New Technology Initiatives in Rural Roads and Use of Marginal Materials

Utilization of waste plastic in Low volume Roads

National Rural Infrastructure Development Agency

Ministry of Rural Development

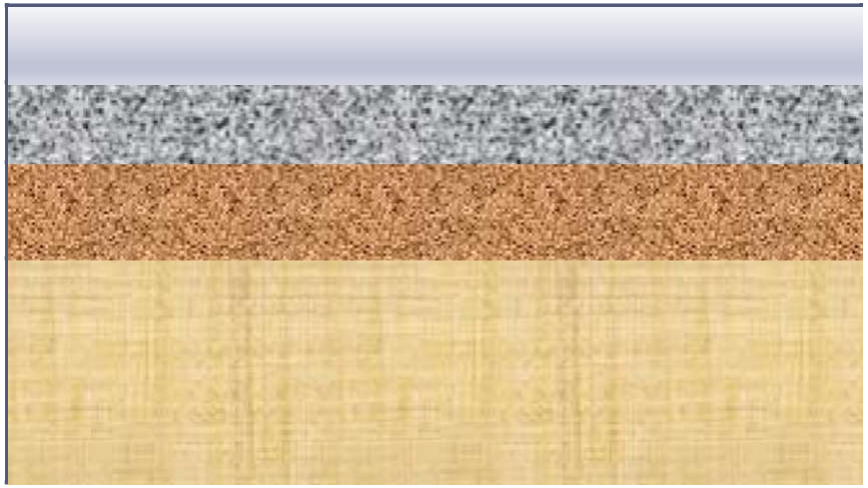
National Institute of Technology

Warangal, Hyderabad

Lecture 3

Utilization of waste plastic in Low volume Roads

Typical bituminous pavement composition



High Volume flexible road cross section

Low Volume flexible road cross section

Major distresses found in Bituminous pavements

Rutting

Cracking

What distress are the mixes expected to withstand ?

- Bituminous mixes should be designed to withstand heavy traffic loading under adverse climatic conditions and provide adequate structural and functional character to pavement
  - Rutting
  - Cracking (bottom up cracking (BUC) and Top down cracking (TDC)
  - Moisture damage
  - Low temperature cracking

Modified binders

- Advantages of modified binders
  - Lower susceptibility to temperature variations
  - Higher resistance to deformation at high pavement temperature
  - Delay of cracking and reflective cracking
  - Better age resistance properties
  - Better adhesion between aggregates and binder
  - Higher fatigue life of mixes
  - Overall improved performance

