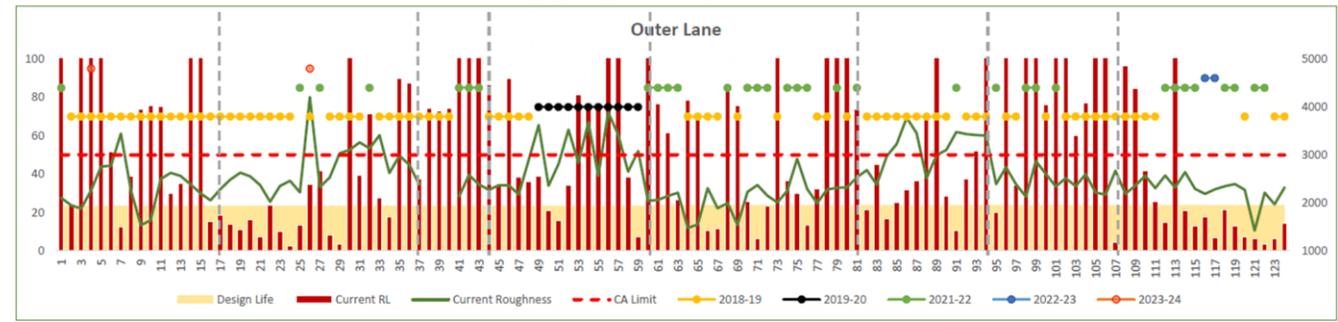
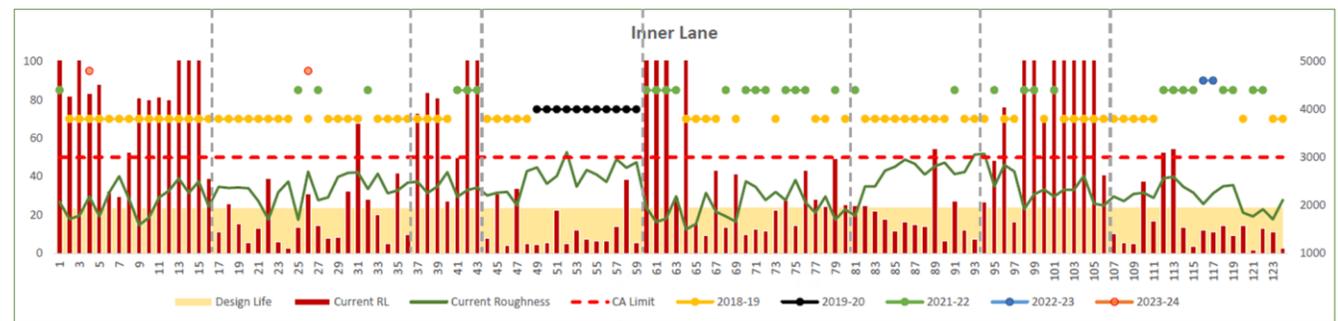




# Selection of Project & Utilization of RAP in Road Projects

- RAP (Reclaimed Asphalt Pavement) locations are identified based on **visual distress assessments** and **Non-Destructive Testing (NDT)** methods such as **Network Survey Vehicle (NSV) analysis** and **Deflection-based tests (FWD)**.
- Once potential RAP locations are identified, they are further examined for pavement composition & **past treatment history**, which includes:
  - Layer thickness & previous overlay details
  - Mix grade and binder grade used
  - Year of construction and past maintenance records
- Based on these evaluations, **homogeneous sections** are created to ensure consistency in material properties. Finally, the RAP sections to be utilized are finalized based on:
  - Project requirements
  - Suitability of RAP with virgin binder

Accordingly, a **mix design** is performed to achieve the desired performance criteria.



# Steps of RAP Processing



1  
Identify the milling location based on pavement investigation

2  
RAP Sample Collection & Source Finalization

3  
Plan logistics for transporting milled material to the plant

4  
Screen RAP material to remove oversized aggregates and contaminants

5  
Screen the RAP material for Fractionalization

6  
Identify the binder content of each fraction of RAP and perform gradation

7  
Perform Mix Design & Do the Trial with HMP Produced Mix & Conduct Performance Evaluation Testing



# Indian Codal Provisions & Recommendations

1. MS-2, 7<sup>th</sup> Edition, Chapter -11 Recycling Asphalt Material in the Mix Design Process
2. Ministry of Road Transport & Highways (MORTH Fifth Revision)
3. IRC 120-2015, Recommended Practice for Recycling of Bituminous Pavements

## Key important points from various sources & guidelines:

- Source of the RAP?
- Importance of Fractionalisation: Fractionated Reclaimed Asphalt Pavement (FRAP)? : It reduces the overall variability.
- Importance of RAP properties & binder content in RAP to determine rejuvenator requirements
- Asphalt Institute suggest: RAP Pavement Binder Ratio approach: RAP Pavement Binder Ratio (RPBR)—the ratio of the RAP binder in the mix divided by the mixture’s total binder content

There are two principal ways of determining the asphalt binder content of the RAP:

- Ignition oven procedure: The ignition oven procedure is detailed in AASHTO T 308, “Determining the Asphalt Binder Content of Hot-Mix Asphalt (HMA) by the Ignition Method.”
- Solvent extraction: The solvent extraction procedure is detailed in AASHTO T 164, “Quantitative Extraction of Asphalt Binder from Hot-Mix Asphalt (HMA).”

- (ii) By adding softer grade bitumen to mix with the hard bitumen extracted from the reclaimed mix to soften it to the acceptable level. Extraction of old bitumen should be done by Abson Recovery Method (ASTM D 1856-95 A) What is the acceptable level of softening can be decided in the following ways:
- (a) By the combined Viscosity of the mixed binder: This can be done by a standard blending chart. One such chart developed by FHWA is shown in the Fig. 3 below.
  - (b) By the combined Softening point: The softening points of the old and new binder combined in various percentages are determined to arrive at the target softening point.

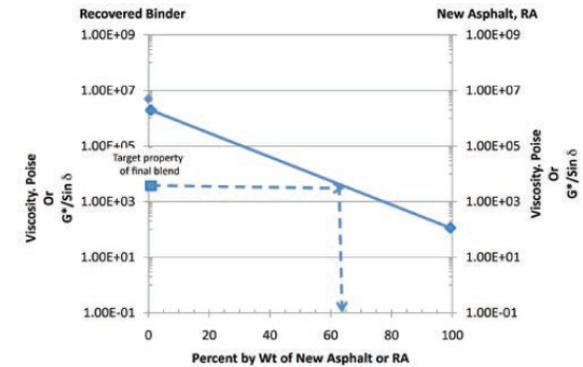


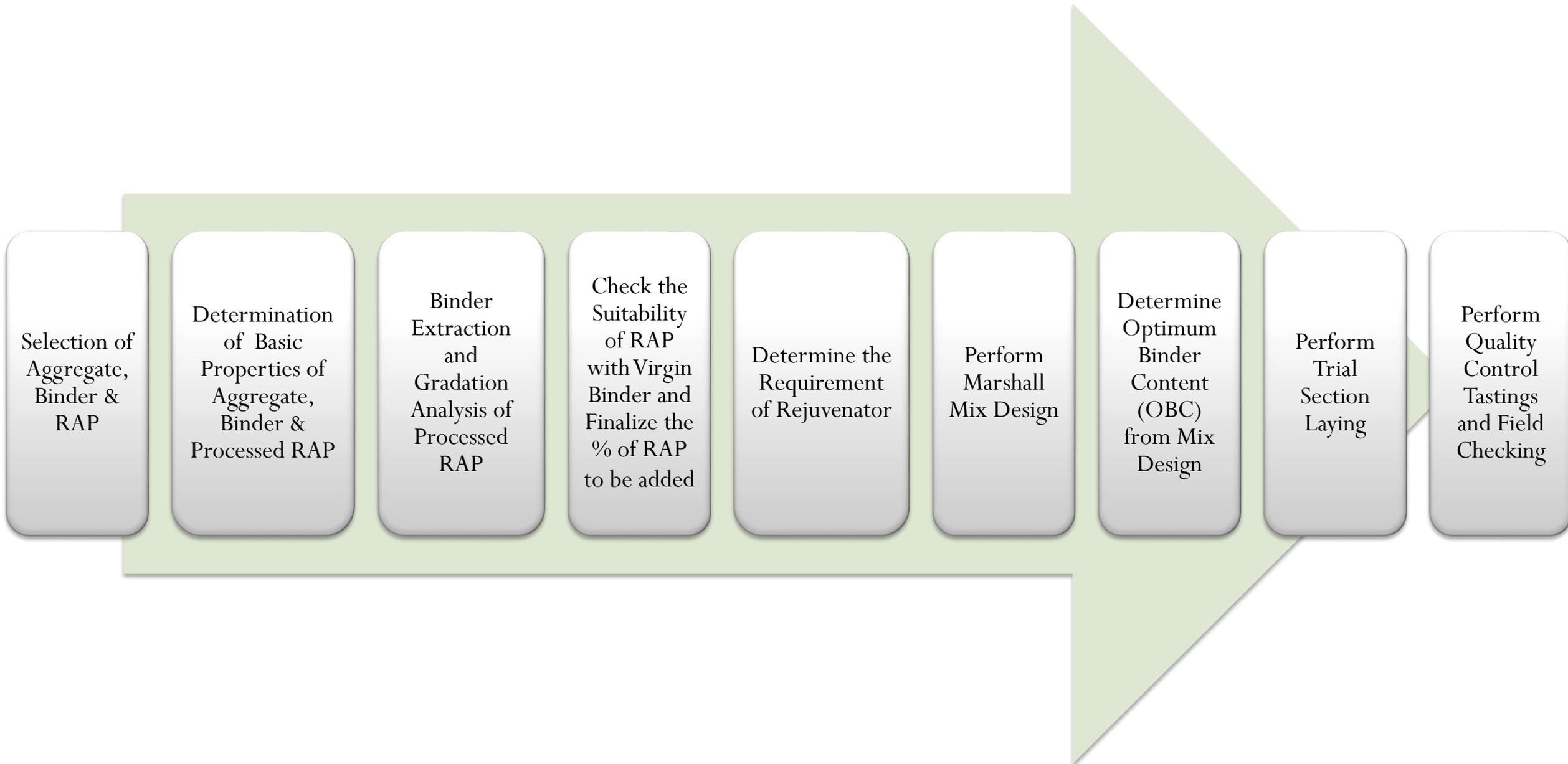
Fig 3. Blending Chart (Source NCHRP Synthesis Report 421)

Defects/ Deficiencies	Preferable Recycling options				
	HIR	HIP	CIR	CIP	
Serviceability of pavement and extent of defects	High Severity defects no structural deficiencies	Y	N	Y	N
	High severity defects extending up to bituminous bases	N	Y	N	Y
	High severity defects extending up to granular bases	-	-	Y*	-
Structural strength	Only resurfacing	Y	N	Y	N
	Resurfacing with overlay	N	Y	N	Y

HIR: Hot In-place recycling HIP: Hot In-plant recycling CIR: Cold In-place recycling CIP: Cold In-plant recycling

\*Full Depth Recycling

# Steps for Mix design with RAP



# Milling & Screening of RAP

## Milling the Existing pavement

Mill existing pavement layers using a cold milling machine



## Screening of Rap Material

Screening of RAP materials into different Sizes



RAP material is divided into two different sizes finer RAP and Coarser RAP

20% of Fine RAP (12mm down) directly fed into the pugmill allowing immediate integration with hot aggregate without any pre heating in drier drum.

