



**IRF WORLD ROAD
MEETING 2017**

/ 14-17 NOVEMBER / DELHI / INDIA /

**Potential Use of Foamed Bituminous
Mixes with respect to Energy
Consumption and Emissions**

Authors: Siksha Swaroopa Kar, Devesh Tiwari,
Aravind K Swamy & Pramod K Jain

Indian Road Transport Scenario

- Road transport is in great demand since ages
- Second largest road network in the world with 5.4 million road kilometers
- Traffic (both intensity & loads) increasing unabatedly
- To meet the increasing demands, road construction activity is at its all time high

MATERIAL

- In india, about 15,000 tonnes of aggregates are required per kilometer of highway
- A typical NHDP of 60 km road improvement requires 20 lakh ton of material

ENERGY

- 90,000 litres of fuel for drying and heating of aggregates per kilometer of highway
- For a lead of 200 km (very common in North India), 180lakh litre of diesel in transportation is consumed

EMISSIONS

- Caused by heating of bituminous binder and HMA
- Amount of emissions doubles for every 10°C increase in production temperature

Present Need

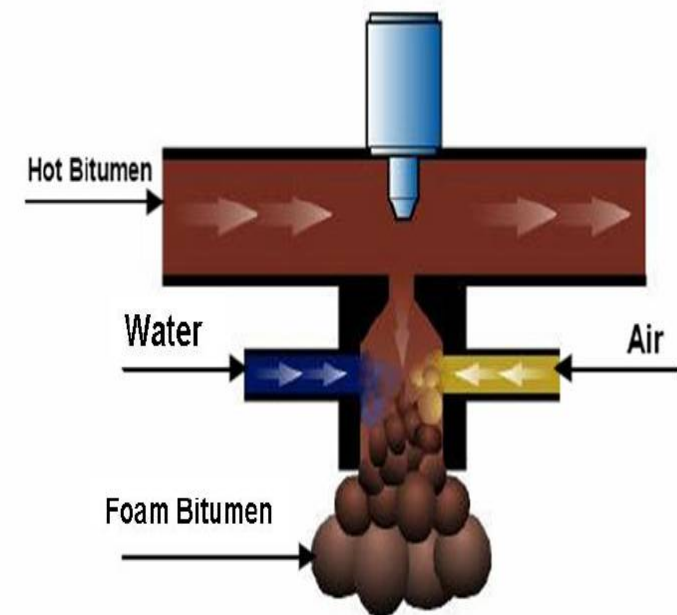
- Stone aggregates constitute more than 80-85% by volume of the pavement materials for construction
- With the increased unrestricted use, sources are fast depleting and may vanish in near future
- The energy sources are diminishing as well
- The greenhouse gases are increasingly emitted, causing disturbance in the environment and ecological balance

Alarming need to explore conservation and environment protection techniques/measures leading to sustainable roads.

e.g " COLD RECYCLING WITH FOAM BITUMEN"

What is Foamed Bitumen?

- First developed at Iowa State University in 1956 by Professor Ladis Csanyi while researching the viscosity of asphalt binders and the effect of steam injection on viscosity of binders.
- Hot bitumen (135–160°C) turns to foam when mixed with a small quantity of cold water (typically 1.5-3.5 % by mass) in a special-purpose expansion chamber.
- Foam dissipates in a very short time in less than a minute and the original properties of bitumen are regained



Source: Wirtgen (2012)

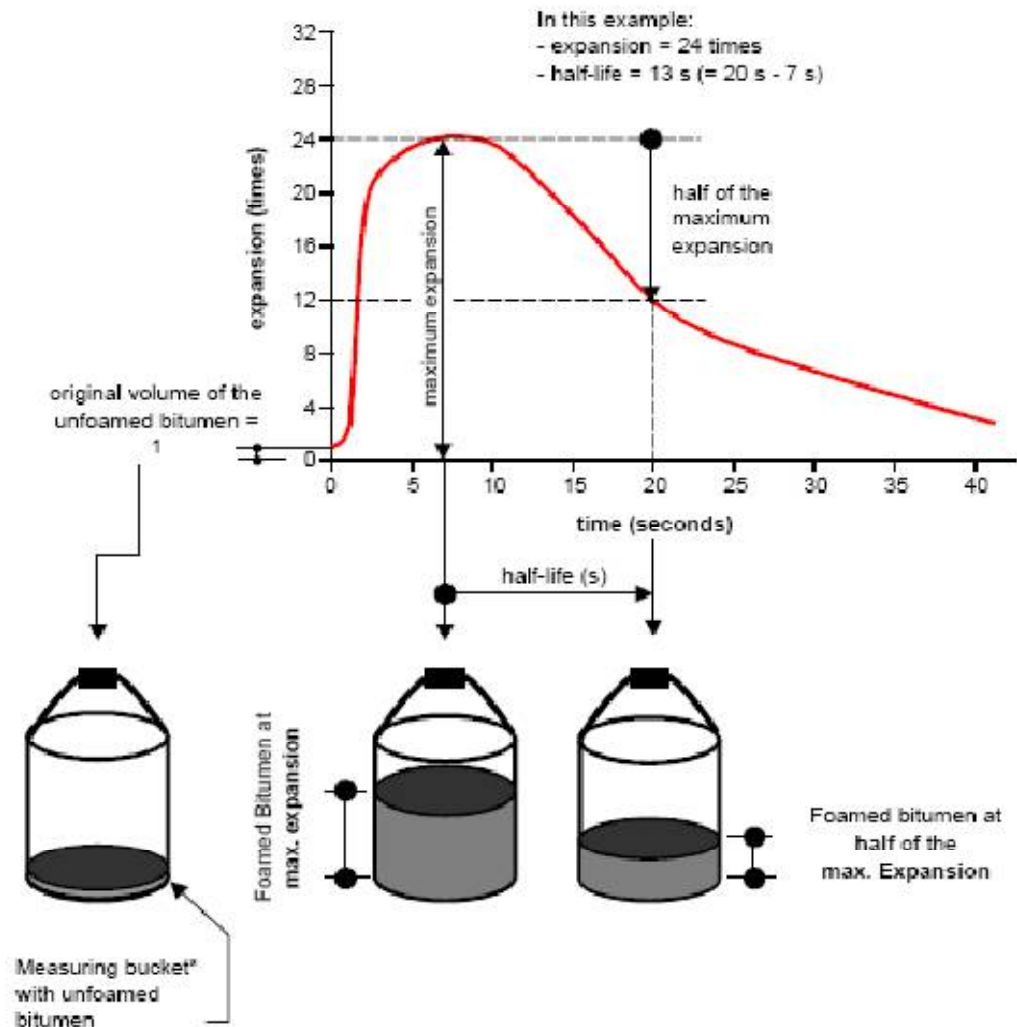
Foamed Bitumen Characteristics

Expansion Ratio

- Maximum volume of foam relative to the original volume of bitumen
- A measure of the viscosity of the foam
- Indicates how the bitumen will disperse

