New Technology Initiatives in Rural Roads and Use of Marginal Materials

USE OF MARGINAL MATERIALS IN LOW VOLUME ROADS

National Rural Infrastructure Development Agency

Ministry of Rural Development

National Institute of Technology

Warangal, Hyderabad

Lecture 9

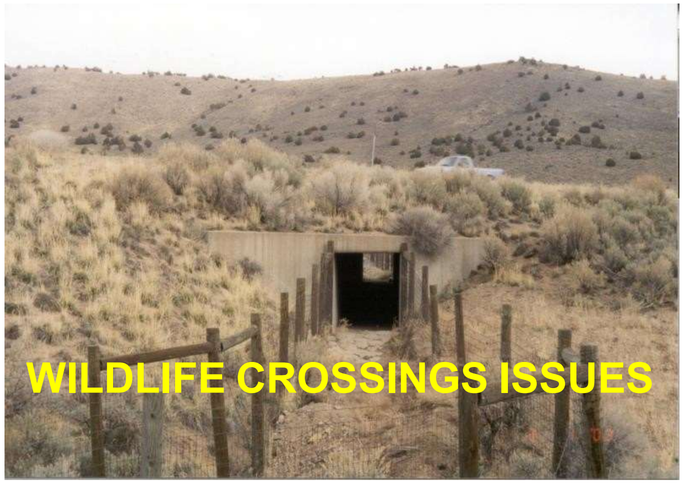
USE OF MARGINAL MATERIALS IN LOW VOLUME ROADS

LECTURE OVERVIEW

- Need for the Marginal Materials
- Conventional Pavement Materials
- Marginal Materials in Pavement Construction
- Treatment Methods for Marginal Materials
- Evaluation System for Marginal Materials
- Works at NIT Warangal
- Summary and Discussions!!


GEO-
MAN

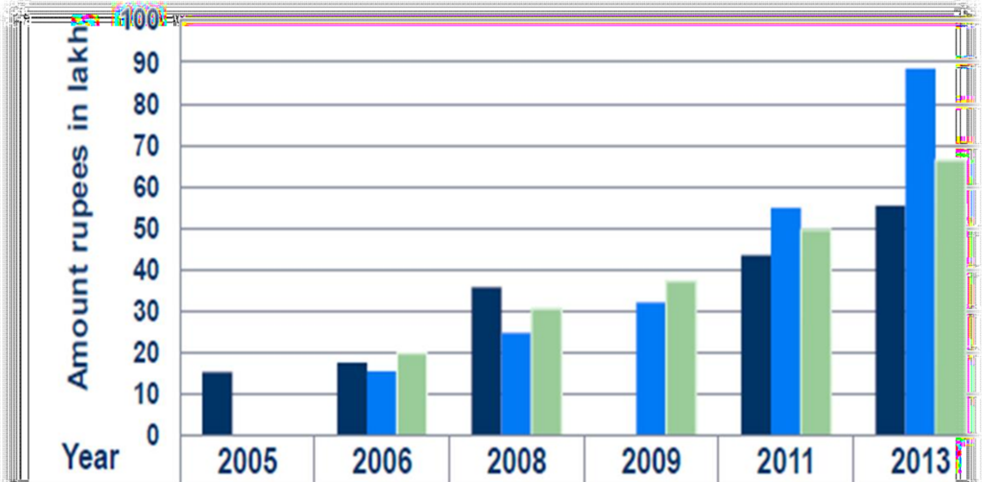
Why Don't we adopt these Practices on Our Roads ??