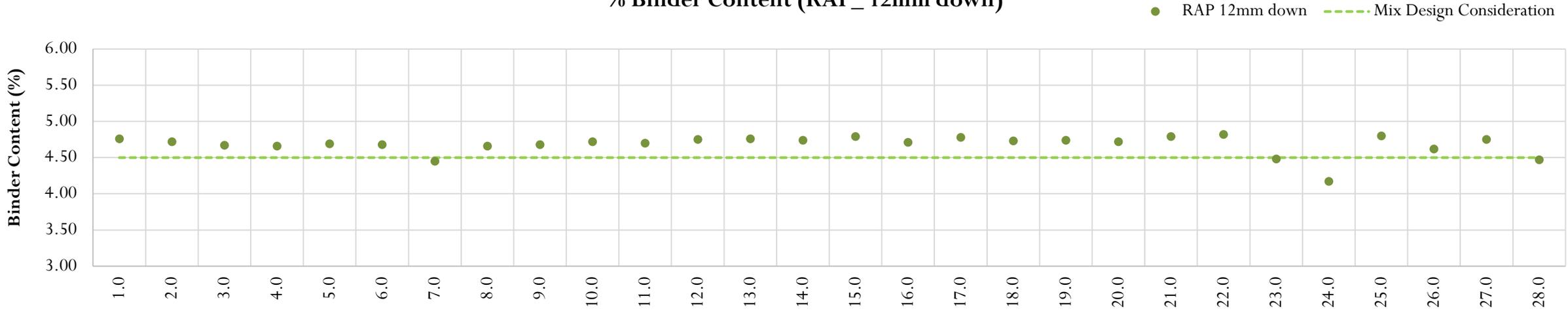


5% of Coarser RAP (20-12mm) pre-heated in the drier drum for ease of mixing bigger size RAP and to ensure proper blending.

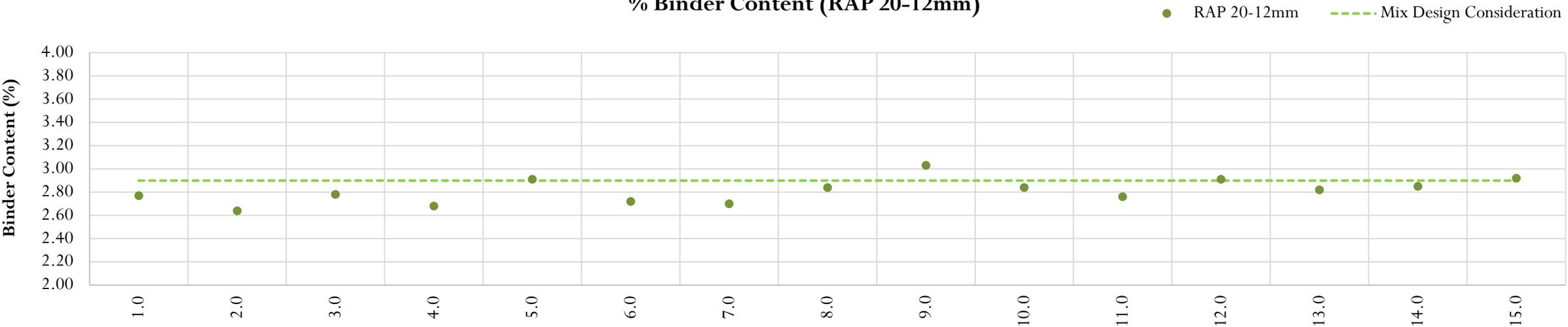


# Fractionalized RAP Binder Extraction Test

**% Binder Content (RAP\_ 12mm down)**

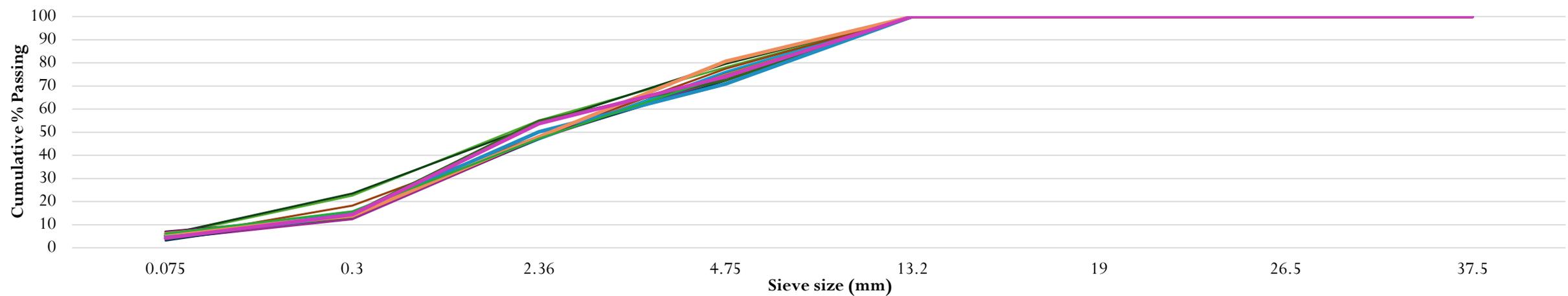


**% Binder Content (RAP 20-12mm)**

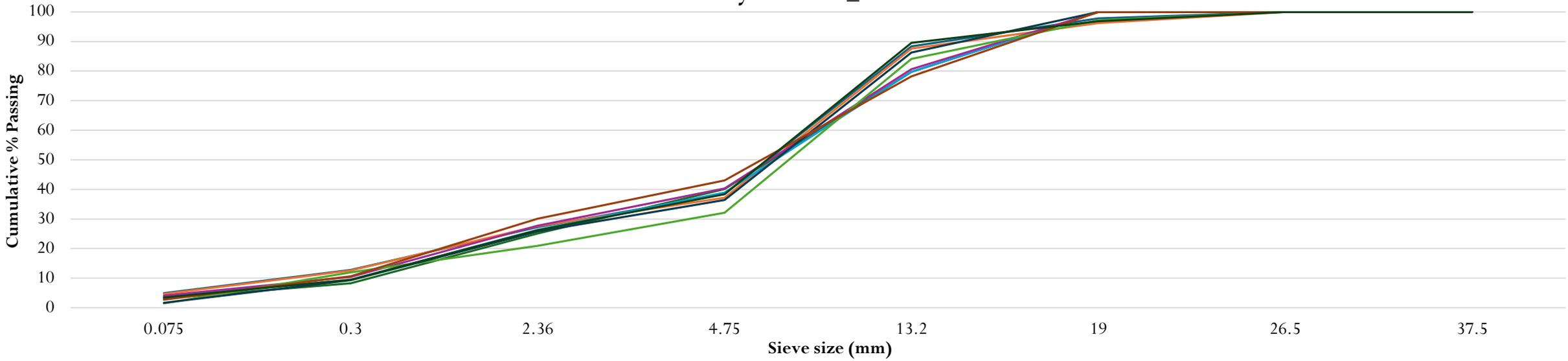


# Gradation Analysis Curve\_ Fractionalized RAP

### Gradation Analysis Curve \_ RAP 12 mm down



### Gradation Analysis Curve \_ RAP 20 - 12 mm



# RAP Feeding in HMP



Screening of RAP material



Cold RAP feeding without preheating (12 mm down)



Hot RAP feeding with preheating (12 mm – 20 mm)

- Oversize Aggregates: Screening of RAP material is conducted to remove oversized aggregates and contaminants.
- Fractionalization: Screening fractions the RAP not appropriate sizes for ease of operation.
- RAP material is fed into the HMP in such a way that 20% of fine RAP (12mm down) is directly introduced into the pugmill, allowing immediate integration without preheating. These RAP material is getting from preheated virgin aggregate by indirect heating.
- Additionally, 5% of coarse RAP (20-12mm) is heated in the dryer drum using induction heating of inner drum fitted internally over the ignition chamber to remove moisture and ensure proper blending.

# Materials : Coarse Aggregates, Fine Aggregate and RAP

**Coarse Aggregate :** Crushed rock, crushed gravel or other hard material retained on 2.36 mm sieve

Table : Physical properties of Aggregates specified by MoRTH for DBM-II mix.

Test	Method	MoRTH Specification Limits
Aggregate Impact Value, %	IS 2386 (Part IV)	24 Max.
Combined FI & EI Index, %	IS 2386 (Part I)	35 Max.
Specific Gravity	IS 2386 (Part II)	2.5-3.0
Water Absorption Value, %	IS 2386 (Part III)	2.0 Max.
Stripping Value, %	IS 6241	95 Min.
Polished stone value	BS 812-114	55 Min.
Soundness, %	IS 2386 (Part V)	12.0 Max.