Half-life

- Time (seconds) for the foam to collapse to half of its maximum volume
- Measure of the stability of the foam

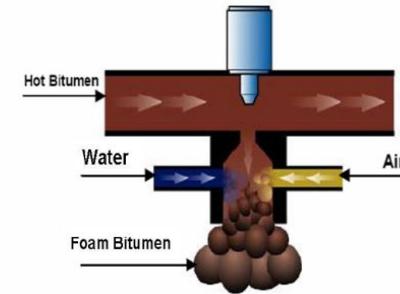


Foam Bitumen Mix (FBM) or Bitumen Stabilized Material (BSM)

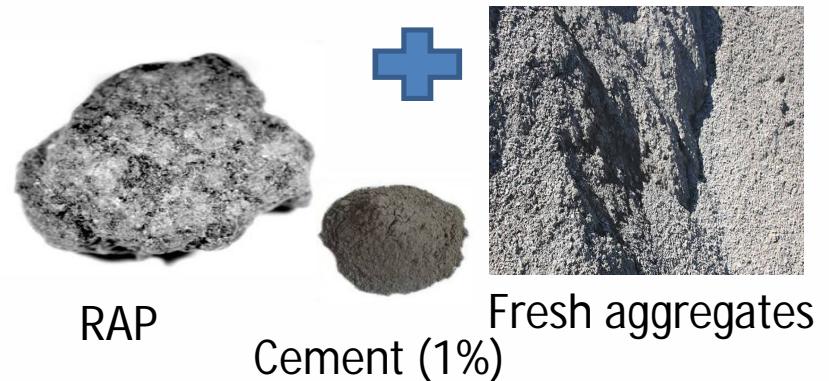
Foamed bitumen - ~ 180 °C

RAP + fresh aggregates - room temperature

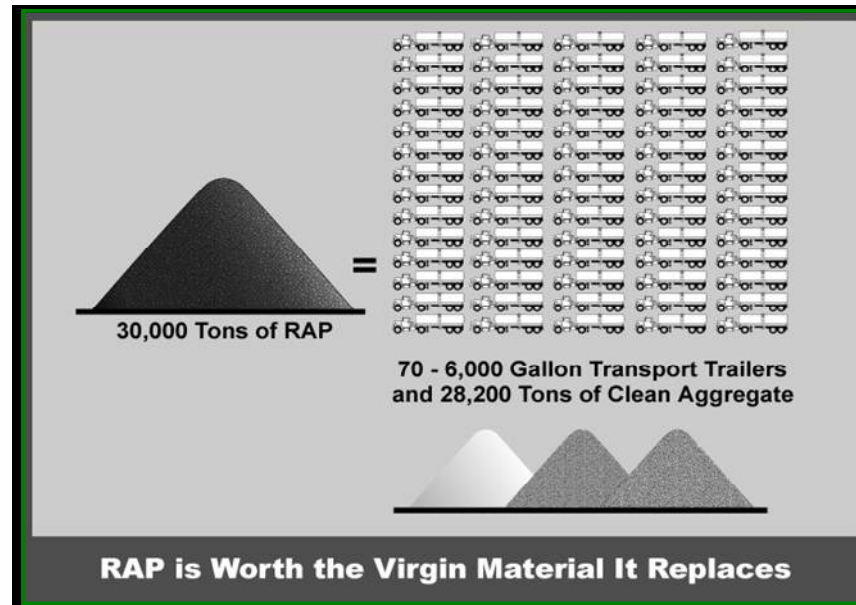
Finer aggregates **"spot -welds"** the coarser aggregates



Foamed bitumen



Why Recycling with Foamed Bitumen ??



- Reduces amount of virgin aggregates & bitumen which reduces material costs along with material transportation costs
- Reduction in energy requirements to heat virgin aggregates
- Time saving and rapid strength gain compared to other cold in situ recycling

Leading to Greener Road Construction Approach.....

Existing Foam Mix Guidelines

- **TG-2 (2009)**
- **Wirtgen (2012)**
- **Austrroads Guide Part 4D, 2006**
- **IRC 120 (2015)**

Foaming of bitumen is to be done at 170 to 200°C with 60 to 150 penetration grade of bitumen.

Objective of study

- To produce foam with lower and higher viscosity grade bitumen and to compare the foam characteristics in terms of half life and expansion ratio with respect to binder grade.
- Also to evaluate different viscosity grade bitumen in terms of performance of mix i.e indirect tensile strength and moisture resistance of foamed bituminous mixes using 80% RAP material

Experimental Plan

- **Stage I:** Preparation of low viscosity and characterization of bitumens
- **Stage II:** Assessment of the foaming properties
- **Stage III:** Mixture Design and Performance of foam asphalt mixes (FAM) using 80% of RAP.

