Revolutionizing Road Infra with Modern Equipment, Technologies, Sustainable Materials and Policy Guidelines

February 29th - March 1st, 2024, Manekshaw Centre, New Delhi

Performance Grade (PG) Bitumen in Highway Construction

Arpan Ghosh, Cube Highways Technologies

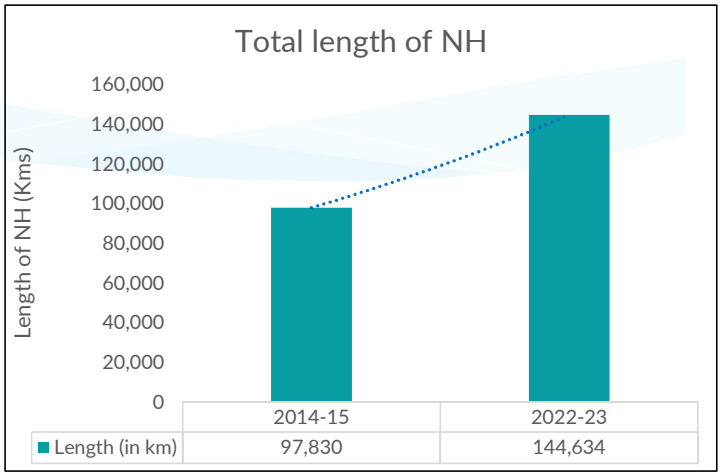
International Road Federation
India Chapter

www.indiairf.com | india@irf.org.in

Introduction

Highway Industry Expansion:

- Indian national highways increased by 47.85% in 8 years (FY 2014-15 to November 2022).
- Currently, the length of National Highway is 1,44,634 km, up from 97,830 km (FY 2014-15 to November 2022).
- Most highways upgraded to 4 lanes, expanding to 6 lanes and beyond.

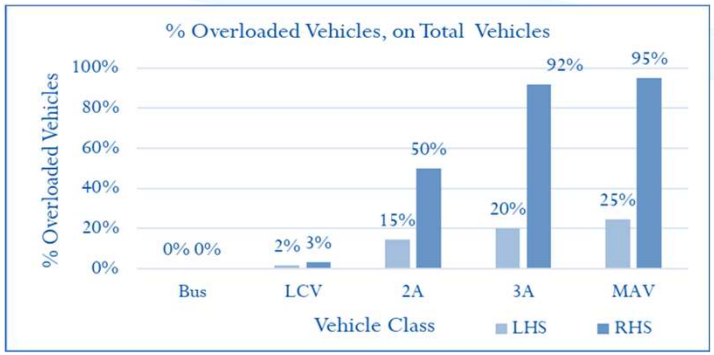


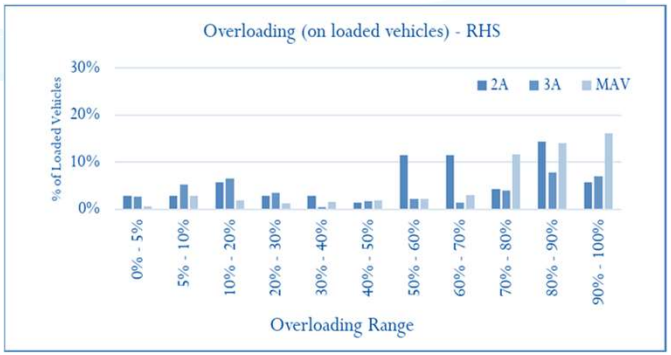
Bitumen Market :

- India's annual bitumen consumption: 8 million metric tons.
- Expected to double by 2030.
- Indian Bitumen market to exceed Rs 50,000 Crores by 2026 (Allied Market Research).

Challenges for Indian Highways

Overloading

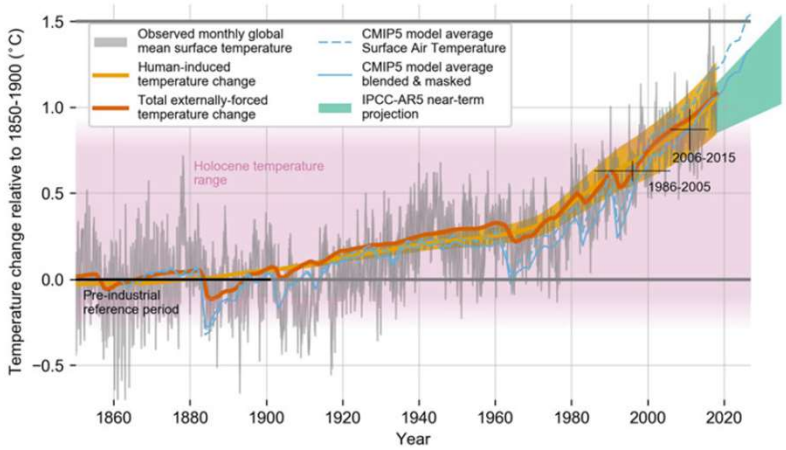




VDF from Axle Load Survey						
Vehicle Category	Design Period		After 50% Construction		O&M period	
	LHS	RHS	LHS	RHS	LHS	RHS
BUS	2.70	0.86	0.51	1.19	1.02	0.97
LCV	0.86	1.60	0.59	0.87	0.99	1.84
2A	1.60	10.86	1.85	22.49	3.58	30.80
3A	6.53	14.06	1.90	37.46	3.35	106.82
MAV	2.70	1.58	7.35	11.39	6.82	164.18