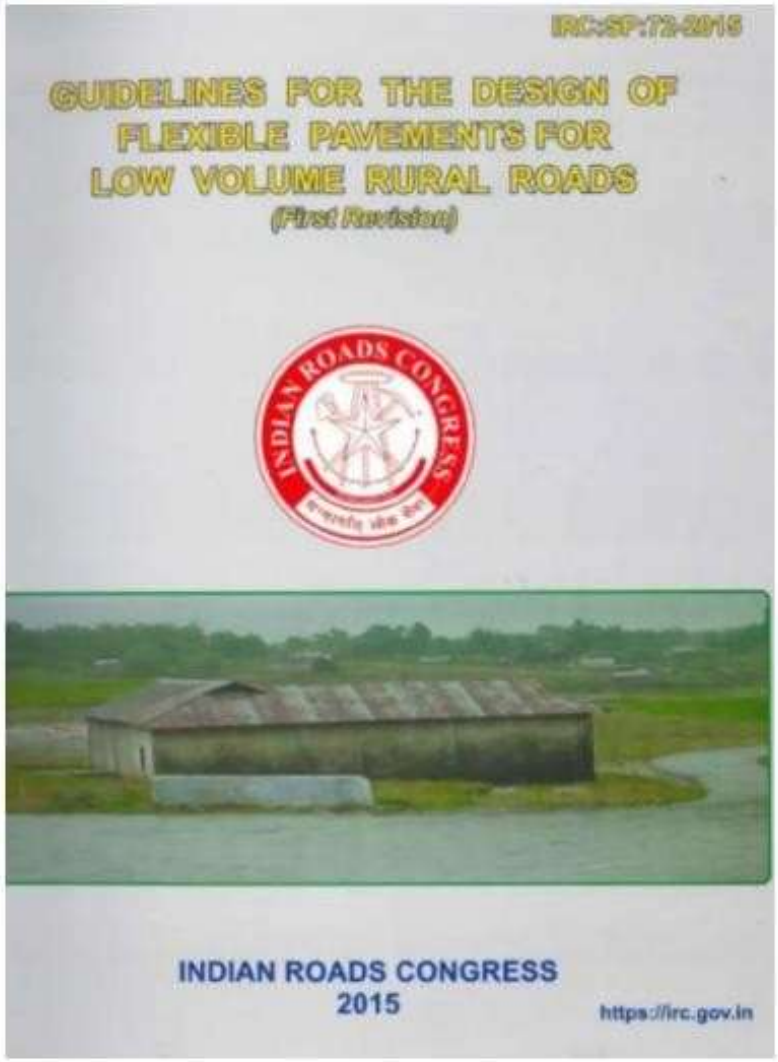
Modified binders

- Modified binders is obtained with the incorporation of selected thermoplastic polymers (plastomeric or elastomeric), crumb rubber or natural rubber in bitumen
  - Compatible with bitumen
  - Resist degradation at mixing temperature
  - Capable of being processed by conventional mixing and laying machineries
  - Provide coating viscosity at application temperature
  - Maintain premium properties during storage, application and in service
  - Capable of providing homogeneous blend with bitumen

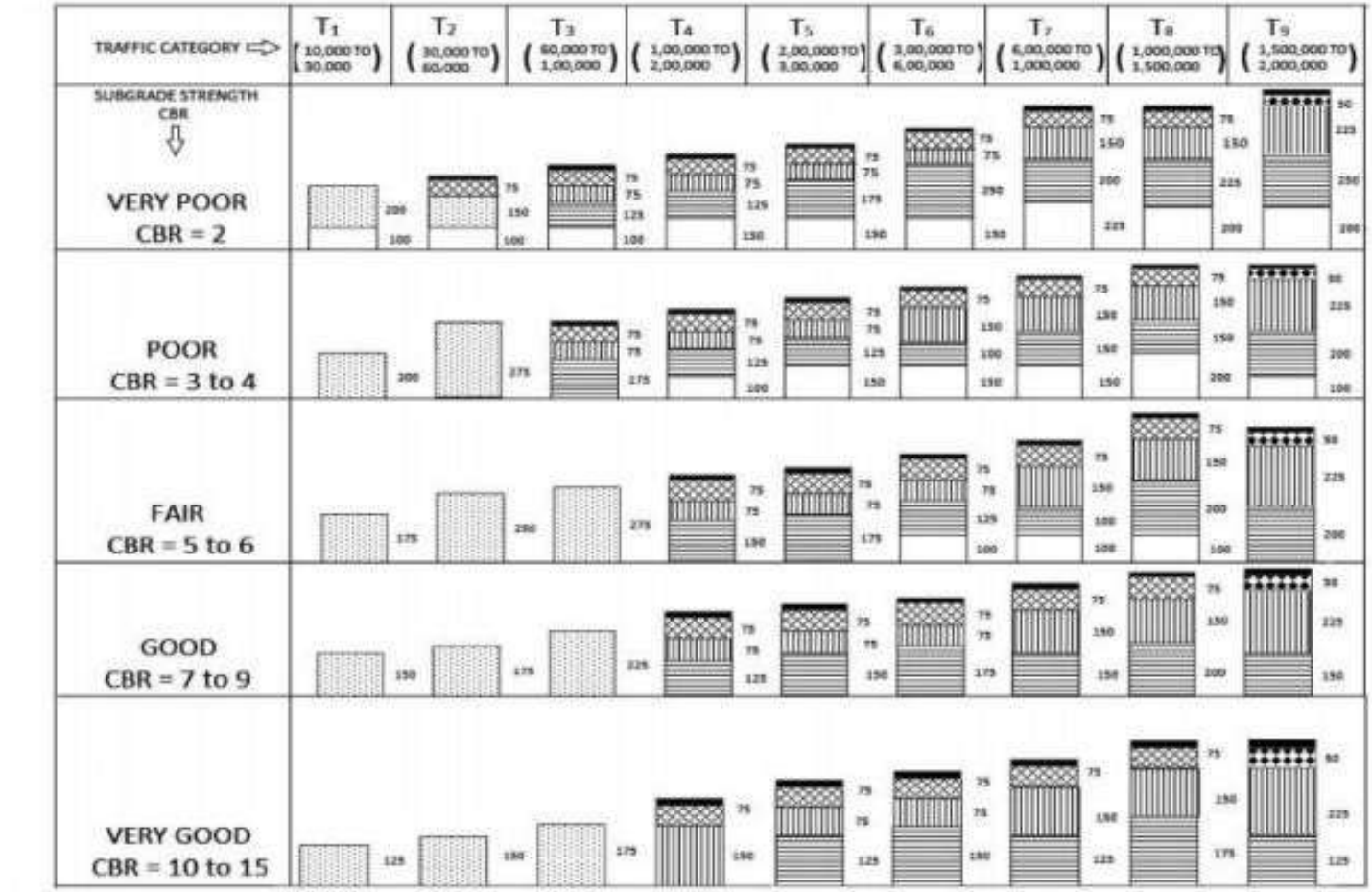
Types of Modifiers	Examples
Plastomeric Thermoplastics	Polyethylene (PE), Ethylene Vinyl Acetate (EVA), Ethylene Butyl Acrylate (EBA), Ethylene-Methyl-Acrylate copolymers (EMA) etc.
Elastomeric Thermoplastics	Styrene Isoprene Styrene (SIS), Styrene-Butadiene-Styrene (SBS) block copolymer, Styrene-Butadiene Rubber , and Ethylene Ter Polymer (ETP) etc.
Synthetic Rubber Latex	Styrene Butadiene Rubber (SBR) latex and any other suitable synthetic rubber
Natural Rubber	Latex or Rubber Powder
Crumb Rubber or Treated Crumb Rubber	Crumb Rubber, Treated Crumb Rubber