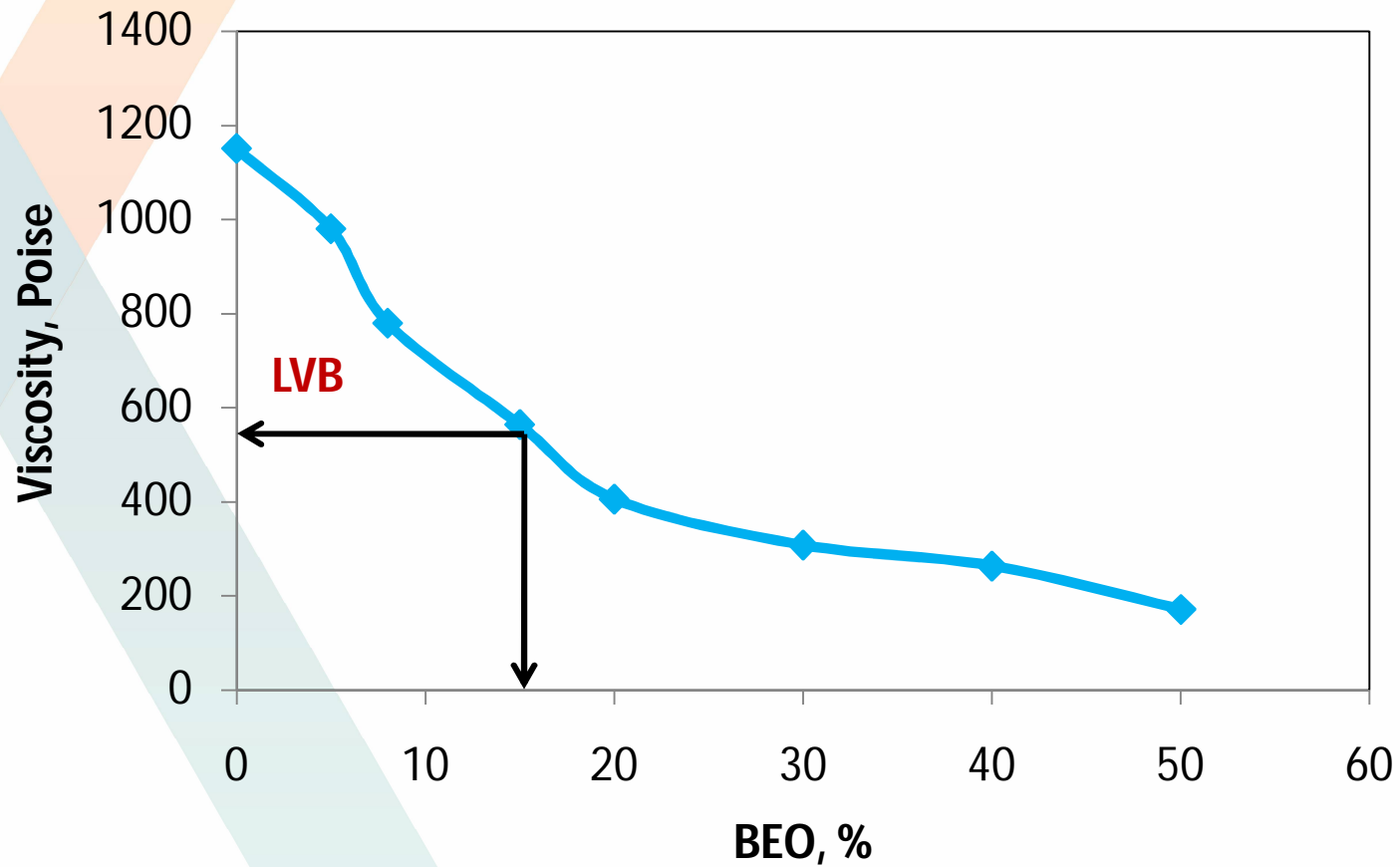
Preparation of Low Grade Viscosity Bitumen

- Different quantity of (by weight of bitumen) of BEO was added to base binder (i.e. VG 10) maintained at 150°C.
- This blending was done using low shear stirrer for 20 minutes.
- The resultant blends were covered with aluminium foil and stored at room temperature for further work.

Properties	Value
Density, kg/m ³	0.98
Kinematic Viscosity at 100°C, cSt	92.80
Flash Point, °C	242.0
Asphaltene content, % wt	0.62
Aromaticity, (by NMR)	0.40