Challenges for Indian Highways

High Temperature & Climate Change



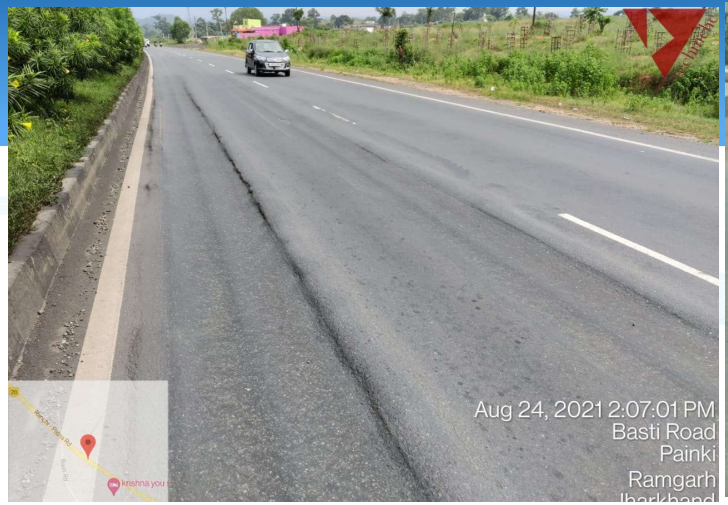
- The all India averaged annual frequency of warm days and nights have increased, and cold days and nights have decreased since 1951.
- The observed warming is also unevenly distributed across India.
- The largest increase in the annual mean temperature are observed in some areas of north India between 1986 and 2015.
- The warming is much weaker in the southern peninsula.

Table 2.1 Observed changes in India land mean annual and seasonal surface air temperature between 1986 and 2015

Season	Temperature trends 1986–2015 (°C per decade)		
	Mean	Maximum	Minimum
Annual	**0.15*** ± 0.09	**0.15*** ± 0.10	**0.13*** ± 0.10
Winter (Dec–Feb)	0.05 ± 0.16	0.03 ± 0.20	0.07 ± 0.18
Pre-monsoon (Mar–May)	**0.26*** ± 0.17	**0.29*** ± 0.20	**0.20*** ± 0.16
Monsoon (Jun–Sep)	0.11 ± 0.12	0.10 ± 0.17	**0.11*** ± 0.08
Post-monsoon (Oct–Nov)	0.17 ± 0.17	0.14 ± 0.22	0.19 ± 0.20

Source : Assessment of Climate Change over the Indian Region
A Report of the Ministry of Earth Sciences (MoES), Government of India. 2021

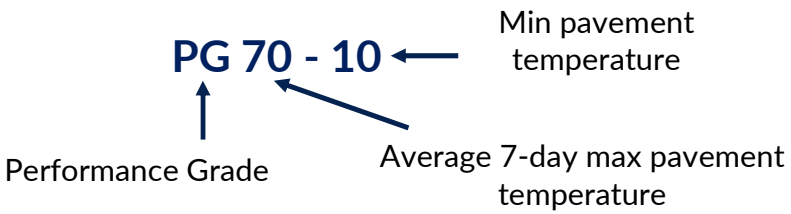
Distressess Observed in Indian Highways



History of Grading and Performance Grade

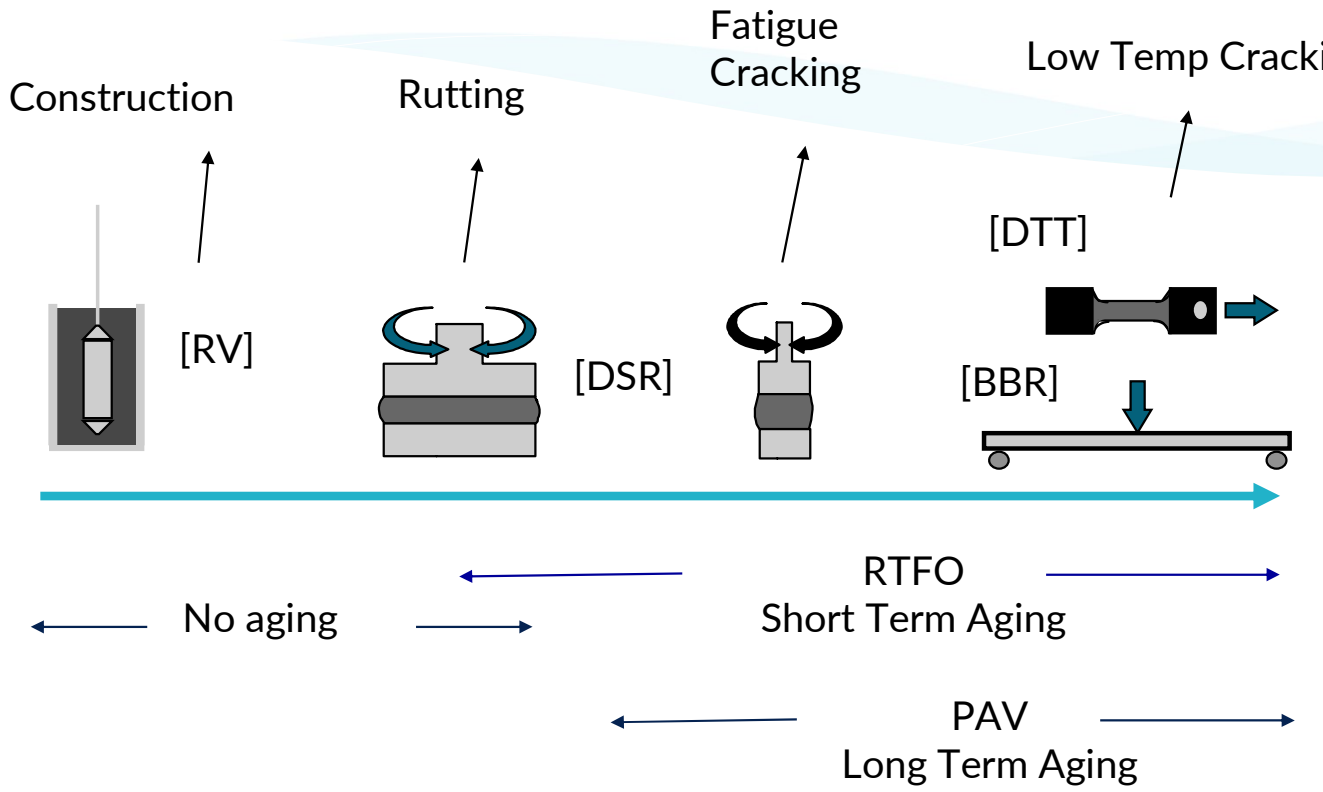
- Grading by Chewing
- Penetration grading (PEN) -India, 1950
- Viscosity Grading (VG)-India, 2006
- Performance Grading (PG) –India 2019 –