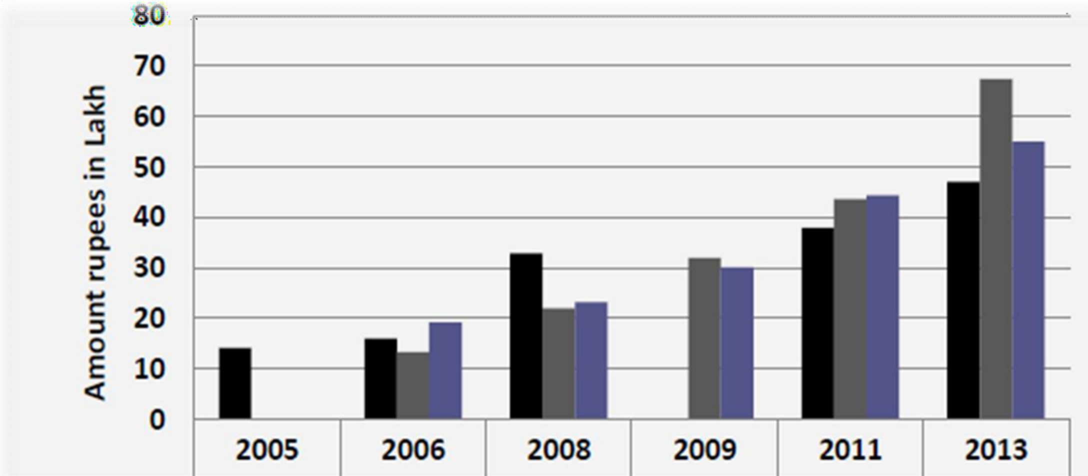
Introduction-Need for the Marginal Materials

- About 34 million km on the face of the earth.
- Government of India Initiatives- Road Development
- GoI 2014-15:12km,2015-16: 23km,2018-19:30km and 41km/day-MoRTH
- Huge demand for road aggregates around the world! (170-200 mt tons/yr)
- Diminishing of conventional aggregates
- Environmental impact concern across the World!
- MM for LVRRs construction is considered to be a possible alternative!
- A pressing need exists to conserve high-quality aggregates for more critical uses and to reduce construction costs of LVRRs.

Trends in Average Cost of LVRs with and without CD Work



Year	2005	2006	2008	2009	2011	2013
Warangal	15.447	17.614	35.834		43.62	55.55
Khammam		15.524	24.888	32.216	54.948	88.47
Karimnagar		19.941	30.724	37.316	49.722	66.478



	2005	2006	2008	2009	2011	2013
Warangal	14.147	16.028	32.92		37.951	47.008
Khammam		13.328	22.011	31.958	43.58	67.368
Karimnagar		19.1976	23.1752	30.1553	44.3907	54.9181

NRRIDA Recommendation….

A target of minimum 5% length of the annual proposals from each state with new materials/ techniques may be considered by the NRRIDA. This can be gradually increased as more experience is gained in handling these materials/technologies.

Technologies With IRC and without IRC Codes

- Lime stabilization IRC:SP:89-2010
- Cement stabilization IRC:50-1973
- Bitumen stabilization IRC:55-1974
- Mechanical stabilization IRC:SP:20-2002
- Use of Fly Ash/Pond Ash IRC:112 -2011
- Roller Compacted Concrete Pavements IRC:SP:68-2005
- Interlocking concrete block pavement IRC:SP:63-2004
- Gravel Sealed Roads IRC:SP:77:2007

- Locally available /Marginal materials, Brick aggregates etc.
- Blast furnace Slag/ Steel Slag /Zinc Slag.
- Rice husk / Bagasse ash/ Quarry Waste Materials

List of IRC Accredited Materials

Terrazyme	Soil Stabilization
RBI Grade 81	Stabilization engineering properties of soil
Geotextiles	Properties of subgrade of roads and hill slopes
Metallurgical Slag	Embankment, sub-base and Cement Concrete
Processed Steel slag	Alternative aggregates in Flexible pavement
Proc. Waste, Jarofix	Filler materials in road embankment
Evotherm	Eco-friendly Construction Technology
TitanTM 7686	Enhancing performance of Modified bitumen
Terraprime	Waterproofing of soil /WMM/WBM.
Zycobond	bonding soil particles, erosion, dust on dirt roads
Terrasil	Water proofing of in-situ soil
Soiltech MK-III	Polymer based stabilizers used for soil stabilization