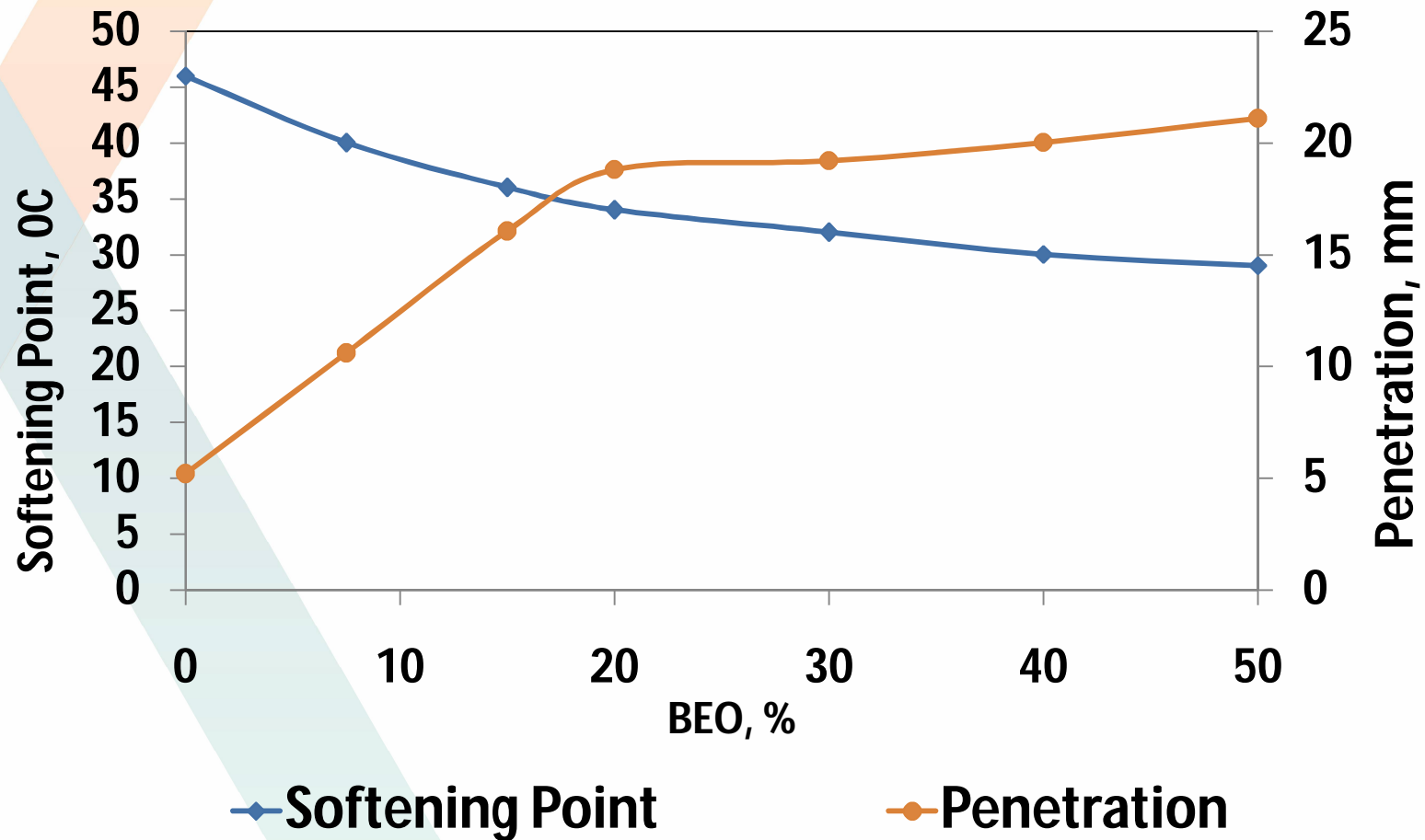


Effect of BEO Dose on Viscosity of VG 10



BEO – Bitumen Extract Oil

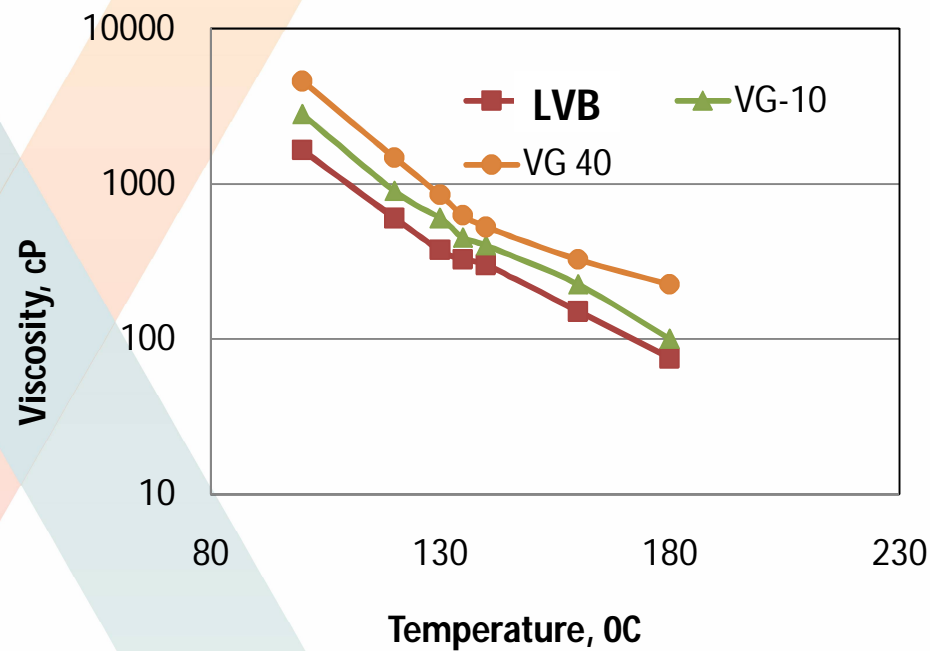
Effect of BEO Dose on Softening Point and Penetration of VG 10



Properties of bitumen

Bitumen	LVB	VG 10	VG 40
Temperature of 1.01 kPa $G^*/\sin\delta$ of unaged bitumen, °C	60.2	68.2	76.8
Temperature of 2.2 kPa $G^*/\sin\delta$ of RTFOT residue, °C	64	73.5	81.2
Softening Point (°C)	42.6	42	53
Penetration at 25°C, dmm	160	80	50
Viscosity at 60°C (Poise)	564	1150	4400
Viscosity at 135°C, cSt	325	500	625
BBR, Temperature in (°C) at 60sec (SHRP B-002 S)	-20	-18	-14

Viscosity Temperature Relationship



Viscosity of the binders were measured at various temperatures ranging from 100°C to 180°C as per ASTM D 4402 at 20RPM.



Brookfield Viscometer

Foaming Procedure

Bitumen foaming was undertaken in WLB-10S laboratory plant to determine the foaming characteristics according to the following test operational conditions:

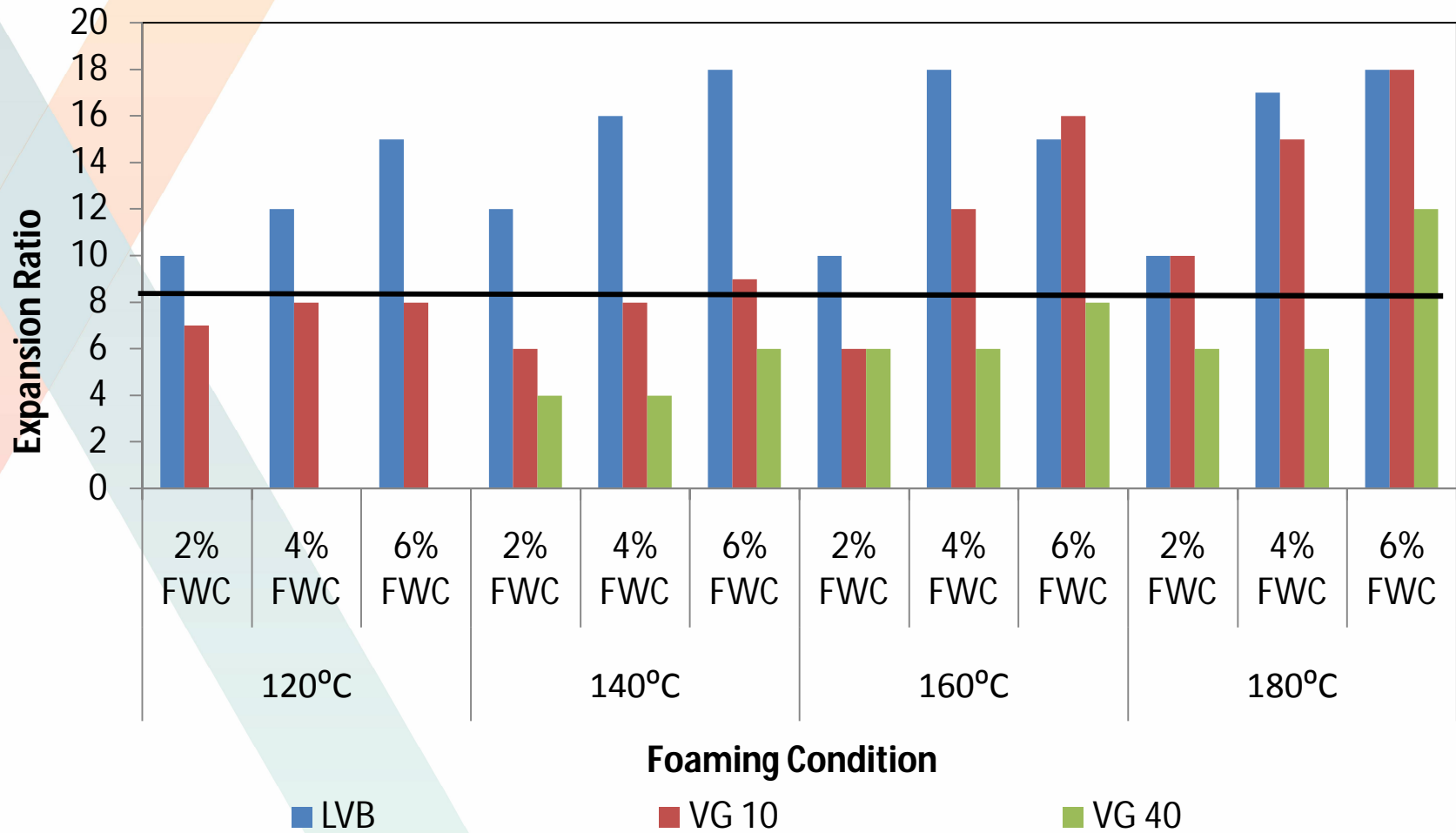
Air pressure: **550 kPa**;