The grading system is based on Climate



1. The PG asphalt binder grading system was developed to address the short comings seen in the traditional asphalt binder specifications.
2. The physical properties measured are related to Fundamental properties related to HMA performance.
3. Tests and specifications are designed to eliminate or minimize three specific types of bituminous pavement distress: rutting (high temperature), fatigue(intermediate temperature) and thermal cracking (low temperature).
4. Test parameters are selected to represent in-service & construction temperatures.
5. Asphalt binder conditioning is undertaken considering construction and environmental factors -Short- and long-term aging
6. The entire range of pavement temperatures experienced at the project site is considered. New testing equipment were developed/adopted for testing bitumen for this purpose – Rotational Viscometer, Dynamic Shear Rheometer (DSR), Bending Beam Rheometer and Direct Tension Tester.

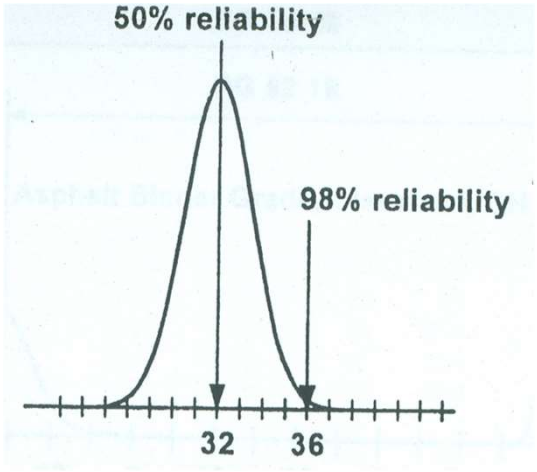
Testing Protocol



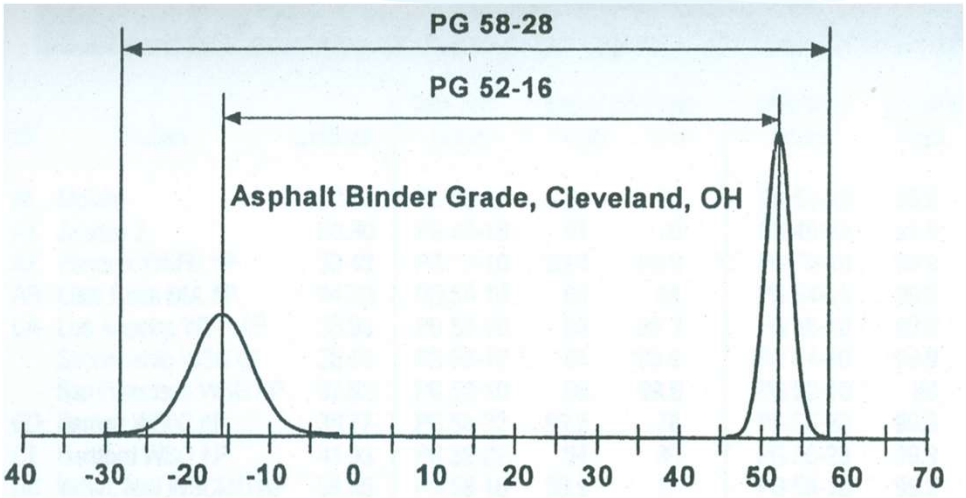
Source: NPTEL Course on Mechanical Characterization of Bituminous Material- Dr. J Murali Krishnan

How do you choose a PG grade?

We use a normal distribution to describe the range of temperatures at a site. By selecting a higher reliability, you can move further out on the "tail" and reduce the amount of risk of encountering a temperature that exceeds the design temperature.



A design air temperature of 36 degree C will give 98% reliability



PG grade 58-28 for 98% reliability

PG grade 52-16 for 50% reliability

Source: NPTEL Course on Mechanical Characterization of Bituminous Material- Dr. J Murali Krishnan

Need for Bitumen Modification

Low Temperature, °C \ High Temperature, °C	52	58	64	70	76
-16	52-16	58-16	64-16	70-16	76-16
-22	52-22	58-22	64-22	70-22	76-22
-28	52-28	58-28	64-28	70-28	76-28
-34	52-34	58-34	64-34	70-34	76-34
-40	52-40	58-40	64-40	70-40	76-40