Bituminous surfaced roads of rural India

IRC SP 72-2015



Design Catalogue



Bituminous Mixes used in low volume rural roads in India

- Premix carpet + Seal coat surface
- Bituminous Macadam
- Bituminous concrete (BC-2) *(States like Telangana – PMGSY projects , Kerala – RKI projects)*

- Open graded gradations
- Thin surface courses intended to waterproof the structural base course

- The longevity of the bituminous mix depends on
  - Placement of correct choice of the mix for the project place
  - Appropriate selection of Binder type based on traffic loading and climatic consideration
  - Construction efficiency

In the case of LVR, the bituminous surface which is intended to prevent the intrusion of moisture is the most costliest layer !!!

Hence it is necessary to look for alternatives which can reduce the bitumen consumption, at the same time, a technology which can improve the longevity of pavements

What are the choices available to increase the longevity and reduce cost ?

- Preferring a dense graded layer with appropriate aggregate gradation
- Using additives/modifiers which can increase the longevity of the pavement
- Looking for additives which can reduce the bitumen consumption in mixes

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This is where the utilization of waste plastics in bituminous road construction comes in…

Waste plastic disposal issue

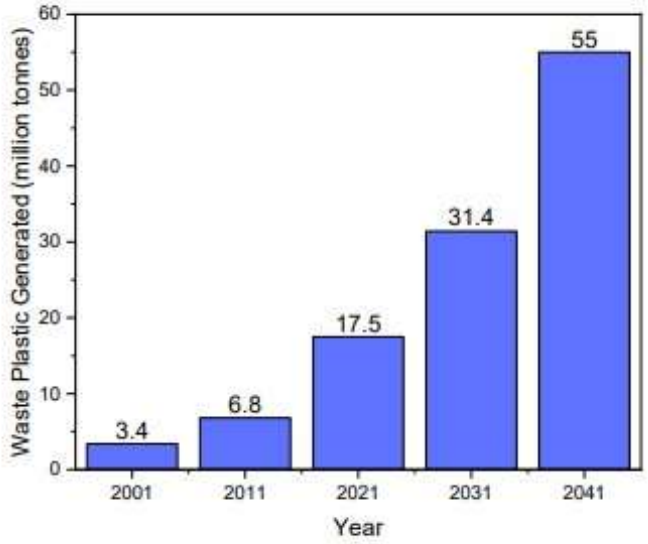
Waste plastic disposal issue

- Nearly 40% of plastic waste generated in India is uncollected Article given in The Hindu (30-August-2019,PTI, India)

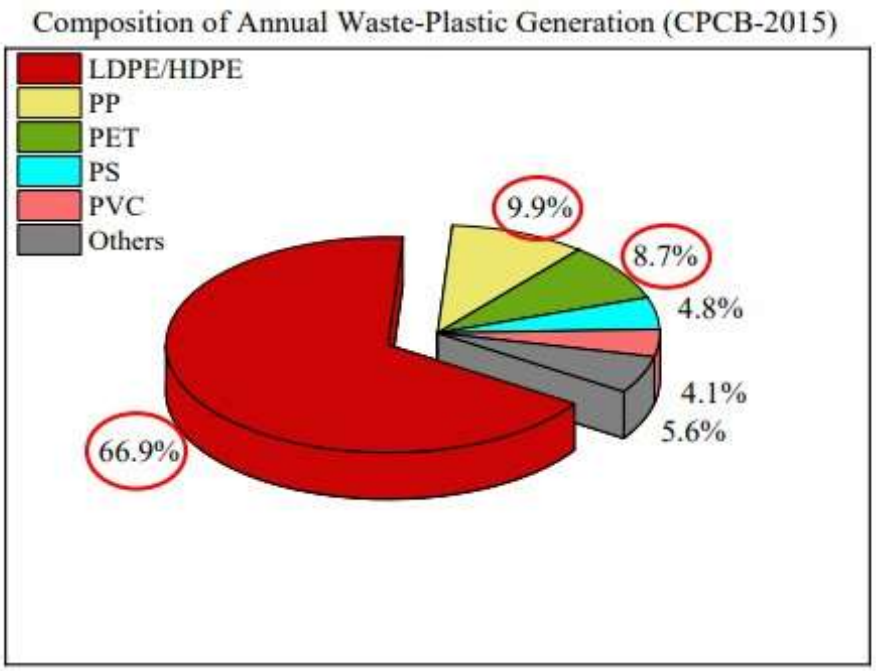
Out of the total waste plastics generated between 1950-2015