Water pressure: **600 kPa**;

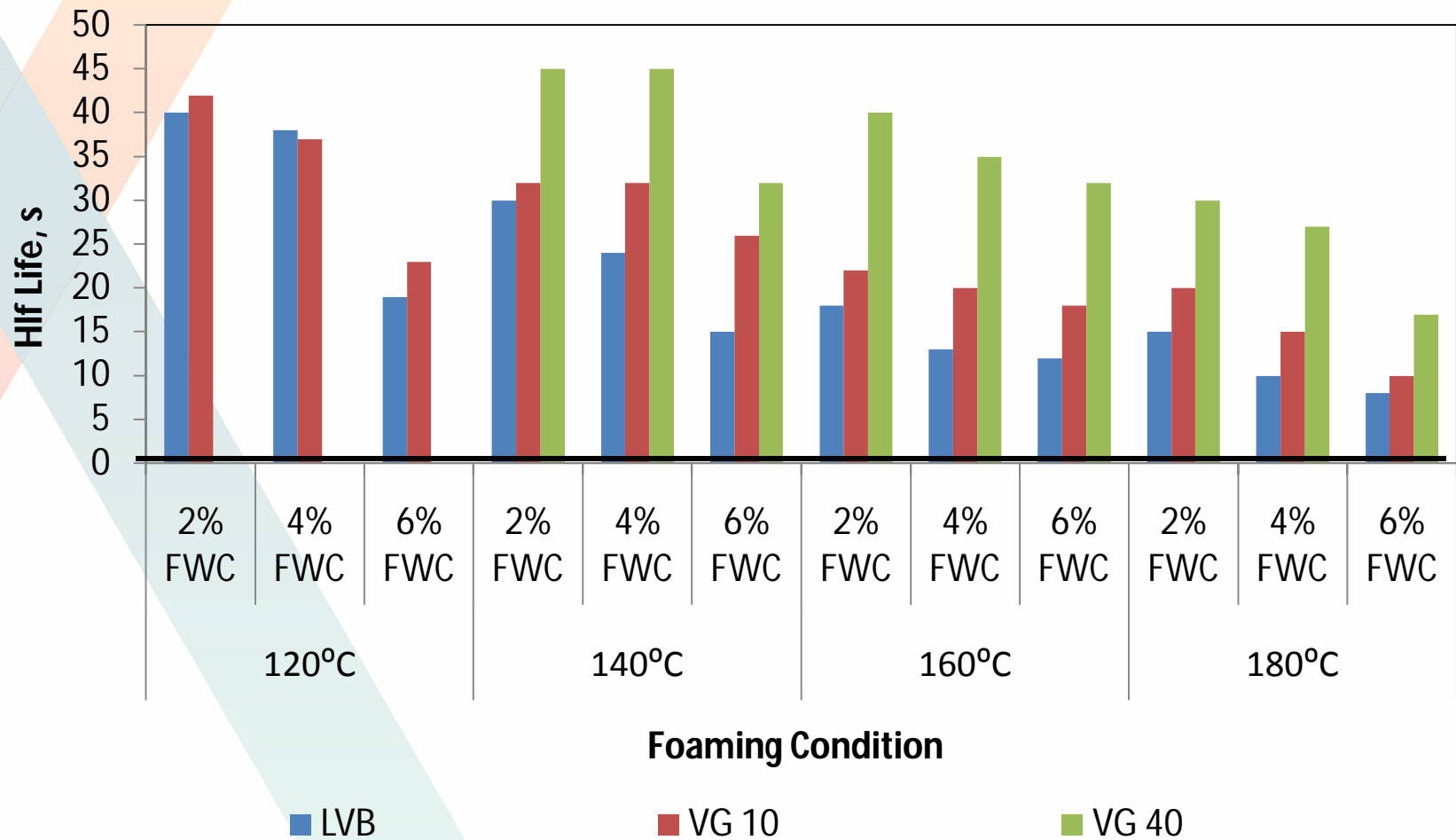
Amount of bitumen being foamed during each test: **500 g at a rate of 50 g/s.**



Variation of ER with respect to FWC and Bitumen Temperature



Variation of HL with respect to FWC and Bitumen Temperature



Optimum Foaming Characteristics

- As temperature of binder higher, less water is required to obtain acceptable expansion ratio.
- With increasing the water content, ER increases and HL decreases.
- With increasing the binder temperature, HL increases and ER decreases
- Expansion Ratio is more for lower grade binder compared to harder grade binder irrespective of temperature of binder and water content.
- Half life is more for higher grade binder compared to lower grade, i.e low viscosity binder.