= Crude Oil
= High Quality Crude Oil
= Modifier Required

pavementinteractive.org

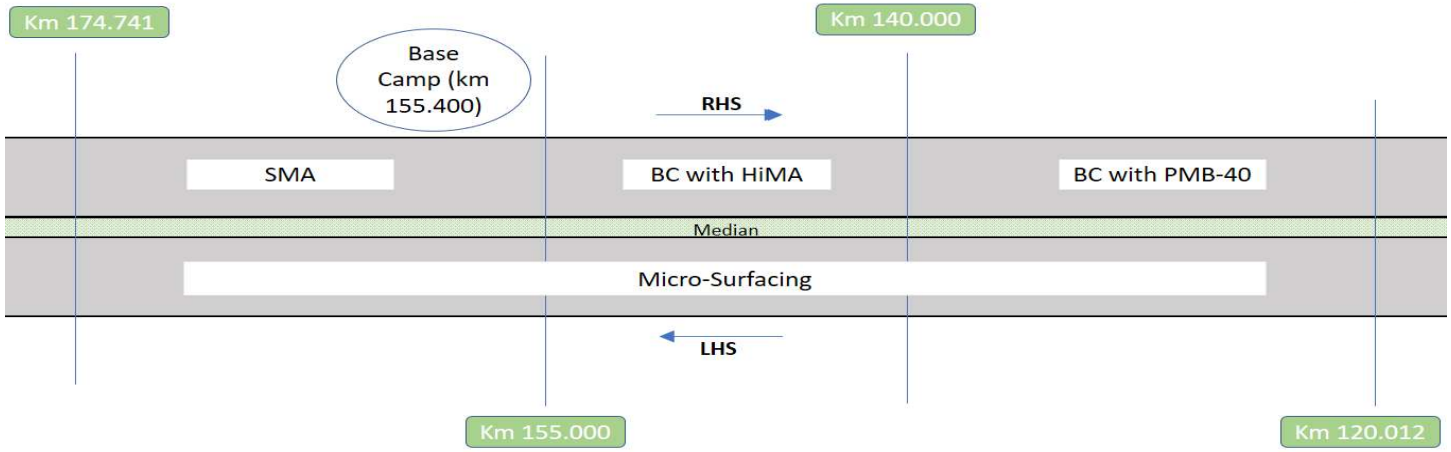
- Standard "S" = traffic < 10 million ESALs and > 70 km/h
- Heavy "H" = traffic 10-30 million ESALs or 20-70 km/h
- Very Heavy "V" = traffic > 30 million ESALs or < 20km/h
- Extreme "E" = traffic > 30 million ESALs and < 20km/h, toll plazas

Jnr	PG Plus
2 - 4.5	PG 64 S - 22
1 - 2	PG 64 H - 22
0.5 - 1	PG 64 V - 22
0.25 - 0.5	PG 64 E - 22

Source: Presentation on Bitumen: Composition, Properties , Usage Specifications – Dr. Ambika Behl

The JMTL Case – Turning Point (2018)

- Design Traffic (MSA) for RHS: 50.13
- Design Traffic (MSA) for LHS: 22.73
- Milling of distressed sections and profile correction
- DBM & BC with PMB for rehabilitation of RHS and LHS
- Rut resistant mix for RHS – Stone Matrix Asphalt for 20km, HiMA (Highly Modified Asphalt) for 15km and PMB based BC for the remaining portion



PMB-40 with enhanced softening point and elastic recovery has been used; whereas HiMA is as per PG specifications

JMTL -Performance of PMB

- Initial 20km section with PMB-40 showed pre-mature rutting within initial six months on a length of approximately 3km

Multiple Stress Creep and Recovery tests (As per ASTM D 7405:2015)

Parameter	Trial 1	Trial 2	Average
MSCR, Jnr3.2 @64°C, kPa^{-1}	1.782	1.868	1.83
MSCR, Recovery R3.2 @64°C,%	4	3.8	3.9

Multiple Stress Creep and Recovery tests (As per ASTM D 7405:2015)

Parameter	Trial 1	Trial 2	Average
MSCR, Jnr3.2 @58°C, kPa^{-1}	0.108	0.107	0.108
MSCR, Recovery R3.2 @58°C,%	68.61	71.97	70.29

JMTL -Performance of PG graded Bitumen

S. No.	Properties	Obtained values	Specification
	Grade	94	PG76E-28
1	Solubility	100	100
2	Temperature at which G*/Sin$^{\delta}$ >1 kPa	105.6	Min 76
3	Viscosity at 135^{0}C Pa.sec	5.26	Max 3
4	Separation Test	1.48	Max 10
5	Softening point, ^{0}C	94	Min 90
6	Elastic Recovery at 15^{0}C	90	Min 90
7	Shear Modulus G*/Sin$^{\delta}$	4.57	Min 1.0
8	Test on RTFO Residue		
a	Loss in Mass	0.05	Max 1
b	Temperature at whichG*/Sin$^{\delta}$ > 2.2kPa	96.1	
c	MSCR Jnr 3.2@ 76^{0}C,1/kPa	0.0235	Max 0.3
d	MSCR,Recovery R3.2@ 25^{0}C	96.3	Min 90
9	Test on PAV Residue		
A	Temperature at which G*. Sin$^{\delta}$ is max 5000 kPa	5.7	
B	Dynamic Shear*Sin$^{\delta}$ at 25 and 10 rad/sec, kPa	1061.21	Max 5000