Aggregates stockpile

**Fine Aggregate :** Crushed or naturally occurring material passing through 2.36 mm and retained on 0.075mm sieve

Tests	Method	MoRTH Specification Limits
Sand equivalent test	IS 2720 Part 37	Min 50.
Plasticity Index	IS 2720 Part 5	< 4%



RAP

**RAP:** The use of RAP in bituminous mixes is being used by following Indian codal provisions, primarily:

- **IRC 120:2015** “Guidelines for Recycling of Bituminous Pavements.”
- **MoRTH, Section 519** “Recycling of Bituminous Pavement.”
- **The Asphalt Institute MS-2**

- Binder is selected based on climatic conditions of the project location and its traffic levels

**Table: Properties of binder (VG40 Grade)**

Tests	Method	Achieved	IS 73-2013 Limits for VG-40
Softening Point , °C, Min	IS 1205	55	50
Penetration at 25°C, Min	IS 1203	39	35
Absolute Viscosity at 60°C, poises	IS 1206 (part 2)	3790	3600-4800
Kinematic Viscosity at 135°C, Min	IS 1206 (part 3)	516	400
Flash point, °C, Min	IS:1209-1978	-	220
Specific Gravity	IS:1202-1978	1.025	0.9-1.09
<b>Tests on residue from RTFO</b>			
Ductility at 25°C, Min	IS 1208	>40	25
Viscosity ratio at 60°C, Max	IS 1206 (Part 2)	-	4



**Binder Sample (VG 40)**



# Mix design: Aggregate & RAP Proportions



Collecting individual Aggregates sizes from hot-bin



Stockpiling and sampling of Hot-bin individual size aggregates



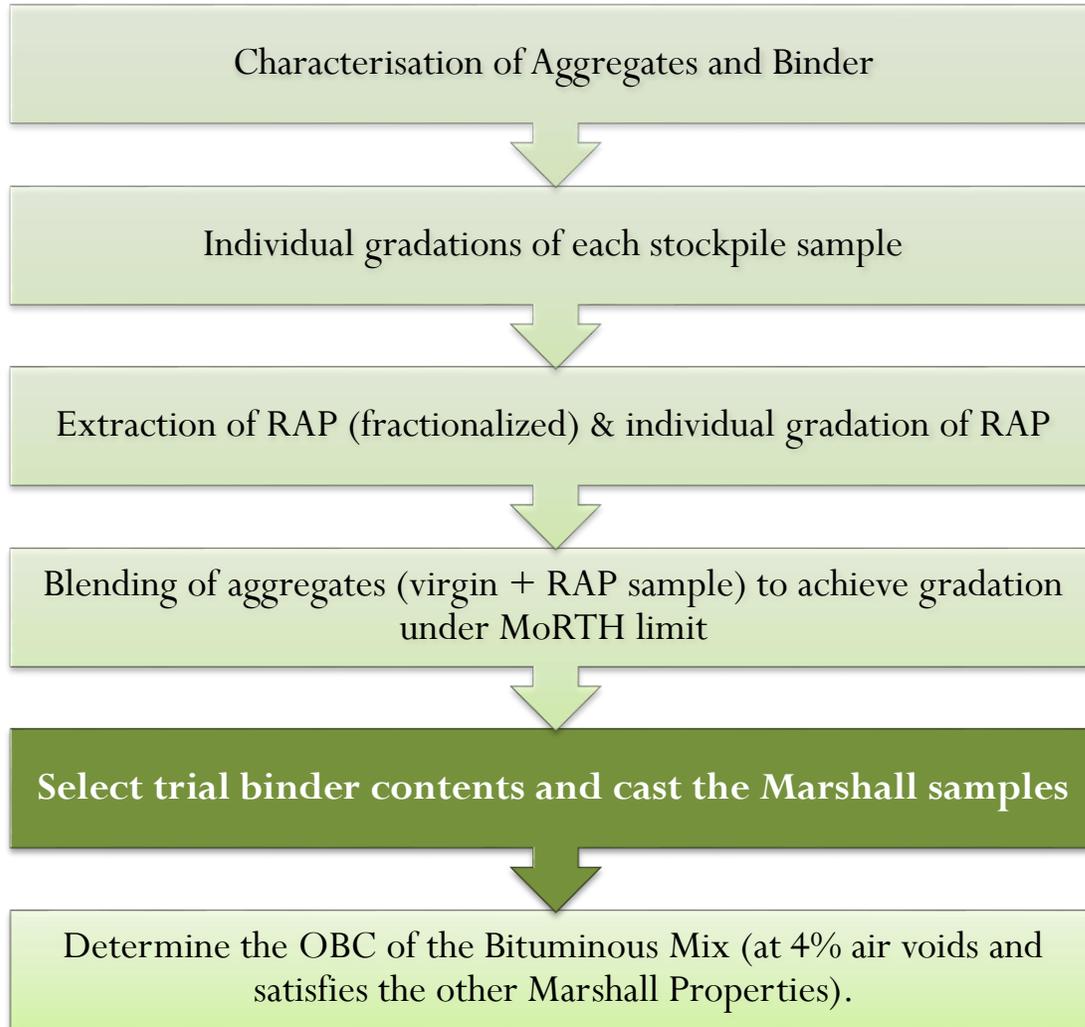
Gradation of individual bin size Aggregates and lime sample

Dense Bituminous Concrete Gradation as per MoRTH		
	Specification Limits (%)	
	DBM-I	DBM-II
Layer Thickness	75-100 mm	50-75 mm
Sieve Size (mm)	Cumulative % passing	
45	100	
37.5	95-100	100
26.5	63-93	90-100
19	-	71- 95
13.2	55-75	56-80
4.75	38-54	38-54
2.36	28-42	28-42
0.300	7-21	7-21
0.150	-	-
0.075	2-8	2-8
<b>Bitumen Content</b>	<b>Min. 4.0%</b>	<b>Min. 4.5%</b>

Aggregate Size	% Weight of Aggregate
40-26mm	13.40%
26-20mm	10.50%
20-12mm	10.50%
12-6mm	9.60%
6mm down	27.80%
12 above RAP	5%
12 down RAP	20.0%
OBC	3.2%
Total	100%

- Based on trial and error, the blending of different size of aggregates are performed to achieve the desired MoRTH gradation shown in table above

# Mix design: Calculation of Binder Content



Binder calculation of using RAP		
Particular	Fractionalized RAP_12 mm (+)	Fractionalized RAP_12 mm (-)
Bitumen content in RAP	2.92%	4.50%
Proposition in Mix	5.00%	20.00%
% of Bitumen use in DBM	0.15%	0.90%
Total RAP Binder (Fixed)	1.05%	
Marshall Mould Preparation		
Trial Binder (Virgin+ RAP) %	Virgin Binder %	RAP Binder %
3.5	2.45	1.05
4.0	2.95	1.05
4.5	3.45	1.05
5.0	3.95	1.05
5.5	4.45	1.05

# Mix design: Mix Preparation and Marshall Testing



Sieving of RAP material.