Binder	Temperature (°C)	Water content, (%)	ER	HL
LVB	120	6	15	22
VG 10	160	4	13	14
VG 40	180	6	13	20

Evaluation of RAP

Determination of bitumen content (ASTM D-6307) – 3.61%

Gradation of the recovered aggregates

Recovery of binder by using distillation followed by Absorbance recovery (ASTM D 2172 and D 1856)

Property	Test Method	Test Results
Penetration 25°C, 100g, 5s 0.1mm	IS 1203	37
Softening point (R & B), °C	IS1205	61.2
Viscosity, at 60°C, Poises	ASTM D4402	4802
Viscosity, at 135°C, Poises	ASTM D4402	875



Aggregates and Recovered Aggregate Testing

Property	Test Results		MoRTH, 2012 Specifications
	Virgin Aggregate	Recovered Aggregate	
Aggregate Impact Value	20.6 %	27.5%	30% max
Combined Index (EI + FI)	21.2 %	25.7%	30% max
Water Absorption	0.7 %	*	2% max
Specific Gravity	2.66	*	-
Stripping	98 % Retained Coating	95%	≥ 95 % Retained Coating

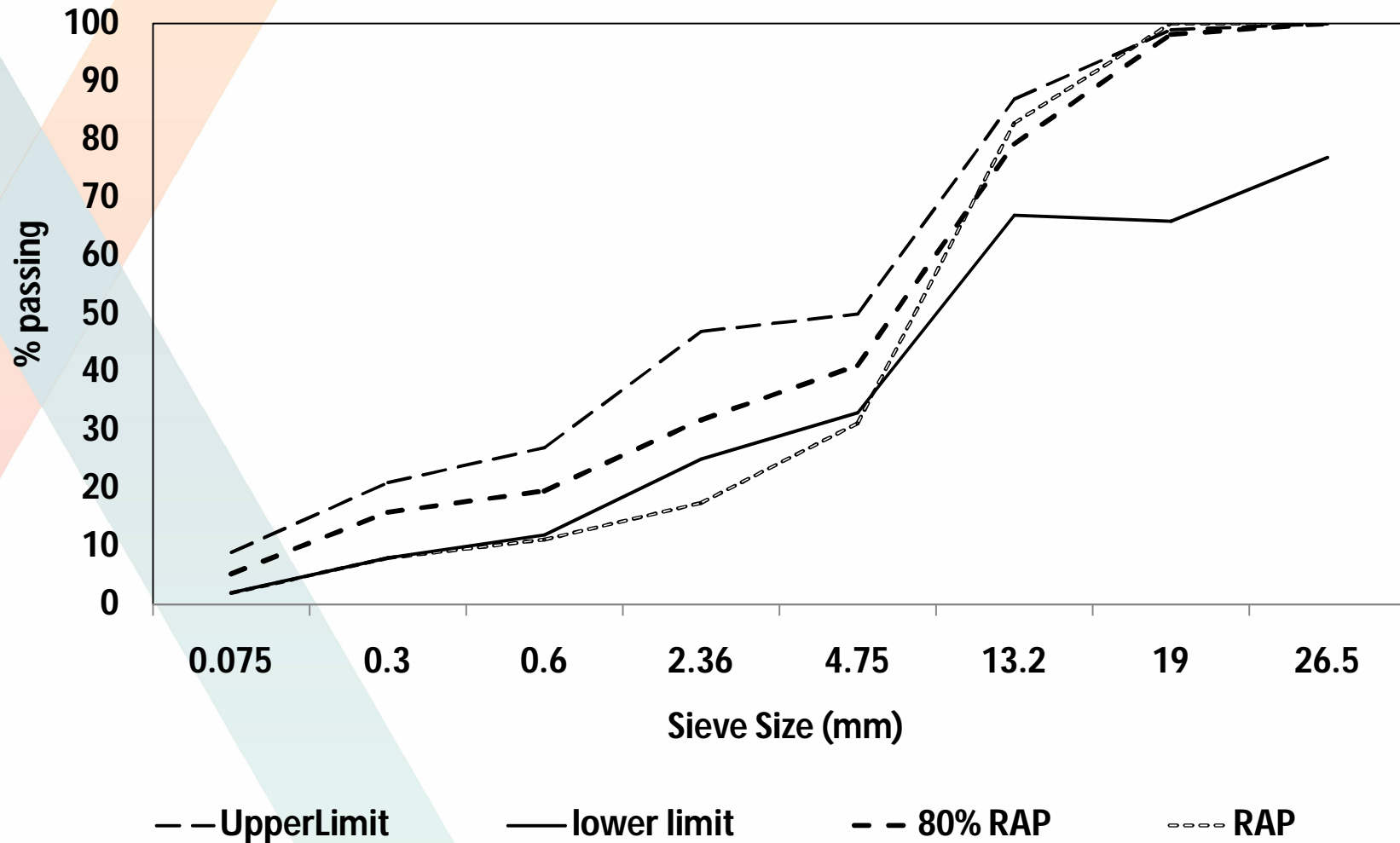
Mix Design: Preparation of Foam Mix

- **Gradation of Mix:** IRC 37
- **Optimum Moisture Content:** Maximum dry density
- **Optimum Foaming Condition:** Water Content and Bitumen temperature
- **Sample Mix and Compaction:** Marshall Samples with 75 blows in each face
- **Curing of samples:** 40°C for 72hrs
- **Dry Indirect tensile Strength:** Minimum 225kPa
- **Wet Indirect Tensile Strength:** Minimum 100kPa

Gradation of Mix (IRC 37:2012)