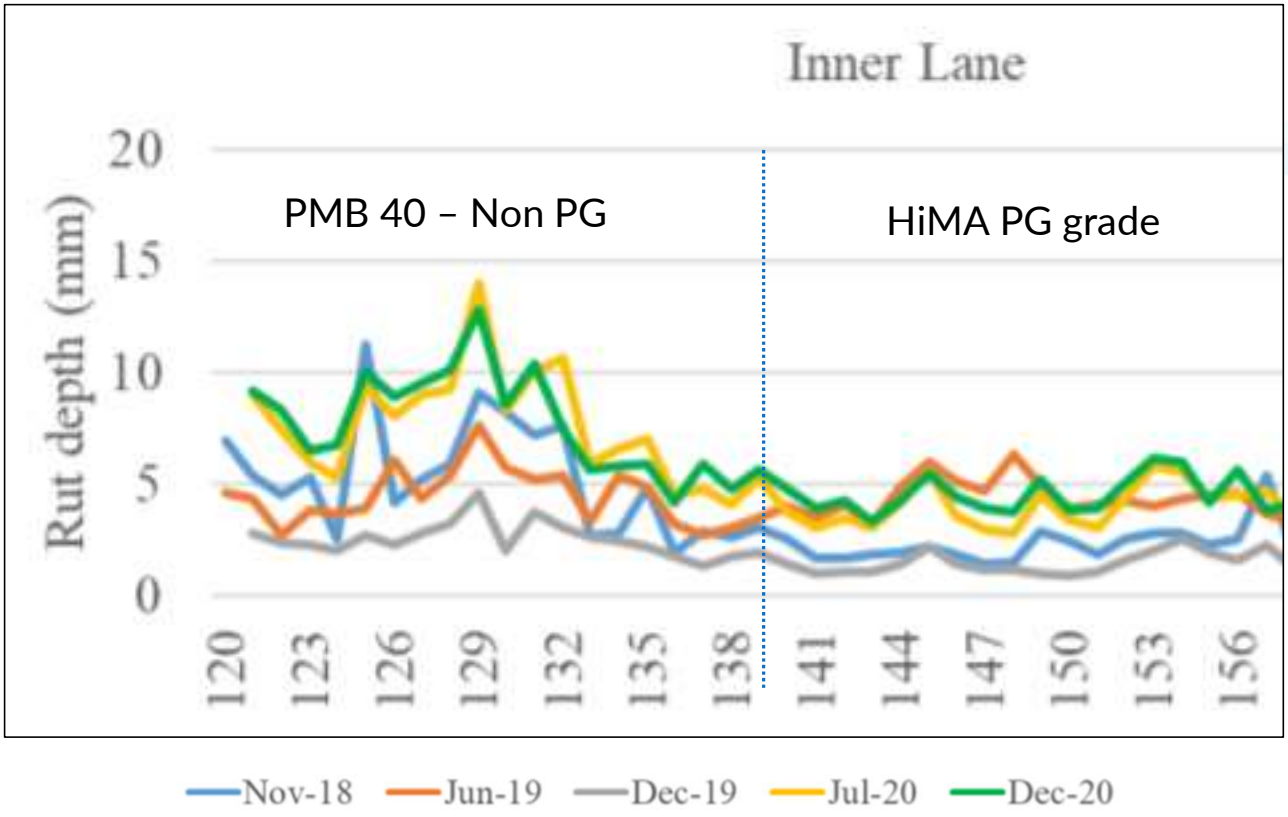
Parameter	Trial 1	Trial 2	Average
MSCR, Jnr3.2 @76°C, kPa^{-1}	1.0	0.936	0.968
MSCR, Recovery R3.2 @76°C, %	52.3	55.6	54

Laying of HiMA

Finished surface of HiMA

- Marshall mix design is followed and nothing different to normal mix design
- Temperatures during mixing, production and laying are similar to normal PMB mixes
- No rehabilitation carried out in 1.5 years of life (2 seasons of summer with high temperatures)