- Only 9% is recycled
- 79% ends up in landfills and in our water bodies

Composition of Waste Plastic generation



https://www.statista.com/statistics/1009095/india-plastic-waste-generation/



Composition of Annual Waste-Plastic Generation (CPCB-2015)

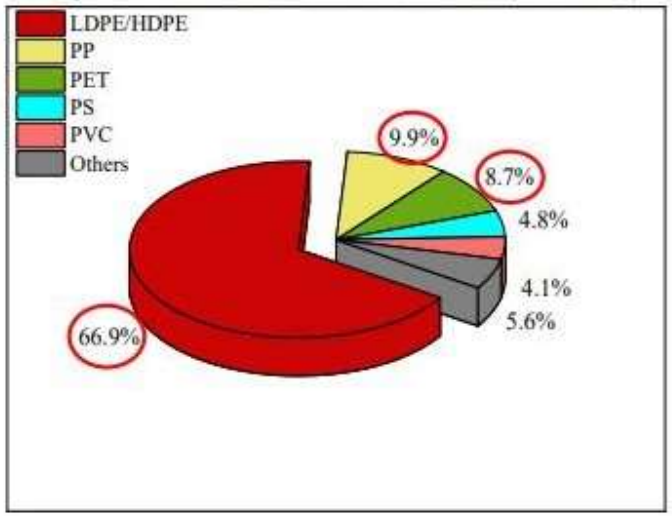


Table 1: Types of Plastics and Applications

Recycle Number	Polymer Type	Application Products
1 PETE	**PET**- Polyethylene Terephthalate	Water bottles, Salad trays.
2 HDPE	**HDPE**- High Density Polyethylene	Milk bottles, Shampoo bottles.
3 V	**PVC**- Polyvinyl Chloride	Pipes, fittings, toys and credit card. Thermal insulation, automotive parts.
4 LDPE	**LDPE**- Low Density Polyethylene	Carry bags, Bin liners and Packaging films.
5 PP	**PP**- Polypropylene	Microwave trays, fibers and ropes and vehicle upholstery.
6 PS	**PS**- Polystyrene	Plastic cutlery, protective packaging material.
7 OTHER	Others	Polycarbonate -Car Windows, glazing for the aircraft, Polyamides – cloths, tooth brushes.

RPW	Recycle label	Melting point (°C)	Blending temp. (°C)
PET	1	250	–
HDPE	2	132	180
PVC	3	298	–
LDPE	4	110	160
PP	5	162	190
PS	6	>300	–

Source: Dalhat et al. 2015

Suitability of waste plastic for road construction

- The bitumen is a thermoplastic materials which means bitumen becomes soft when it is heated and becomes hard when it is cooled.
- Hence, the plastic which are thermoplastic in nature are preferred.
- The following plastics can be preferred for constructing the plastic roads
  - LDPE/HDPE/PP/PET/PVC/PS/ABS
- In order to incorporate the recycled plastic, two methods have been adopting.
  - *Wet Method or Bitumen Modification*
  - *Dry method or Aggregate Modification*
- Due to high melting points of some plastics (PET), they are preferred in only dry method. Because these plastics need to be heated to high temperatures (>180°C) which results in emission of toxic compounds and at lower temperatures these are not providing good compatibility with bitumen.

Wet Method	Dry Method
LDPE	***PET***
HDPE	*LDPE*
PP	*HDPE*
PVA	*PP*
ABS	*PVA*
PS	*ABS*

IRC SP 98: 2013

- Indian Road Congress guideline IRC SP 98:2013
- Utilization of waste plastic through dry process

Table 3 Requirements for Waste Plastic Modified Dense Graded Bituminous Pavement Layers

Minimum stability (kN at 60°C)	12.0
Minimum flow (mm)	2
Maximum flow (mm)	4
Marshall Quotient (kN/mm)	2.5-5
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Per cent air voids	3 – 5
Retained Stability (%)	98
ITS (min) MPa	0.9
VMA	16
VFB	65-75
Quantity of Waste Plastic % by weight of bitumen	6 to 8 depending on low rainfall or high rainfall areas