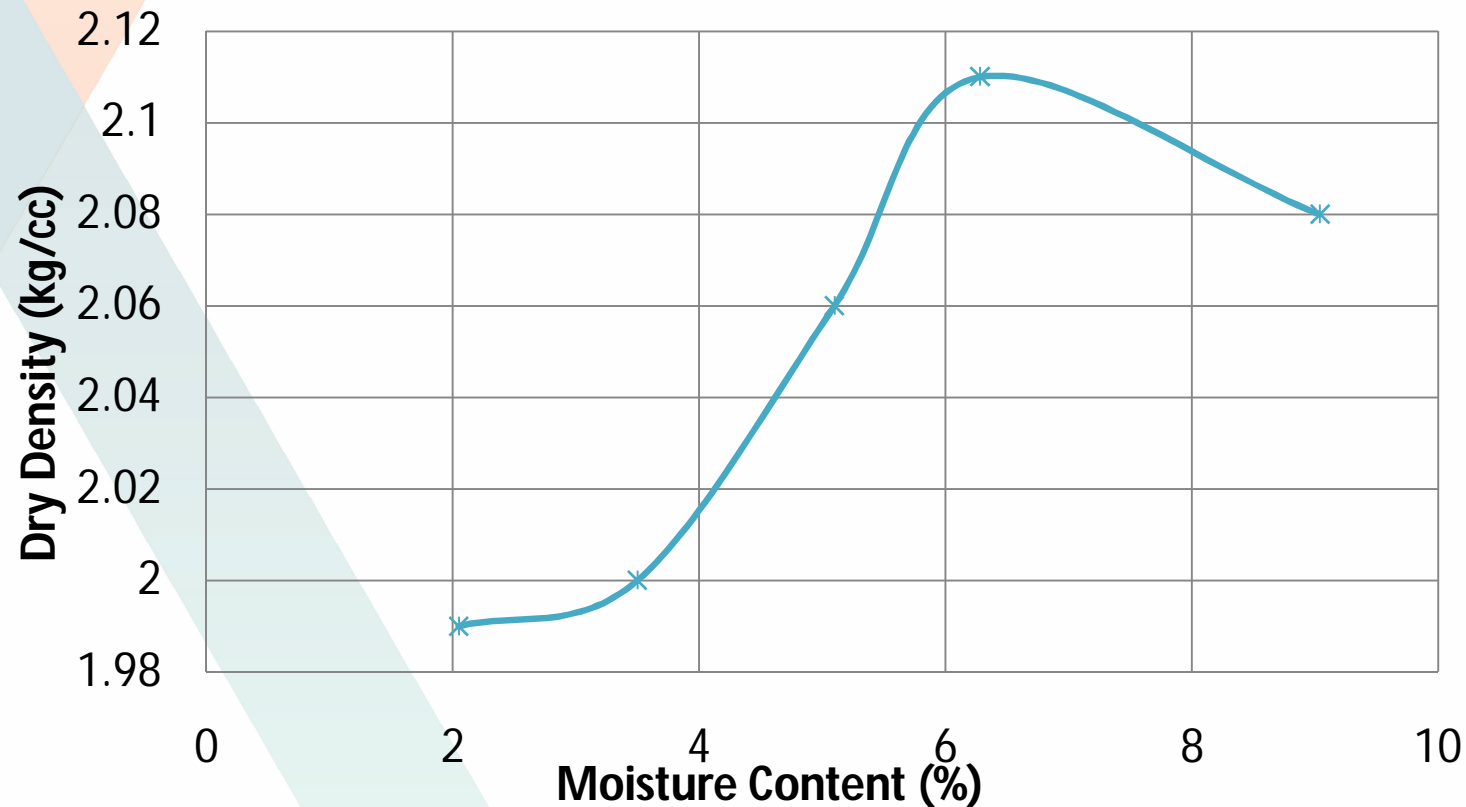
Sieve Size, mm	Percent Passing	RAP Gradation
45	100	100
37.5	87-100	100
26.6	77-100	100
19	66-99	100
13.2	67-87	82.88
4.74	33-50	31.16
2.36	25-47	17.47
0.60	12-27	11.16
0.3	8-21	7.54
0.075	2-9	2.25

Specified Gradation for blended aggregate



Dry density- Fluid Content Relation for Blended RAP Mix

Optimum Moisture Content (OMC) of the untreated blended materials was determined using the moisture-density relationships according to AASHTO T180 (2010).



Optimization of Foam Mix

- Dry Indirect Tensile Test
- Wet Indirect Tensile Strength

Input Parameter

- Foamed Bitumen (1.8, 2.0 and 2.2%)
- RAP Content (80%)
- Bitumen Type (LVB, VG 10 and VG 40)

Indirect Tensile Strength Testing Method



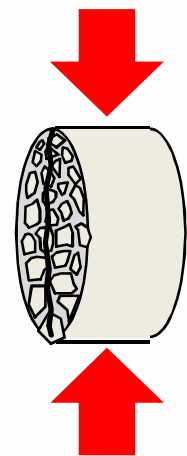
The tensile properties of FBM were evaluated using Indirect Tensile Strength (ITS) as per **ASTM: D6931-12** specifications.