Extraction of Bitumen from RAP material



Preparation of marshall moulds to determine OBC with RAP material



Marshall Samples Preparation



Marshall Moulds preparation



GMM Testing for loose mix



Density test for Marshall mould samples

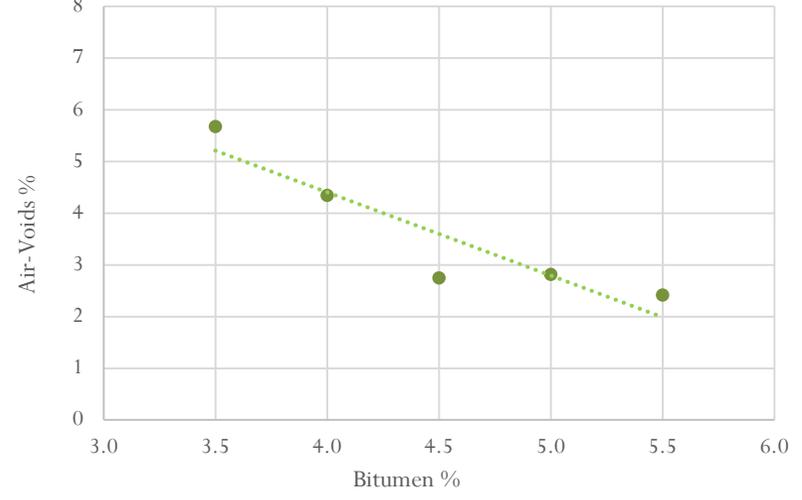


Marshall Stability and Flow test

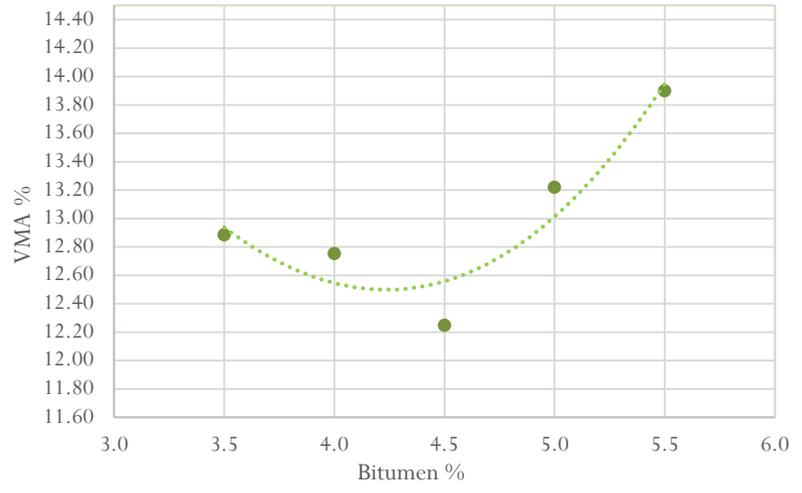


# Marshall Mix Design \_ DBM II with (VG40 + RAP (Old VG-30))

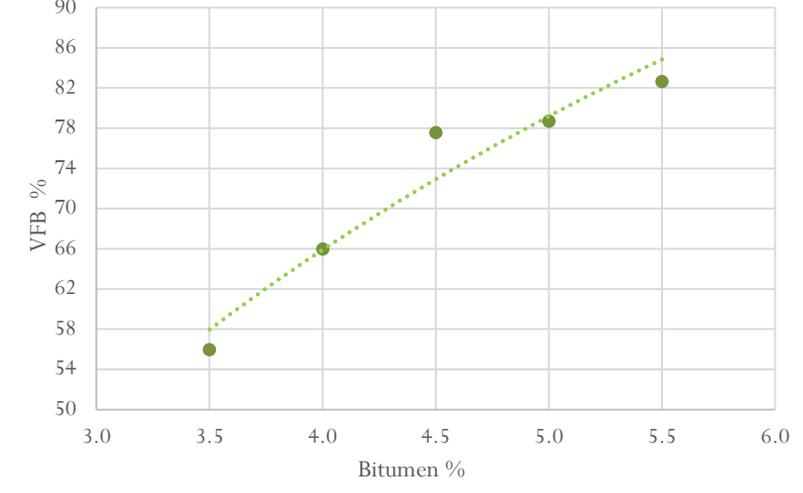
### Bitumen Vs Air voids



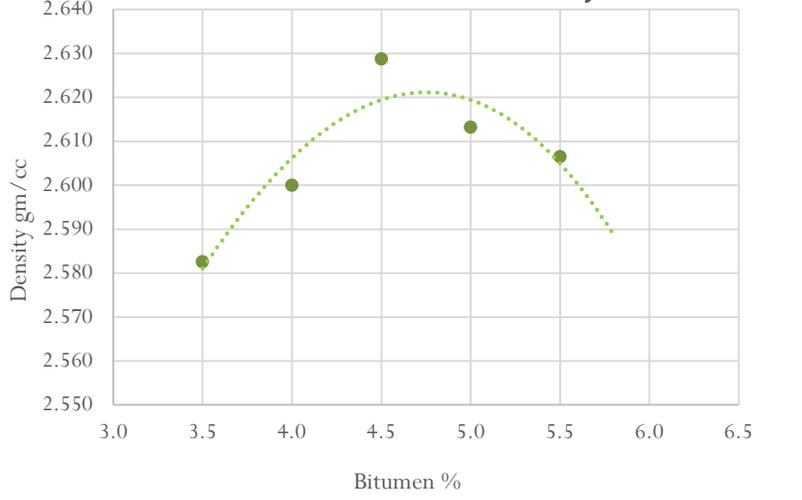
### Bitumen Vs VMA



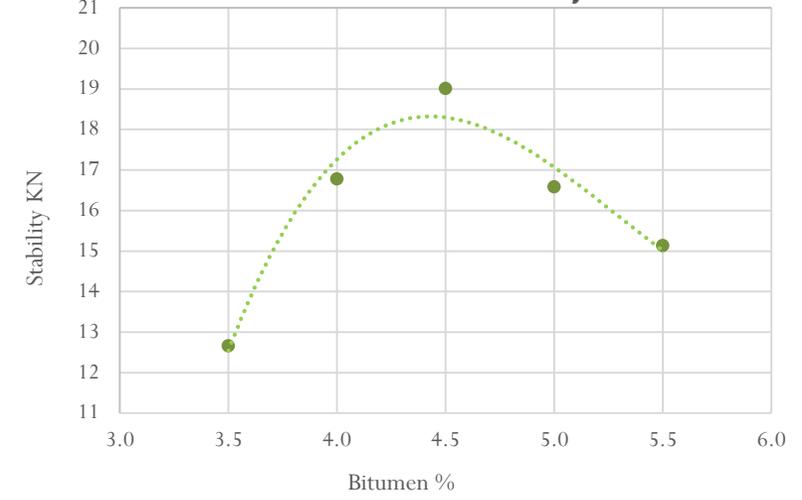
### Bitumen Vs VFB



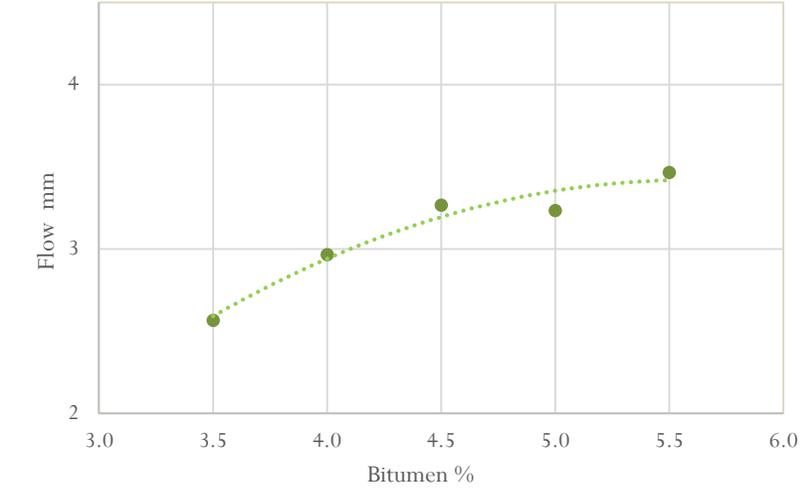
### Bitumen Vs Density



### Bitumen Vs Stability



### Bitumen Vs Flow



**Optimum Binder Content (OBC) at 4% air void : 4.25 % = 3.2% (Virgin) + 1.05% (RAP)**

# HMP Production of DBM II with RAP+VG40



Hot mix loading into transportation vehicle

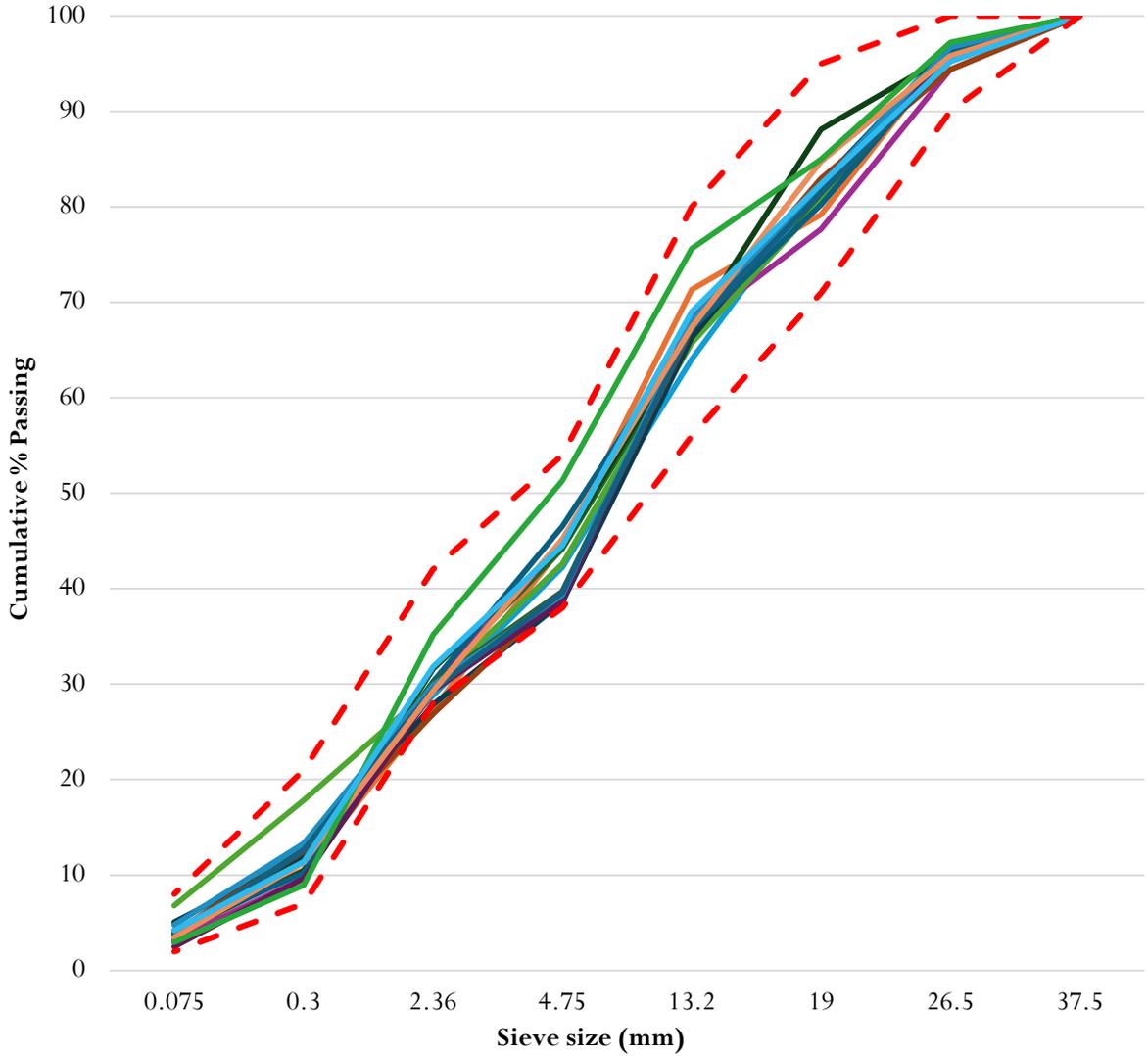


Sample collection for quality control tests

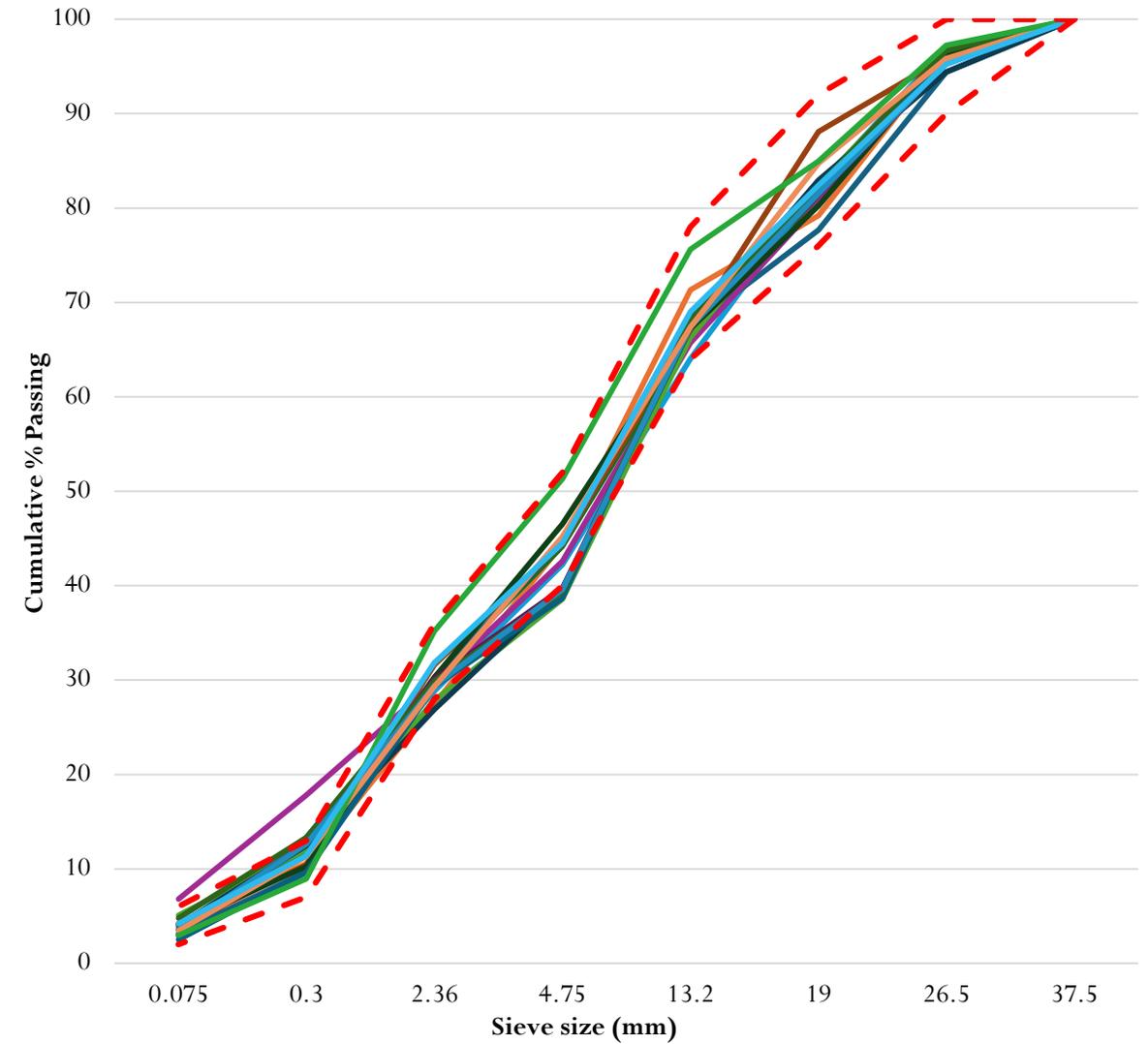
- Quality control tests shall be performed as per test frequency stipulated in MoRTH