Shredding of Waste plastic

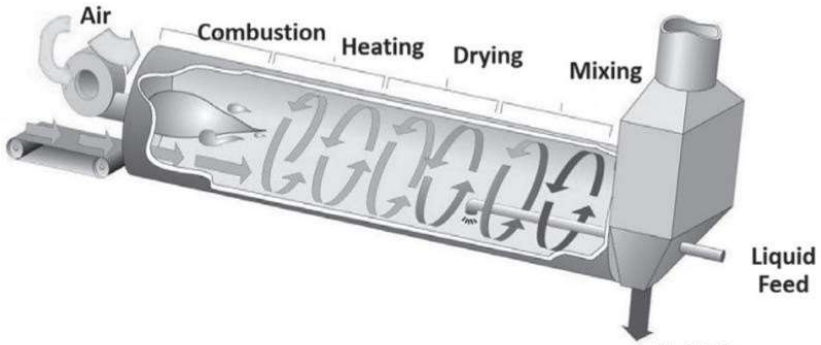
Addition of waste plastic in mini HMA plants

Coated Aggregate

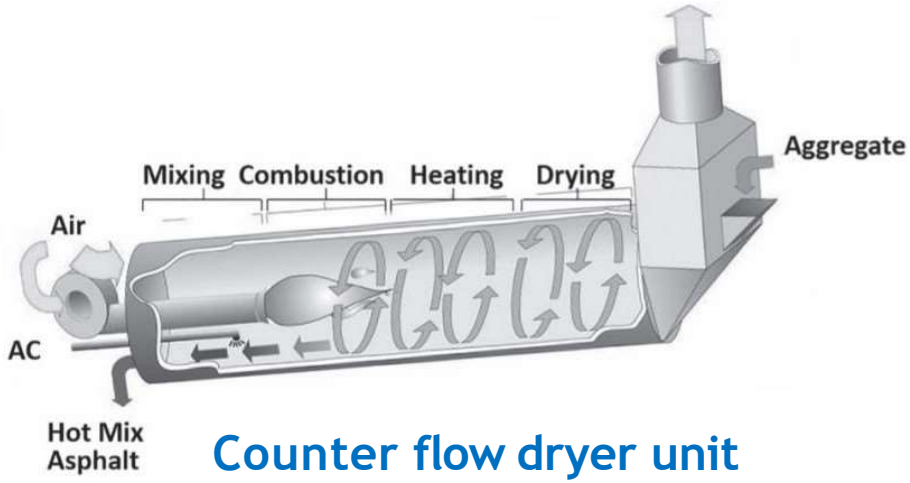
Plain Aggregate

An educational video for utilization of waste plastic in road construction

Aggregate dryer types



Parallel flow dryer unit



Counter flow dryer unit


22 PRADHAN MANTRI GRAM SADAK YOJANA (PMGSY)
WASTE PLASTIC
DISTRIBUTION
UNIT

Earlier research studies (carried out in Thiagarajar college of engineering)

Description	Unit	Percentage of polymer to the weight of aggregate			
		Plain	0.5 %	1 %	2 %
Wet weight of aggregate taken for test	Gram	1002	1004.10	1003	1007
Dry weight of aggregate	Gram	997	999.80	999	1004
Weight of water absorbed	Gram	5.00	4.30	4.00	3.00
Percentage of water absorption	**%**	**0.52**	**0.48**	**0.45**	**0.36**

- Marshall Stability values have also found to increase

S. No	Property	Plain Aggregate (%)				Polymer Coated Aggregate(Polymer is 10% of Bitumen) (%)				MORTH specification	Remarks
1	Stripping Value	2 hrs	24 hrs	72 hrs	96 hrs	2 hrs	24 hrs	72 hrs	96 hrs	Less than 5%	As specified
		0	0	2	5	0	0	0	0		

File photograph of waste plastic incorporated road in Madurai

Wet Process addition

Author	year	type of plastic	Shear Rate (rpm)	Blending Time	Blending Temperature	Bitumen Type
Yousefi	2000	HDPE (1% by binder weight)	Moderate or low	1h	160	150/200
Garcia	2003	EVA/LDPE (5 and 9%)	1200	6	180	60/70
Gonzalez	2003	Recycled EVA (1 and 3%)	1800	6	180	60/70
Sinan	2003	HDPE (4-6, 8% by binder weight)	200	30	145-155, 165 (mixing temp)	AC-20
Sinan	2005	HDPE (1,2,3,4% by binder weight)	3000	60	185	AC10
Imam	2008	HDPE (0.75, 1.5 and 3)	5min low speed stirring 1 hour high speed stirring	5 and 60minutes	160-170	60/70
Mahrez	2010	PET	High speed shear mixer	3minutes	130	80/100
Naskar	2010	Plastic bags (LDPE/HDPE) 1,3,5,7%	3500	45	180	VG-30 (60/70)
mishra	2018	LDPE	na		160	VG-30 (60/70)
Garcia	2005	EVA/ EVA and LDPE (5 to 9%)	1200	6	180	60/70
Punith	2007	LDPE (2.5 to 10%)	3500	20min	170	80/100
kumar	2011 (IIT Roorkee)	HDPE/LDPE/EVA (0.1 to 0.9% by binder weight)	1550	1h	170	60/70 and 80/100
Sevil	2014	PVC (1,3,5% by binder weight)	1300	1h	180	160/220
Nouali	2020	LDPE (0.5 to 1.5%)	1200	1h	170	50/70