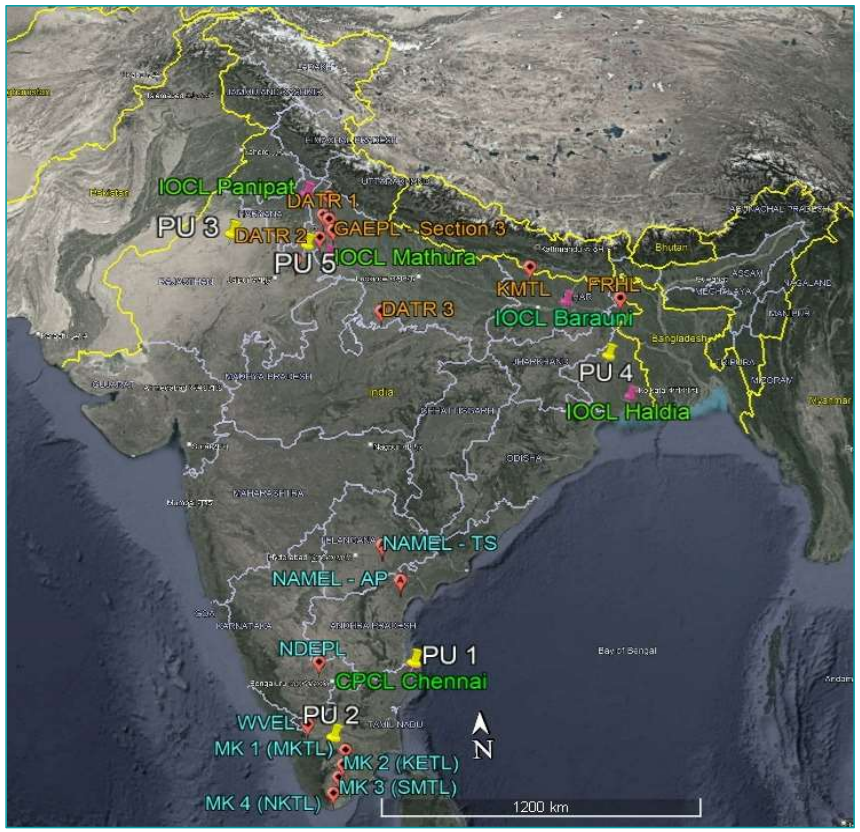
Rutting Progression



Evolution of Internal Specifications @ Cube Highways

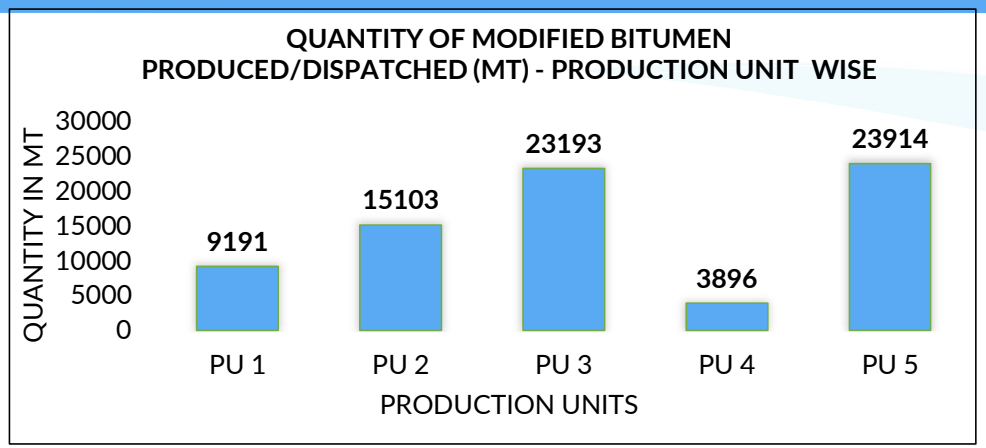
- Conventional binders (as per IS:73 and IS:15462)
- Enhancing Softening Point and Elastic Recovery
- Incorporating PG specifications
- Using MSCR tests to grade binders as per AASHTO MP 19

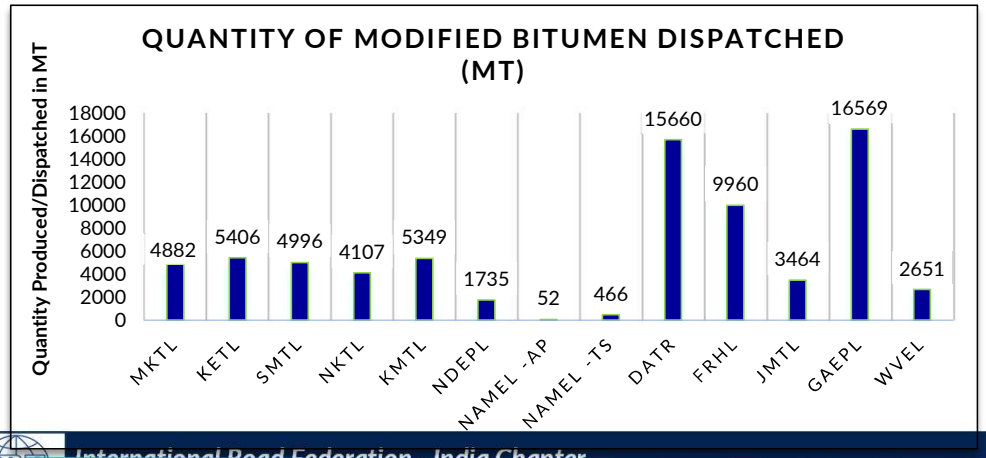
Projects in India with Polymer Modified PG Bitumen



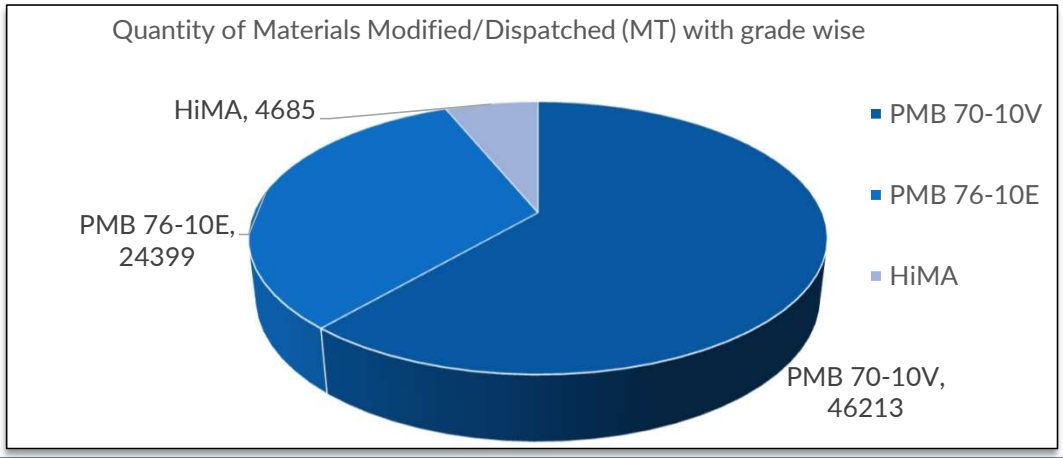
S. No	Production Unit	Responsible Project/ Site for Material Supply	Lane km	States Covered	Refinery for Raw Bitumen Supply
1	PU 1	MK Sections	974	Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Telangana	CPCL Chennai
		NDEPL	320		
		WVEL	214		
		NAMEL - AP & TS	848		
2	PU 2	MK Sections	974		
		WVEL	214		
3	PU 3	KMTL	320	Bihar, West Bengal, Delhi NCR, Uttar Pradesh, Haryana, Rajasthan.	IOCL Mathura
		FRHL	400		
		DATR Packages	1077		
		GAEPL Sections	750		
		JMPTL	654		
		MBEL	228		
4	PU 5	DATR Packages	1077		IOCL Mathura & Panipant
		GAEPL Sections	750		
		JMPTL	654		
		MBEL	228		
5	PU 4	FRHL	400	West Bengal	IOCL Haldia & Baruni