Tests	Method	Frequency
Binder content	ASTM D2172	One set for each 400 tons of mix subject to minimum of two tests per day per plant
Mix grading	IS:2386 part 1	One set for individual constituent and mixed aggregate from dryer for each 400 tons of mix subject to minimum of two tests per day per plant
Stability and voids analysis and Gmm of loose mix	ASTM D6927-15& ASTM D2041	Three tests for stability, flow value, density and void contents for each 400 tons of mix subject to minimum of two tests per day per plant
Density of Compacted layer	-	One test per 700 sqm area

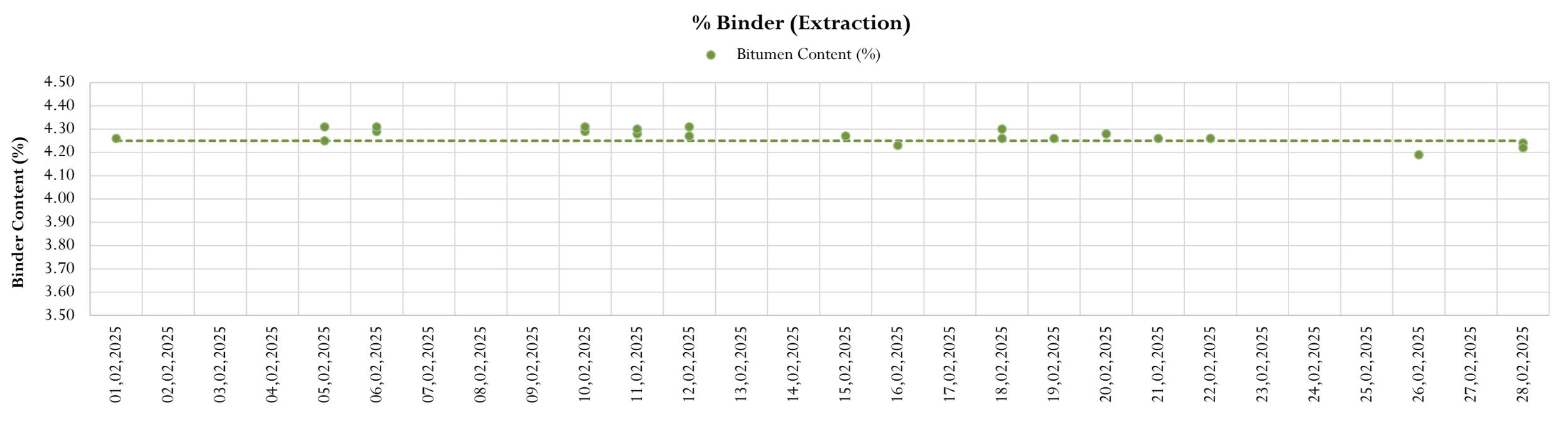
Mix Gradation - DBM II  
MoRTH

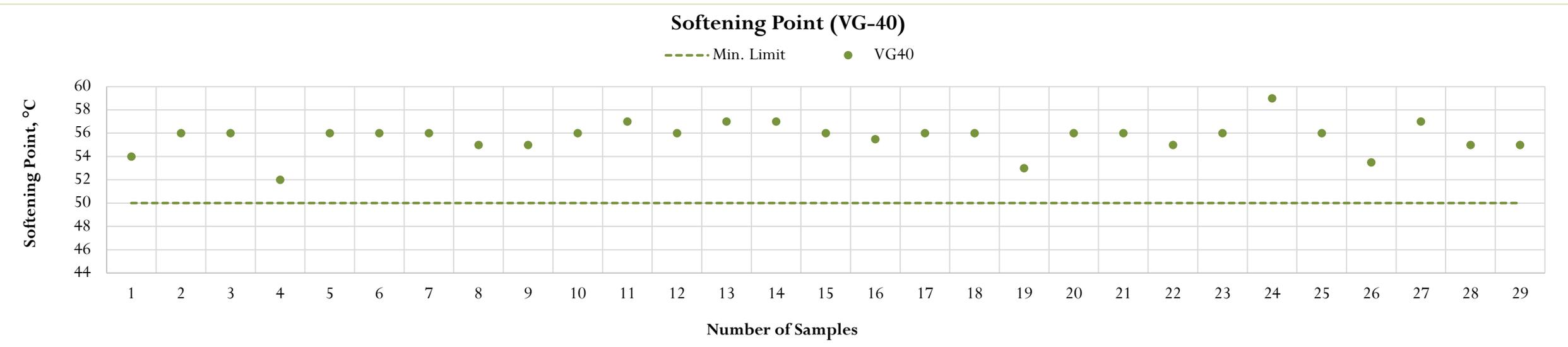
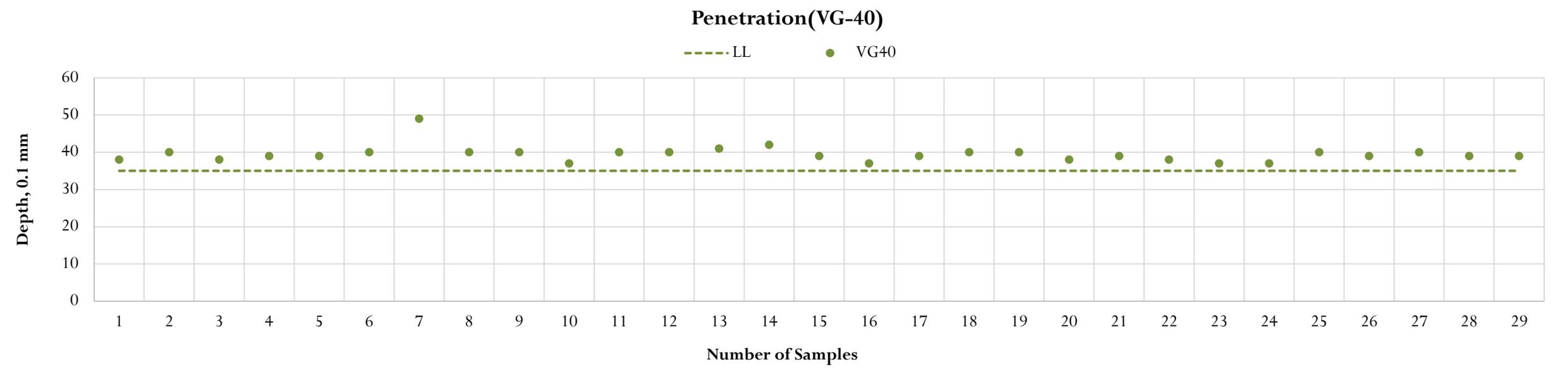