CMR BITPLAST

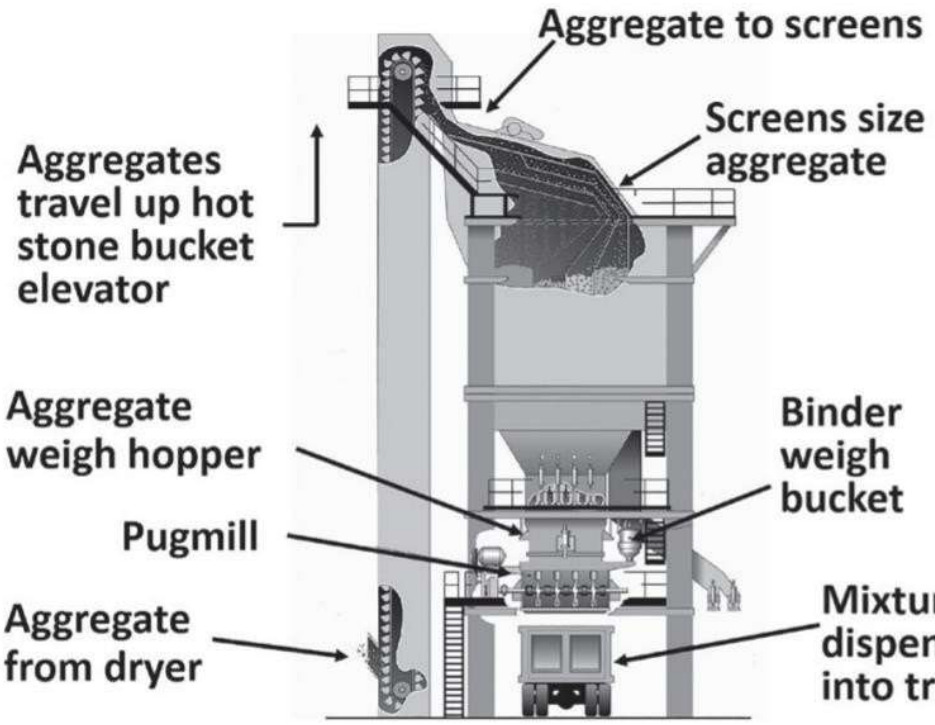
Wet Process - Waste Plastic Road

Filling & Despatching of CMR BITPLAST (Waste Plastic Impregnated Bitumen) to the Road site

Hurdles in using waste plastic in bituminous mixes

- In case of drum mixing, the contractors are hesitated to use the Recycled Plastic because of emission of fumes and pollution caused.
- Lack of adequate plant-setting is one of the hurdles for drum-mix plant setting.
- Separation of bitumen and plastic is the one of the hurdles for storing the Recycled Plastic Modified Bitumen (RPMB). To overcome that researchers suggested the dynamic storage technique for storing the RPMB as similar to the PMB. But, still the research has to be done and provide the specifications for the storing of RPMB to the contractors.
- Hence, the researchers need to work of different types of Recycled Plastics (LDPE/HDPE/PP/PET/PVA) with different dosages and different bitumens (VG10 to VG40) to specify the ranges of stirring speeds and temperatures.

Utilizing batch mix plant for dry process of waste plastic addition



Aggregates coated with Waste plastic in a batch mixing plant

Aggregates coated with Waste plastic in a batch mixing plant

Picture courtesy: L &T

R-85 Research scheme of MoRTH

- The detailed report of this research scheme is available on MoRTH official website Introduction - Need and Importance, Objectives, Scope (morth.nic.in)
- The project was titled as ‘ Investigation on field performance of bituminous mixes with modified binders’
- The field performance of pavements constructed 4 modified binder bituminous mixes were compared with that of mix prepared of unmodified VG30 binder