Experience with Polymer Modified PG Bitumen

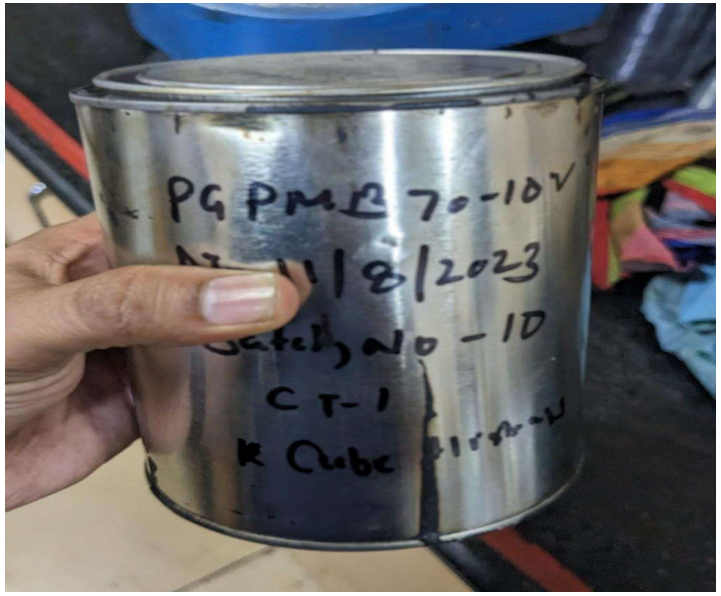




- The team has successfully coordinated **85,000+** MT modified bitumen to the **20+** projects from the five different production units.
- **24,000+** Tests conducted on PMB
- Supplied **2,726 MT** of PMB PG Grade during World Record Attempt of laying 112.5 lane km in 100 hrs.



Experience with Polymer Modified PG Bitumen



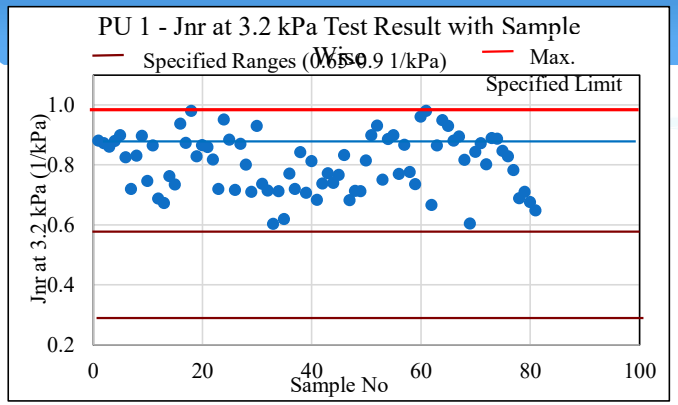
OOMS INDIA

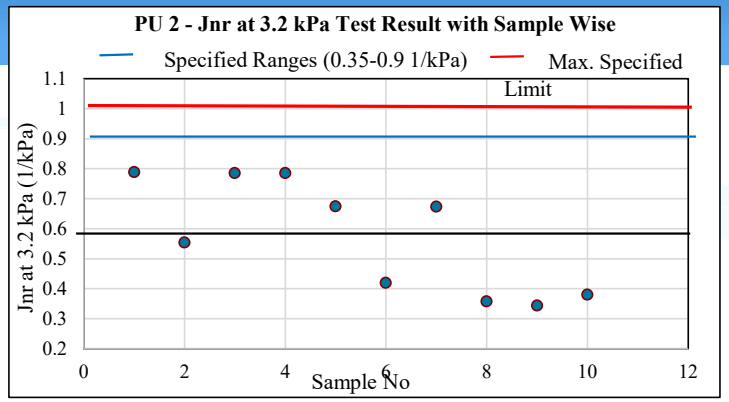
BITCOL

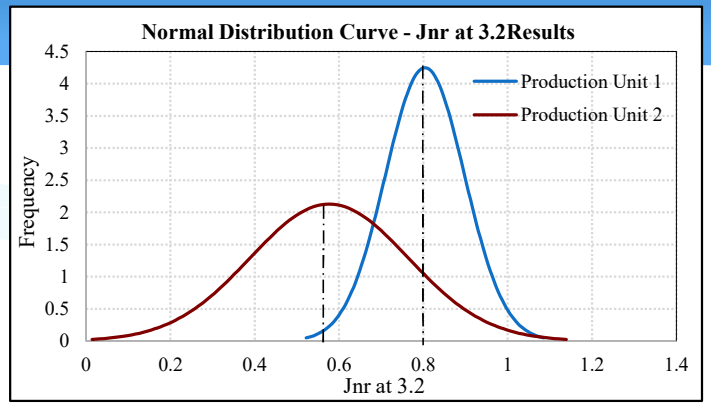
Challenges in the Production Process of PG Binder

- A different modifier has its own production methodology and facilities in the modification of the PG binder. It leads to variation and inconsistency in the quality results of the modified PG binders which are produced with the same source of raw materials (base bitumen and polymers).
- Automation in the production process significantly impacts the test results of the PG binders. The experience in the production process clears the PG binders having consistent test results when it was modified with complete automation in the production process.
- The inadequacy in the dedicated storage tanks for different grades of PG binder will lead to inaccuracy and variation in the quality results of modified PG binders from the production unit to the field.