Mix Gradation - DBM II  
JMF

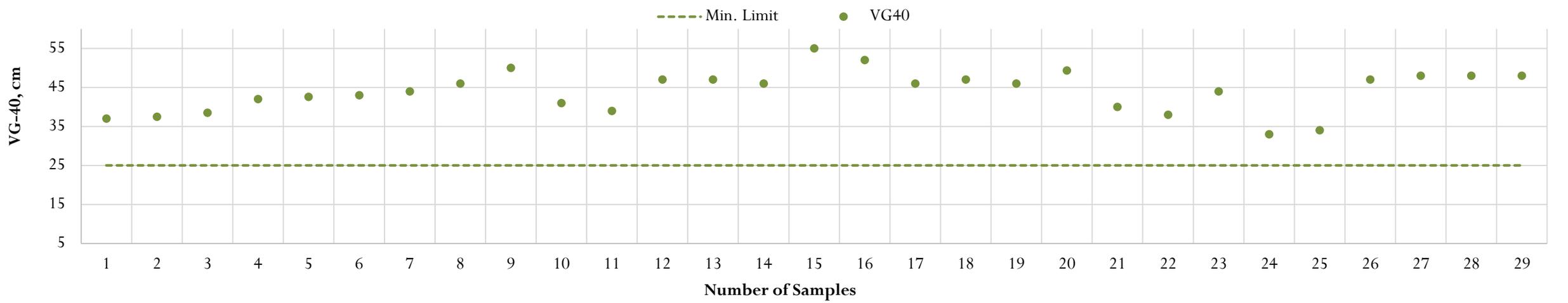


# Binder Extraction Results

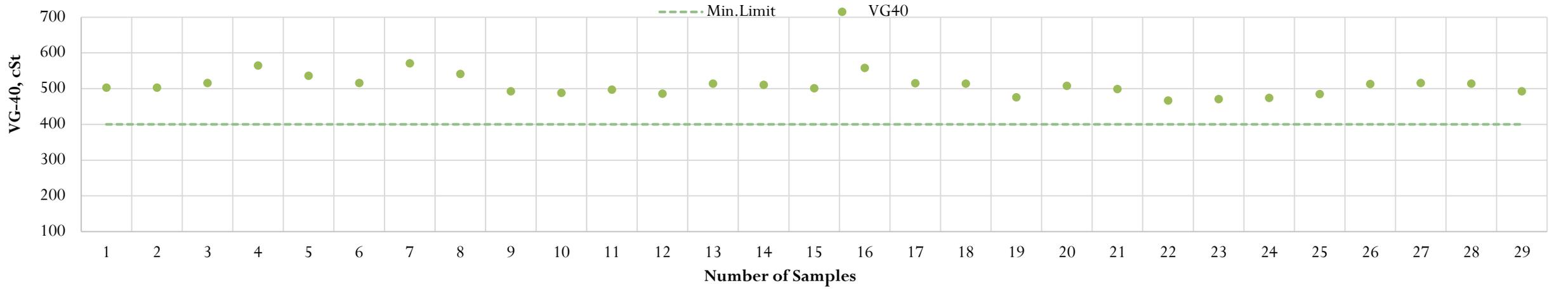




### Ductility (VG-40)

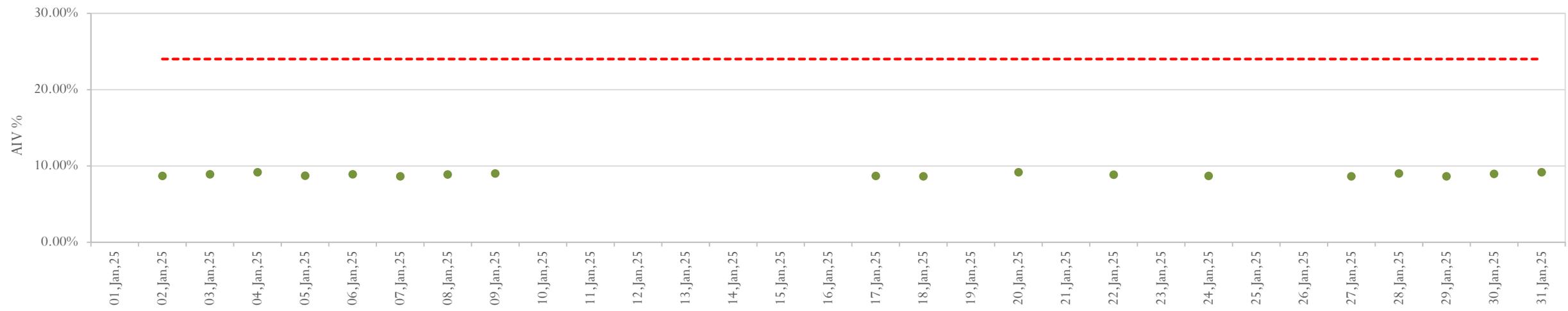


### Kinematic Viscosity (VG-40)

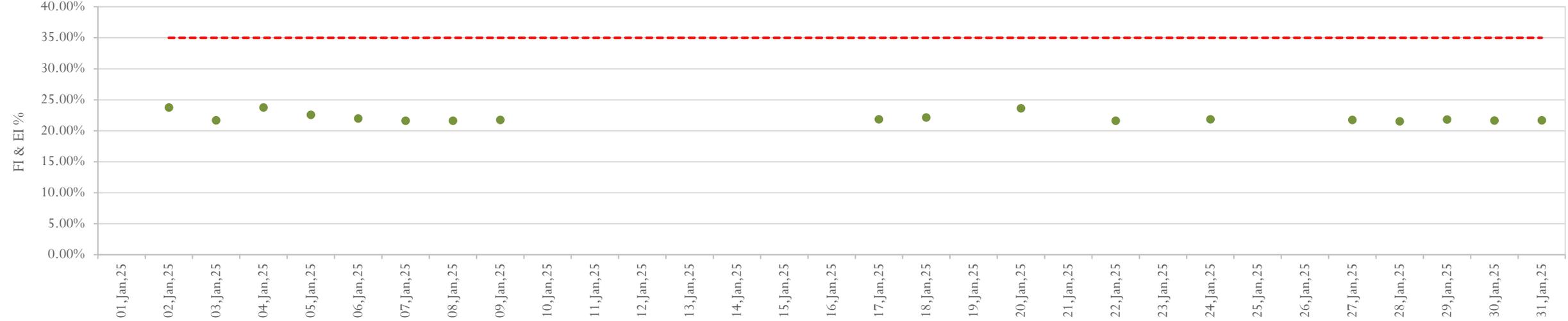


# Aggregate Test Results

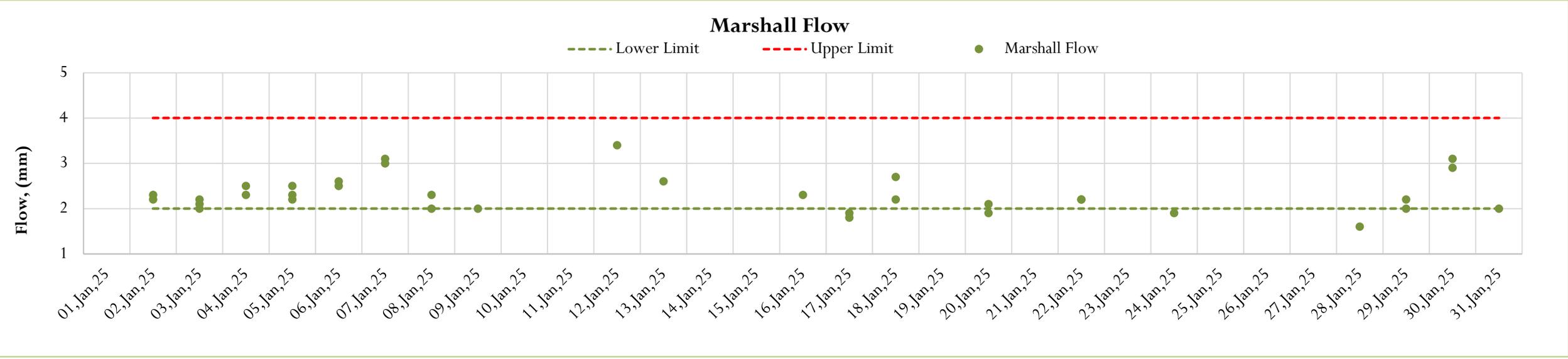
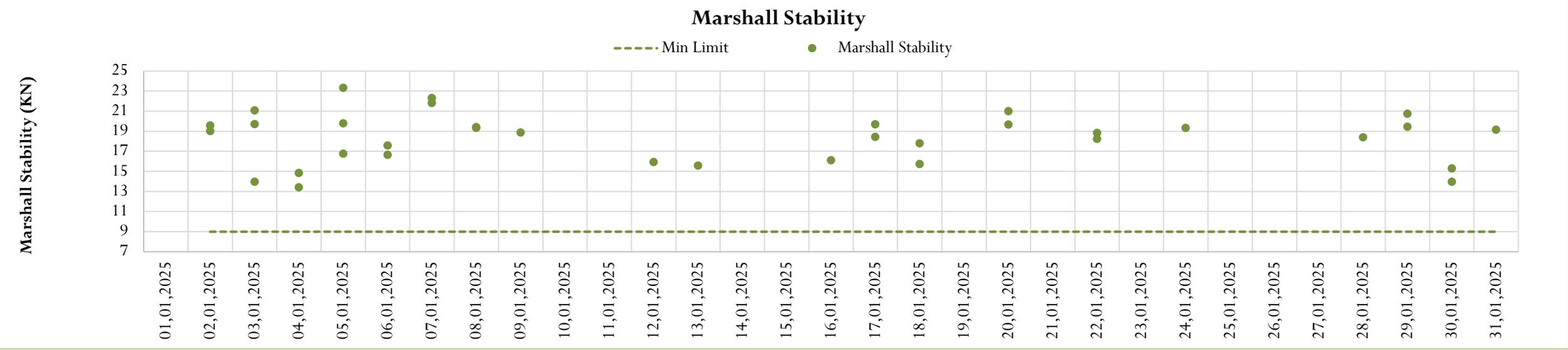
### Aggregate Impact Value



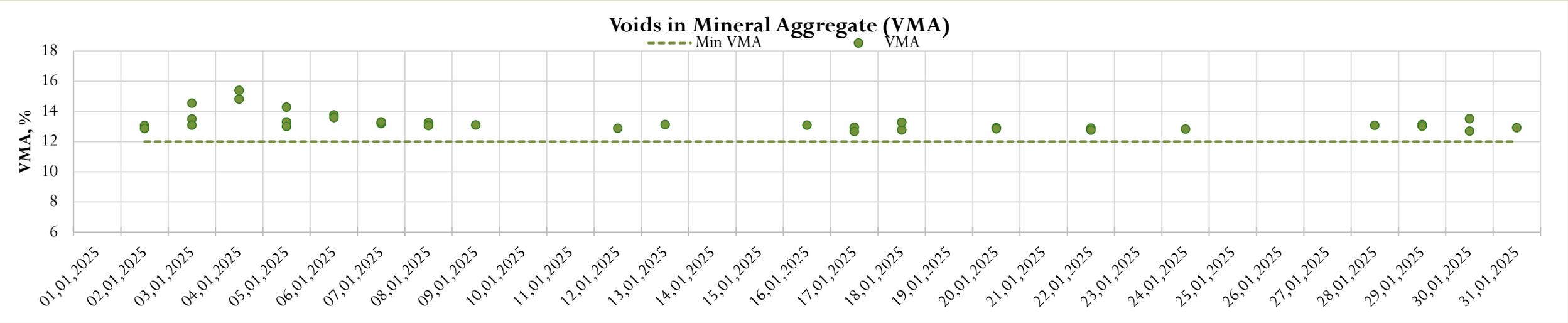
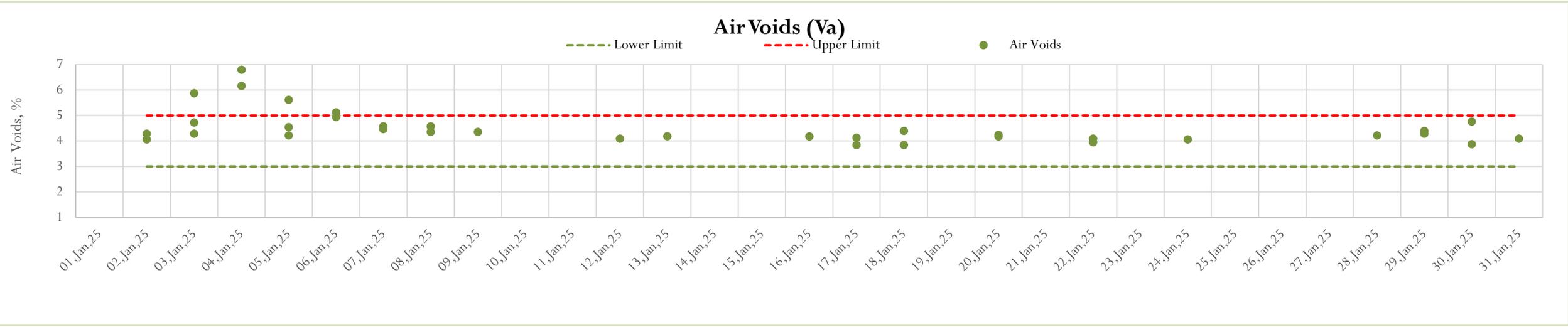
### FI & EI