The modified binders studied were CRMB55, PMB 70, NRMB 70 and WPMB 70

Physical properties of the binders considered in the study

Properties	Binder Type				
	VG30	PMB70	CRMB55	NRMB70	WPMB70
Penetration at 25 °C 0.1mm, 100g, 5s	60 to70 (60 to 70)	50 to 60 (50 to 90)	30 to 40 (< 60)	50 to 60 (50 to 90)	30 to 40 (30 to 50)
Softening point (R&B), °C	46 (45-55)	60 (55 min)	56 (55 min)	50 (50 min)	62 (60 min)
Flash Point, °C	> 220 (175 min)	> 220 (220 min)	> 220 (220 min)	> 220 (220 min)	220 (220 min)
Ductility at 27 °C cm	80 (75 min)	100 +	57.7	78.5	34
Specific gravity, gm/cc	1 (0.99 min)	1.03	1.03	1	1.045
Elastic recovery at 15 °C (%)	71	77 (70 min)	68 (50 min)	55 (40 min)	23.67 (50 min)
Viscosity at 150 °C, (@ 135 °C for VG30), Poise	5.29 (3 min)	7.29 (2-6)	7.87 (2-6)	2.97 (2-6)	5.33 (3-9)
Separation, Difference in softening Point, °C	---	1 (3)	2 (3)	2 (3)	3 (3)
After subjecting to aging in thin film oven					
Loss in weight (%)	0.42 (1 max)	0.19 (1 max)	0.35 (1 max)	0.3 (1 max)	1.01 (1 max)
Reduction in penetration of residue at 25 °C (%)	18.23 (48 max)	12.72 (35 max)	28.57 (40 max)	11.67 (40 max)	26.67 (35 max)
Increase in softening Point, °C	4	2 (6 max)	4 (6 max)	3 (6 max)	7 (6 max)
Elastic recovery at 25 °C (%)	---	60 (50 min)	48 (35 min)	32 (25 min)	23 (35 min)

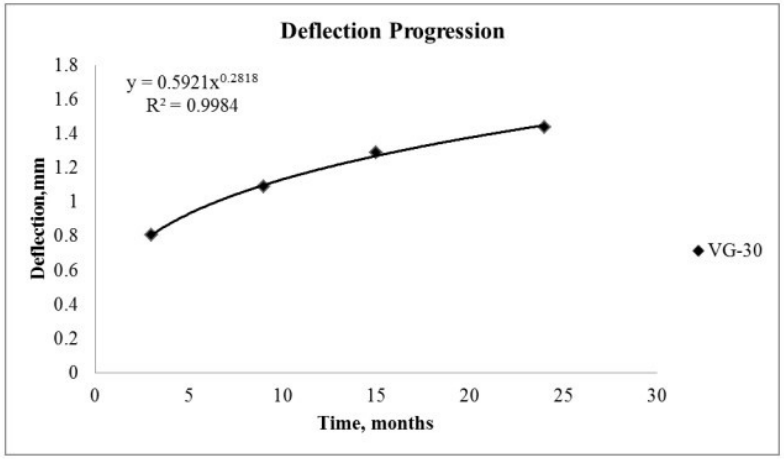
* Values in the parentheses show the specification requirements.

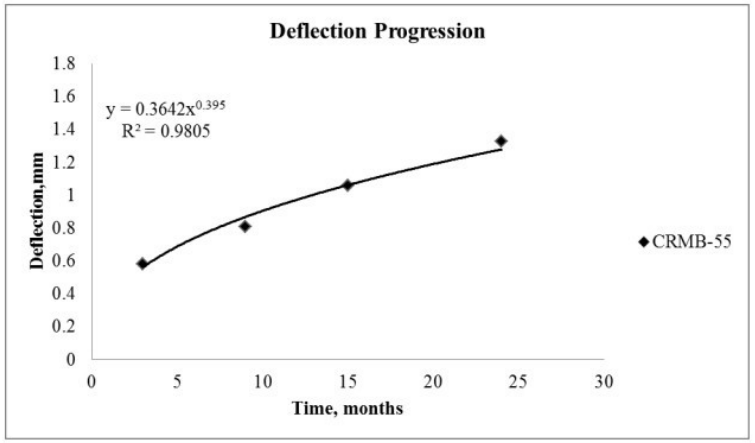
Source: R 85 final report of MoRTH 2013

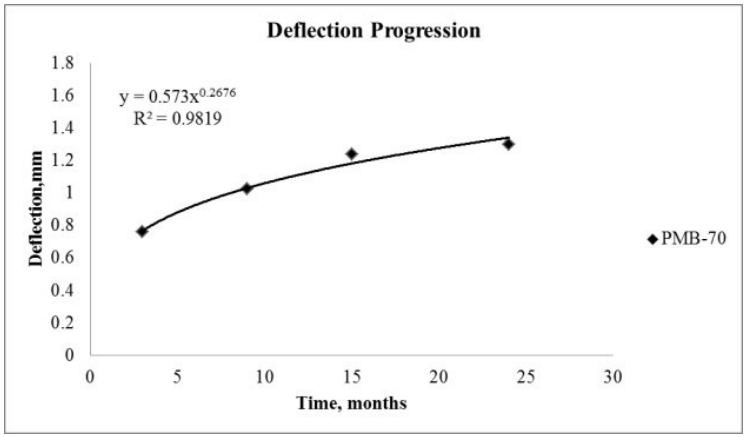
Pavement deflection studies conducted in R85 research scheme