$$\sigma_t = \frac{2P}{\pi Dt}$$

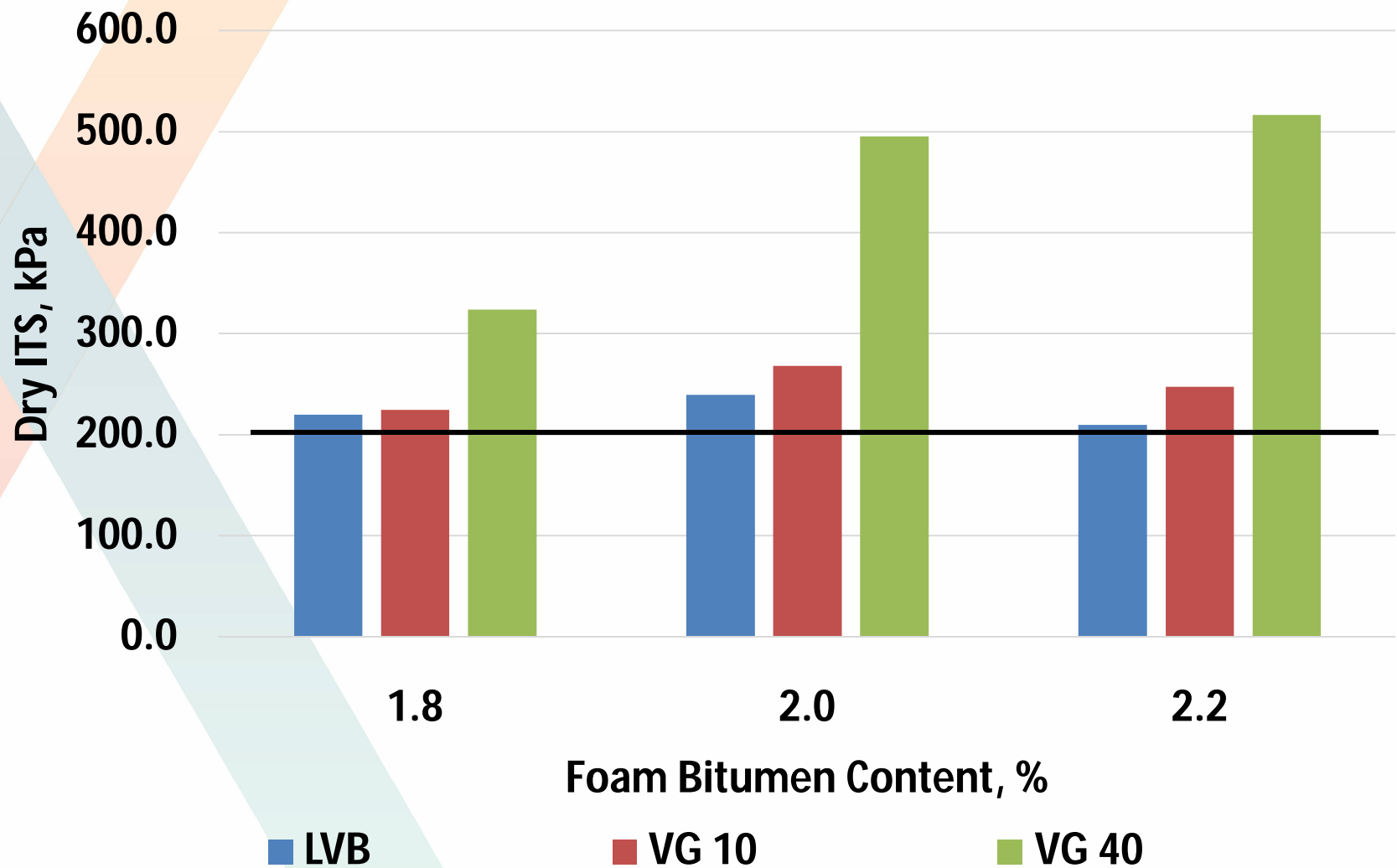
where, P =maximum load,

D = diameter of the specimen,

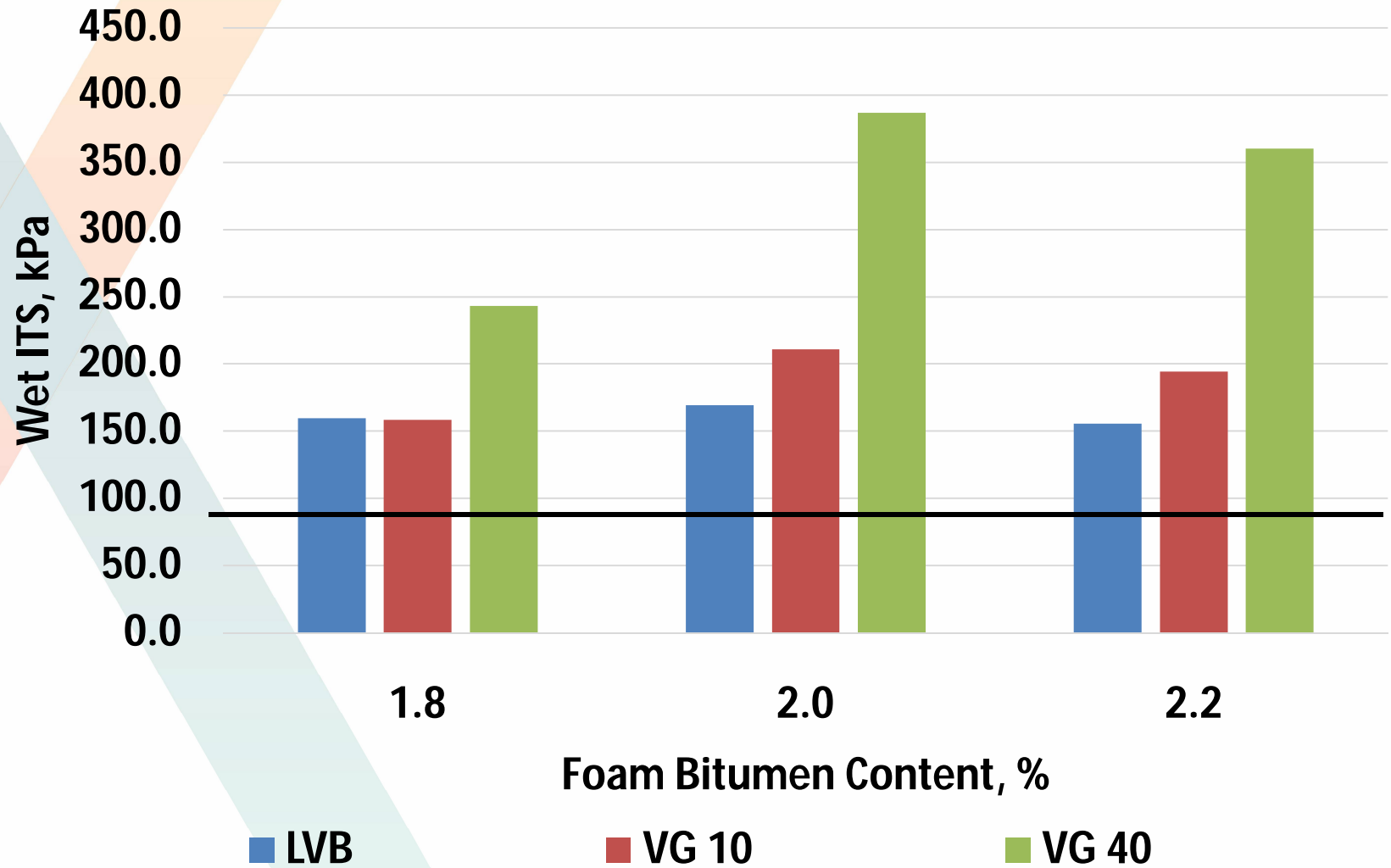
t = thickness of the specimen.



Dry Indirect Tensile Strength



Wet Indirect Tensile Strength



Conclusion

- With increase in temperature, less water is required to obtain acceptable expansion ratio. With increasing the water content, ER increases and HL decreases. With increasing the binder temperature, HL increases and ER decreases.
- Expansion Ratio is more for lower grade binder compared to harder grade binder irrespective of temperature of binder and water content. Half life is more for higher grade binder compared to lower grade, i.e low viscosity binder.
- It was found that the low viscosity grade bitumen consumes low energy during foaming process compared to high viscosity bitumen.
- LVB can be produced at 40⁰C lower temperature and which leads to huge saving in energy consumption and greenhouse gases emissions.

Conclusion

- LVB with higher percentage of RAP material about 80% by weight of total aggregate showed acceptable dry and wet ITS results due to presence of harder grade bitumen in RAP material indicating its usability.
- For a particular foam bitumen content and RAP material content, higher ITS was observed with mixtures prepared with higher viscosity grade binder. This can be attributed to the higher stiffness provided by binder.



THANK YOU