# Marshall Results of DBM\_II (RAP+VG40)

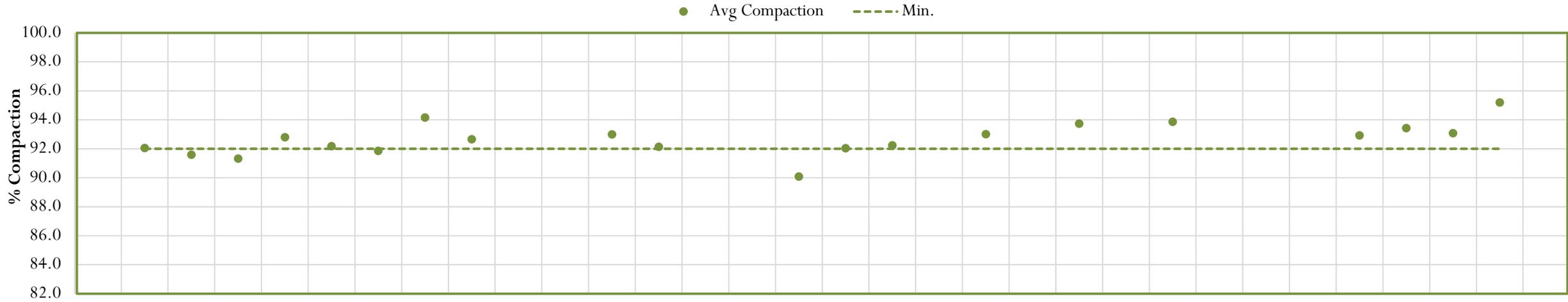


# Volumetric Properties of DBM-II with RAP+VG40

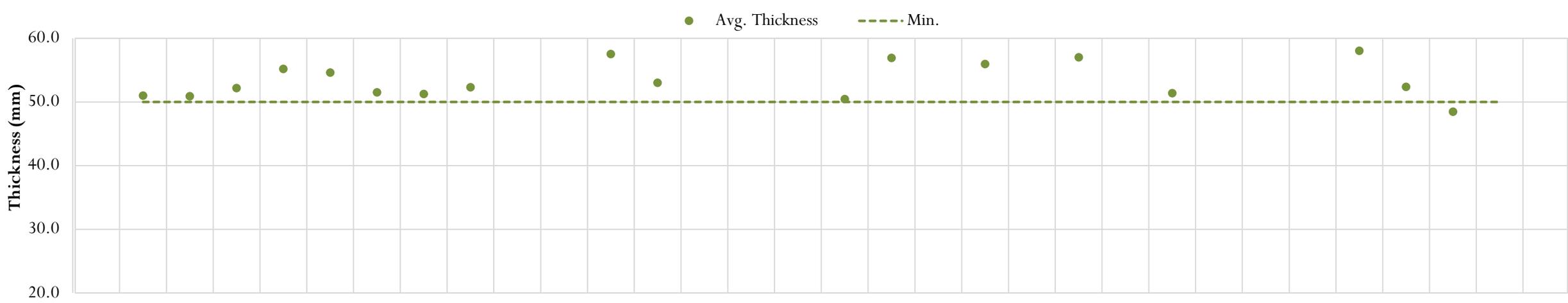


# Core Compaction and Core Thickness Results

### Core Compaction Field Density DBM II



### Core thickness DBM II



# Temperature Ranges\_ DBM II with RAP+VG40

Viscosity Grade	Bitumen Temperature (°C)	Aggregate Temperature (°C)	Mixed Material Temperature (°C)	Laying Temperature (°C)	Rolling Temperature (°C)
VG-40	160-170	160-175	160-170	150 Min	100 Min
VG-30	150-165	150-170	150-165	140 Min	90 Min
VG-20	145-165	145-170	145-165	135 Min	85 Min
VG-10	140-160	140-165	140-160	130 Min	80 Min

Source: Table: MoRTH 5<sup>th</sup> Revision - Table No: 500-2



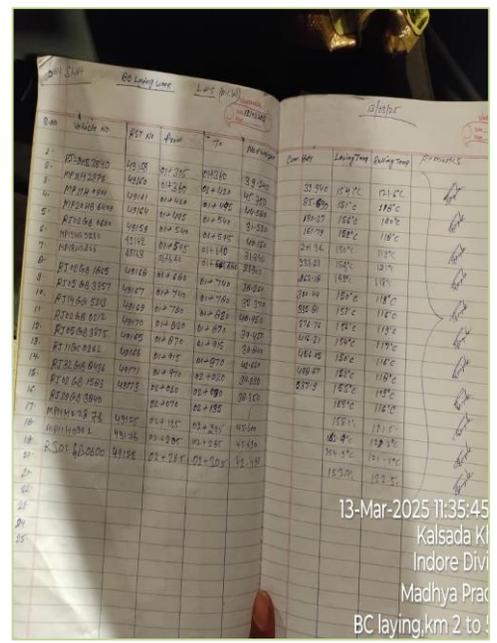
Mix Production Temperature



Laying Temperature



Rolling Temperature



Temperature Register

# Field Execution of DBM II (with RAP+VG40)



18-Mar-2025 3:54:49 pm  
Mhow - Neemuch Road  
Harsora  
Indore Division  
Madhya Pradesh

Mix Transporting & Mix Transferring to Paver



Mar 18, 2025 1:39:00 PM  
338° N  
Mhow Road  
Baggad  
Indore Division  
Madhya Pradesh  
Altitude:472.9m  
Speed:2.7km/h  
Index number: 2

DBM LAYING WORK STARTED AT CH 07+486 LHS

Paving with Paver Finisher



12 Feb 2025 16:20:26  
Borali  
Indore Division  
Madhya Pradesh  
DBM laying km 43 to 44 RHS

Rolling with vibratory roller



05-Mar-2025 21:21:32  
23°8'5.712"N 75°11'59.322"E  
Madhya Pradesh  
WMPTL

Mix Temperature Checking



Temperature Segregation Checking with IR Camera



2 Mar 2025 6:19:03 pm  
316° NW  
Altitude:457.5m  
Speed:1.9km/h

Surface Finishing with Final Rolling Pass



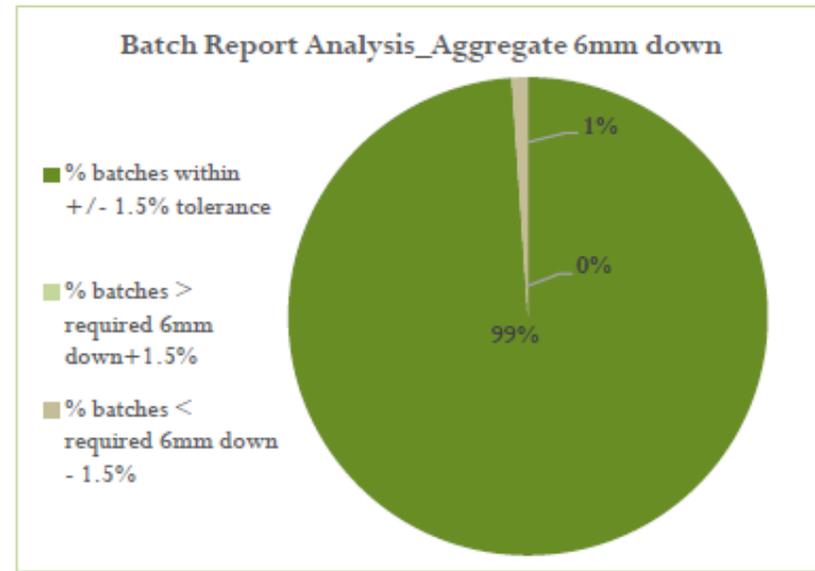
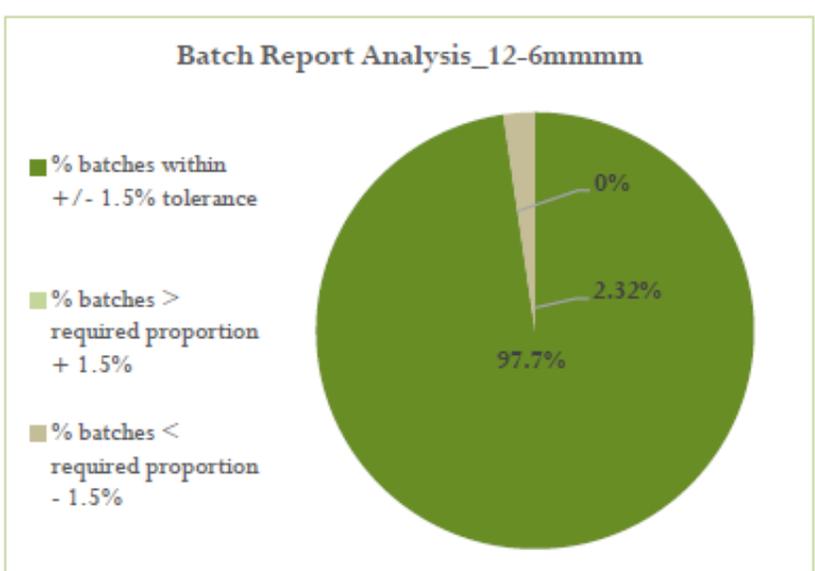
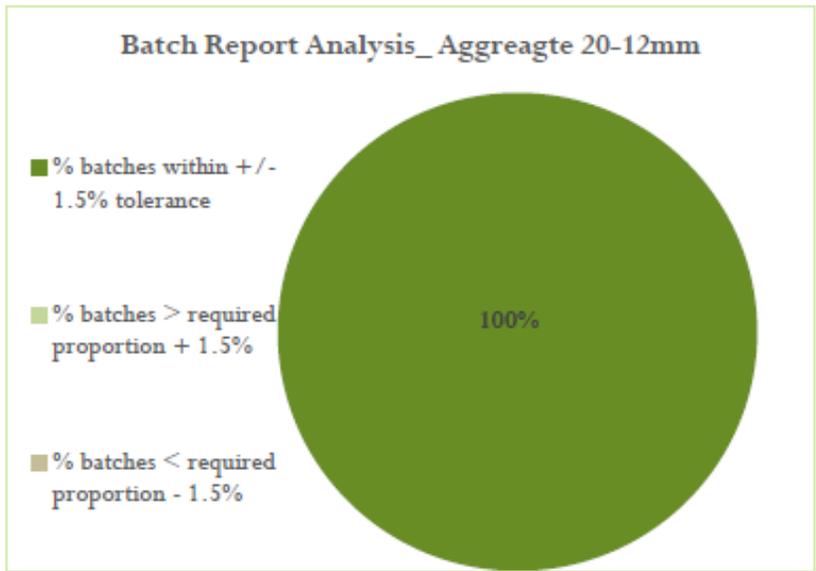
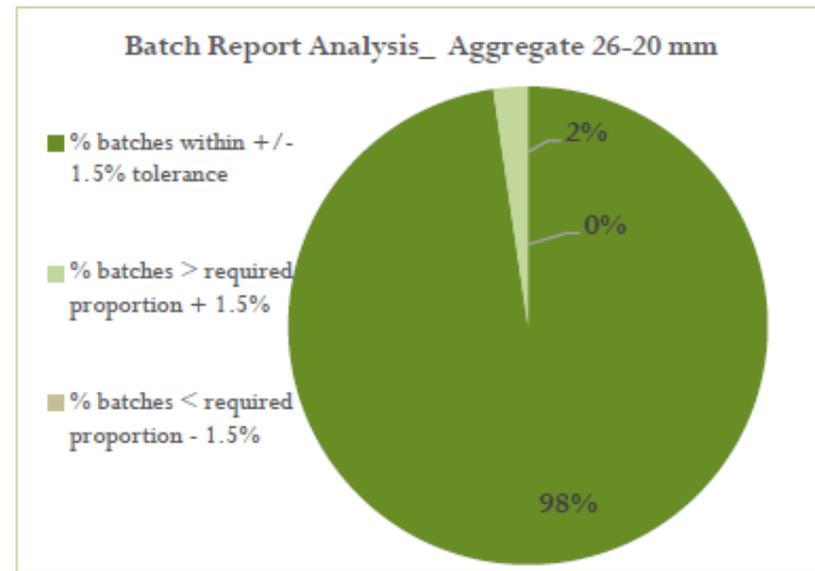
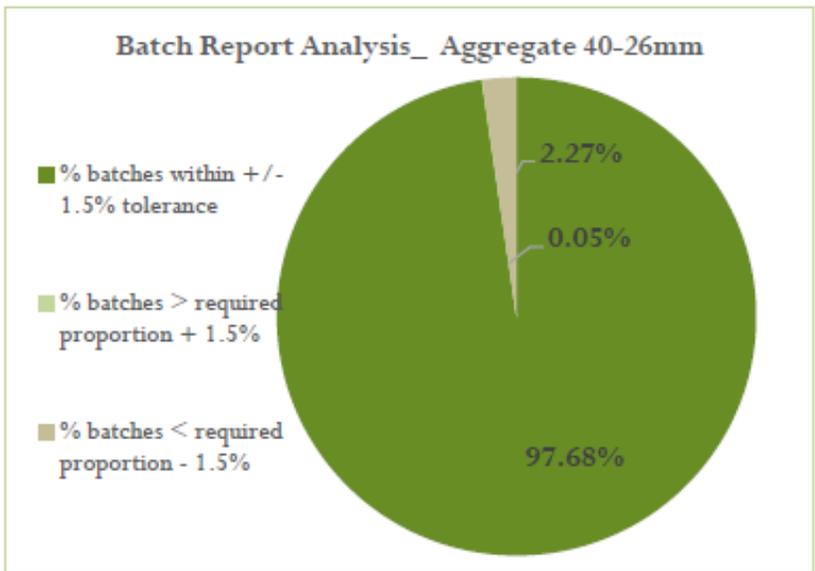
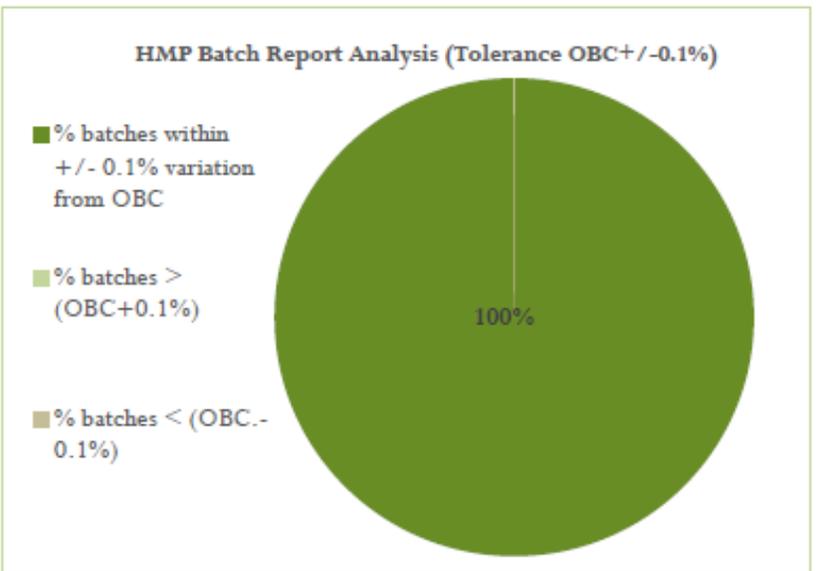
# Batch Report Analysis: Bituminous Mix with RAP Material