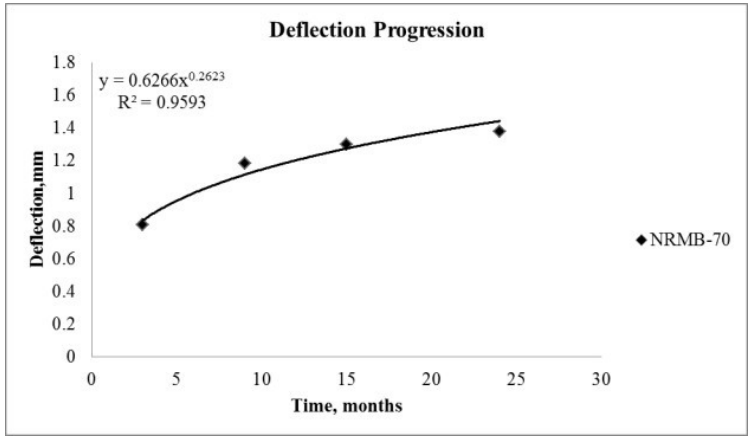
Pavement roughness studies conducted in R85 research scheme

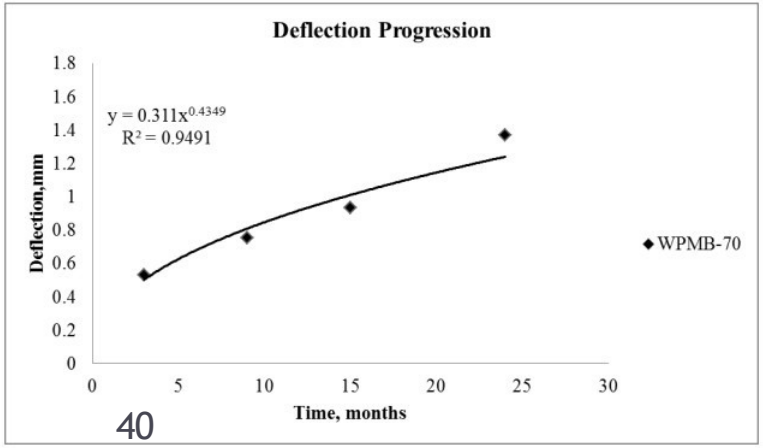
Axle load surveys conducted prior to test section construction


Deflection Progression
y = 0.5921x^0.2818
R² = 0.9984
Deflection,mm
Time, months
VG-30


Deflection Progression
y = 0.3642x^0.395
R² = 0.9805
Deflection,mm
Time, months
CRMB-55


Deflection Progression
y = 0.573x^0.2676
R² = 0.9819
Deflection,mm
Time, months
PMB-70


Deflection Progression
y = 0.6266x^0.2623
R² = 0.9593
Deflection,mm
Time, months
NRMB-70


Deflection Progression
y = 0.311x^0.4349
R² = 0.9491
Deflection,mm
Time, months
WPMB-70

Progression of Roughness

Research Scheme R-85 report

Chainage	Bitumen	Roughness, m/km		
		First cycle after construction	Second cycle after construction	Third cycle after construction
84 to 88	VG30	3.27	3.42	3.66
88 to 92	CRMB55	3.34	3.49	3.58
92 to 96	PMB70	2.91	3.04	3.25
96 to 100	NRMB70	3.08	3.20	3.47
100 to 104	WPMB70	3.30	3.37	3.45

GOVERNMENT OF INDIA
MINISTRY OF ROAD TRANSPORT & HIGHWAYS
AN ISO 9001:2008 CERTIFIED MINISTRY
SR&T(R) ZONE

IAHE Campus,
A-5, Sector-62,
Noida-201301.

F. No. RW/NH-33044/24/2015/S&R (R) Dated: the 27th December, 2016

Subject: Use of plastic waste in bituminous mixes in construction of National Highways

Madam/Sir,

As per Ministry's circular of even number dated 19th November, 2015 bituminous mixes with the waste plastic is the default mode for the periodic renewal with the hot mixes within 50 km periphery of urban area having population more than five lakhs. In addition to this, it has been decided that in each State/UT , bituminous mixes with the waste plastic may be used as per IRC:SP:98:2013 in at least a stretch 10 km as pilot project. In order to study the performance of the roads constructed with the use of waste plastic, CRRI/reputed engineering college(s) like IITs/NITs/Government Engineering colleges may also be engaged so that the efficiency of the system can be confirmed before making it mandatory in the contracts.

2. In view of the above, all the agencies are requested to take necessary steps for implementation of this circular and send the details of identified stretches to be constructed with waste plastic to Chief Engineer, Standard & Research (Roads). In future, the feedback on the performance of the stretches constructed with waste plastic as prepared by the above mentioned institutes may also be sent to Chief Engineer, Standard & Research (Roads) at every 6 months interval.

this all the agencies are requested to take necessary steps and action taken report may please be send within 15 days of the issue of this circular to the Chief Engineer, SR&T (Roads).