MSCR_Jnr@3.2 of PMB 70-10V (IS 15462:2019)



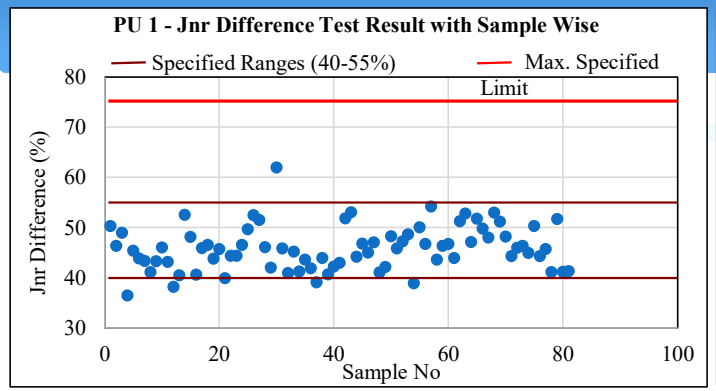


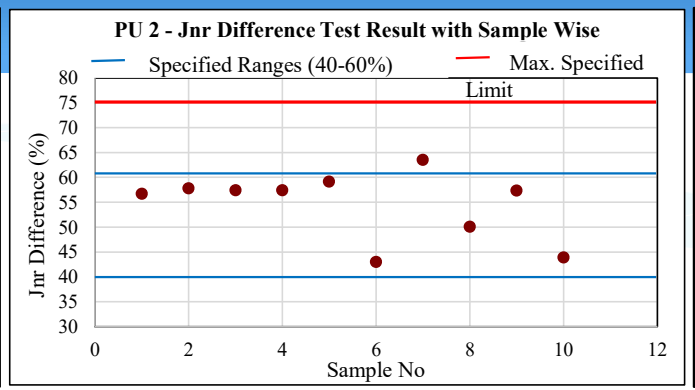


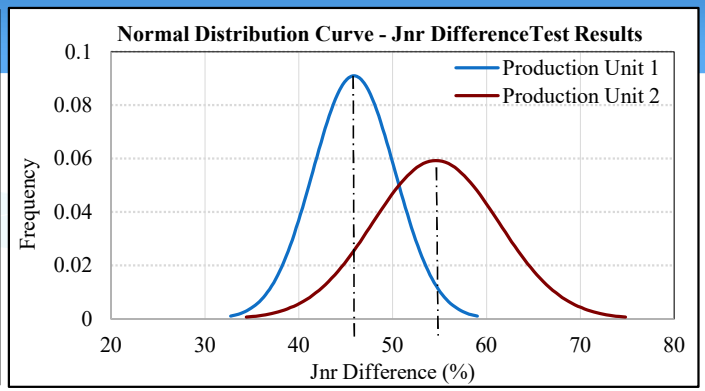
Jnr at 3.2 (1/kpa)	Min	Max	Average	Range	Standard Deviation	Variance	Median	Mode	Specified limit (Max)
PU1	0.6	0.98	0.8	0.38	0.0939	0.0088	0.82	0.88	1
PU2	0.34	0.79	0.58	0.44	0.1875	0.0352	0.61	0.79	1

- **84%** of the tested samples lie in the range of **0.65 to 0.9 1/kPa** of Jnr 3.2 from **PU1** whereas, in **PU2** it is **50%.**
- When the range is being shifted in the range of **0.35 to 0.9 1/kPa** of Jnr 3.2, in **PU2** where **84%** of the samples are found to be lying within the range.
- The bell shaped curve obtained from the PU1 which is narrow denotes less variation and that of PU2 which is wide shows more variation in Jnr 3.2.

MSCR_Jnr Difference of PMB 70-10V (IS 15462:2019)







Jnr difference (%)	Min	Max	Average	Range	Standard Deviation	Variance	Median	Mode	Specified limit (Max)
PU1	36.42	61.95	45.89	25.53	4.384	19.217	45.79	46.5	75
PU2	42.98	63.54	54.62	20.56	6.730	45.294	57.36	57.39	75

- The **92%** of the tested samples lie in the range of **40 to 55%** of Jnr difference from **PU1** whereas, in **PU2** it is **30%.**
- When the range is being shifted in the range of **40 to 60%** of Jnr difference, in **PU2** where **92%** of the samples are found to be lying within the range.
- The bell shaped curve obtained from the PU1 which is narrow denotes less variation and that of PU2 which is wide shows more variation in the Jnr difference.

Key Issues in the Existing PG Binder Specifications (IS 15462:2019)

PMB76-10E	Original Binder Grading (AASHTO T315)			RTFO Grading (AASHTO T315)			MSCR-Test (AASHTO T350)			
Temperature	|G*|/sin(&)	|G*|	&	|G*|/sin(&)	|G*|	&	J_nr(3.2)	J_nr_diff	Traffic Grade	Remark
°C	Kpa	Kpa	°	Kpa	Kpa	°	1/Kpa	%		Pass/Fail
64	5.3156	4.6011	59.95	10.4721	8.8566	57.74	-	-		-
70	3.2277	2.7932	59.93	6.1695	5.2048	57.53	-	-		-
76	1.9855	1.7304	60.64	3.6965	3.1368	58.06	0.3806	47.17	E	Pass
82	1.2112	1.0734	62.40	2.2327	1.9235	59.49	1.3263	79.47	-	Fail
84.3/82.2	0.7374	0.6700	65.40	1.3384	1.1820	62.00				
88	0.6705	0.6705	65.41	1.3384	1.1820	62.02				

- The current specifications bring two different grading systems i.e., temperature (Original Binder and RTFO verifications) and traffic (MSCR) to define the particular grade of PG binder. Which, the MSCR characteristics are not achieved in most of the cases for the PG binder which was passed in the RTFO/Original Binder verification tests.

- Also, the minimum specified limits of G*/Sinδ are given for the original binder (1.1 kPa), and RTFO binder (2.2 kPa) verifications are needs to be verified as per the Indian PG grading conditions. Since most of the time, the test results of the PG samples are lies between 2.2-3 kPa for Original binder verification and 4.2-5.5 kPa for RTFO binder verifications.

Thank You