Production date:		04/15/24		Prod.Quantity:		157.0 t		Operator:		Ammann		
				AM02	AM03	AM05	Total	AEF01	AB01	Total	RAC	Total
				0-4	4-10	17-28	Mineral	EF 1	Bit 1	Bitumen	RAC	
Batch: 1	MT: 36s	MMT: 162°C	Nominal:	339kg	299kg	443kg	1081kg	33.5kg	40.5kg	40.5kg	345kg	1,600kg
09:12:18	DrMt: 8s		Actual:	390kg	291kg	403kg	1084kg	17.0kg*	40.0kg	40.0kg	346kg	1,487kg
			Temperature:	224°C					167°C			
Batch: 2	MT: 37s	MMT: 166°C~	Nominal:	339kg	299kg	443kg	1081kg	33.5kg	40.5kg	40.5kg	345kg	1,600kg
09:13:33	DrMt: 8s		Actual:	362kg	307kg	417kg	1086kg	29.0kg	40.0kg	40.0kg	345kg	1,600kg
			Temperature:	223°C					167°C			
Batch: 3	MT: 37s	MMT: 162°C~	Nominal:	339kg	299kg	443kg	1081kg	33.5kg	40.5kg	40.5kg	345kg	1,600kg
09:14:37	DrMt: 8s		Actual:	347kg	313kg	418kg	1078kg	30.0kg	40.0kg	40.0kg	343kg	1,491kg
			Temperature:	221°C					167°C			
Batch: 4	MT: 30s	MMT: 163°C~	Nominal:	339kg	299kg	443kg	1081kg	33.5kg	40.5kg	40.5kg	345kg	1,600kg
09:16:40	DrMt: 8s		Actual:	338kg	312kg	446kg	1096kg	30.0kg	40.0kg	40.0kg	348kg	1,614kg
			Temperature:	221°C					167°C			
Batch: 5	MT: 27s	MMT: 149°C~	Nominal:	339kg	299kg	443kg	1081kg	33.5kg	40.5kg	40.5kg	345kg	1,600kg
09:16:36	DrMt: 8s		Actual:	339kg	311kg	430kg	1080kg	34.0kg	41.0kg	41.0kg	348kg	1,603kg
			Temperature:	220°C					167°C			
Batch: 6	MT: 63s	MMT: 163°C~	Nominal:	339kg	299kg	443kg	1081kg	33.5kg	40.5kg	40.5kg	345kg	1,600kg
09:17:30	DrMt: 8s		Actual:	362kg	292kg	432kg	1076kg	34.0kg	40.0kg	40.0kg	347kg	1,497kg
			Temperature:	220°C					167°C			

- Mixing Time: Approx 55 – 56 sec for 1.6 tons batch size
- Time Break up = RAP + Aggregate feeding : Dry Mixing Time : Bitumen Mixing : Mixer Gate Opening = 17 + 10 + 25 + 4 = 55 sec



# Batch Report Analysis: Bituminous Mix (DBM with RAP)



# Performance Testing on DBM (with RAP) mix

## RESULTS

Sl.	Test Characteristics	Unit	Test Method	Results	Standard Limits	Conformity
1.	Hamburg Wheel Rut Test on Compacted Mould- Rutting Depth at 60°C	mm	BS EN 12697-22: 2020 (Procedure B in water)	1.26	1.90 Max.	Yes
2.	Total Number of Passes by Rubber wheels at 53±2 passes per min. <ul style="list-style-type: none"> <li>• Dia of Wheel: 200-205 mm</li> <li>• Width: 50±5 mm</li> <li>• Hardness: 80±5 IRHD</li> <li>• Thickness: 20±2 mm</li> <li>• Virgin Binder: VG-40</li> </ul>	Passes		40,000	40,000 Min.	Yes

## RESULTS

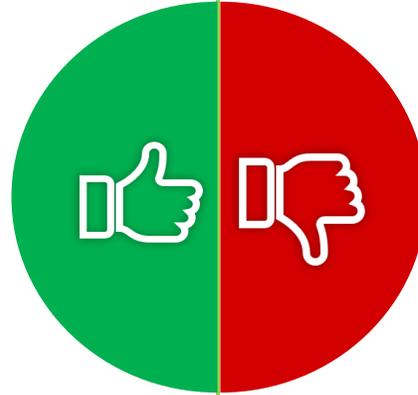
Sl.	Characteristic Parameters	Unit	Test Method	Results	IRC 37 : 2018 Std. Limits	Conformity
1.	Resilient Modulus- $M_r$ of DBM Grading II at 35°C <ul style="list-style-type: none"> <li>• Loading Pulse : 0.1 s</li> <li>• Rest Period : 0.9 s</li> <li>• Poisson's Ratio : 0.35</li> <li>• Virgin Binder : VG-40</li> </ul>	MPa	ASTM D4123-82 (1995)	3590	3000 Min.	Yes

*A comparative cost analysis was conducted for a 1 km stretch of a Dense Bituminous Macadam (DBM) layer with a pavement width of 8.75 meters and a thickness of 50 mm. The cost comparison accounts for binder, aggregate, and operational costs between a conventional virgin mix and a RAP-incorporated mix (25% RAP content).*

Cost Component	Conventional Mix (₹)	RAP Mix (₹)	Cost Reduction (₹)	Overall Cost Saving (%)
<b>Binder Cost</b>	2,460,937.50	1,859,375.00	601,562.50	24.5%
<b>Aggregate Cost</b>	1,044,531.25	820,312.50	224,218.75	21.5%
<b>Operational Cost</b>	500,000.00	550,000.00	(-50,000.00)	(-10.0%)
<b>Total Cost</b>	4,005,468.75	3,229,687.50	775,781.25	19.4%

# Do's and Don't's

- ✓ Screen RAP material for fractionalisation of RAP in appropriate material sizes to reduce variability in proportioning. It also helps in removing contaminants/oversize RAP content, if any.
- ✓ Ensure proper mix design to meet standard specifications.
- ✓ Do regular testing of RAP - binder content and gradation analysis, and check the variation if any.
- ✓ Maintain proper temperature during mix production, at laying and compaction and maintain records.
- ✓ Inspect and clean the surface post-milling.
- ✓ Ensure tack coat is applied evenly.
- ✓ Transport mix promptly to maintain temperature and cover it with tarpaulins.
- ✓ Check environmental conditions before laying the mix.
- ✓ Calibrate HMP and weigh bridge frequently for accuracy in proportioning.



- ✓ Use appropriate proportion of RAP – avoid using excessive % of RAP, if it does not meet mix design requirements and specifications.
- ✓ Don't allow the mix to cool excessively before laying.
- ✓ Don't apply tack coat on a wet or contaminated Surface.
- ✓ Don't neglect the maintenance of joints, which can lead to cracks.
- ✓ Don't lay mix during unfavourable weather conditions.

# *Global Road Infratech Summit & Expo (GRIS-2026)*

*05-06th February 2026, New Delhi, India*

# THANK YOU



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