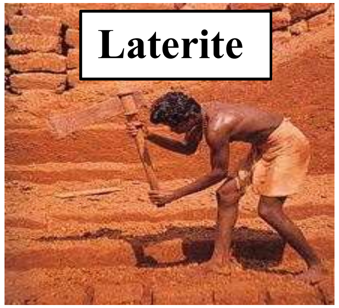
Definition of Marginal Materials

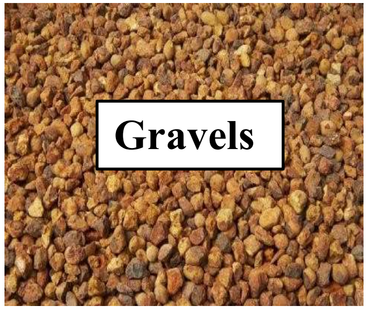
"Material which is not wholly in accordance with the standard specifications in use in a country or region for highway materials but which can be used successfully, either under special climatic conditions or treatment to enhance its properties".

-PIARC Technical Committee D.4

"Non-standard road-building materials which do not comply with standard specifications but are known to successfully perform as granular base and subbase materials for selected roads".

-AUSTOROADS, Technical Report AP-T333-2018





5-Tier System of Marginal Materials

Tier-I

On crushing and processing that result in a material that does not fully meet the requirements of a crushed stone base

Tier-II

Weakly cemented, poorly consolidated parent deposits (conglomerate and shales)

Tier-III

Transported and residual soils and gravels

Tier-IV

Indurated or partially indurated soils not meeting the minimum material standards for natural gravel road base.

Tier-V

Man-made materials fly ash, Slag, RAP and RCA etc.

Technology Initiative under PMGSY: Overview

- To promote cost-effective and fast construction technologies
- To mainstream the technologies already developed through R&D
- Fear of failure of New Technology and accountability- Rate analysis!!
- QC and additional work -Performance evaluation and LCCA!!
- Lacking knowledge about design req for different technologies!
- Hesitation by states in using New Technologies and reduction in cost!
- Non-availability of standards and specifications for construction
- Non-availability of indigenous equipment

List of MM in Road Construction

Waste Materials and By-Products		Binder	Stabilizing Agent	Filler	Portland Cement Concrete	Aggregate: Bituminous Concrete Surface Course	Aggregate: Bituminous Concrete Binder Course	Aggregate: Base and Subbase Subgrades	Aggregate: Embankment Fill and Improved
Mining and Quarry Wastes									
	a. colliery spoil		P*	P	P	P	P	P	E†
	b. quarry waste							P	E
mining and quarrying wastes	c. mine refuse							P	E
	d. slate waste				P	P	P	P	P
	e. oil shale residue							P	P
	f. china clay sand				E			E	E
	g. potassium salt mine							P	P
Mining and Quarry Wastes									
tailings	a. iron ore					E	E	E	E
	b. taconite					E	E	E	E
	c. fluorspar							P	P
	d. lead-zinc			P				P	P
	e. copper							P	E
	f. gold							P	P
mud, sludges	red mud (alumina)			P					
Metallurgical Wastes									
	a. blast furnace slag								
	- air cooled				E	E	E	E	E
ferrous slags	- granulated	E	E		E			E	
	- pelletized	E	E		E		P	P	
	- expanded				E				
	b. steel slag	P	P			E	E	E	E

non-ferrous slags	a. zinc (lead, lead zinc)		P		E		P	P	P
	b. copper		P					E	E
	c. nickel		P					E	E
	d. phosphate waste		P		E	E	E	E	E
	foundry sand								
	ceramic and refractory wastes						P	P	P
Industrial Wastes									
ash	a. flyash	E	E	E	E	P	P	E	E
	b. bottom ash (wet & dry)					E	E	E	E
	c. mixed kiln dust			E					E
	sulphur	E							
	dredge spoil				P	P	P	P	E
	boiler and furnace clinker and slag					E	E	E	E
	waste plastic				P	P	P		P
	pyrite cinders (kiesabbrand)								E
Municipal Wastes									
incinerator residue	a. ash		P	P					E
	b. clinker					E	E	E	E
demolition wastes	a. building rubble					P	P	P	E
	b. asphalt pavement					E	E	E	E
	c. concrete pavement				P	E	E	E	E
	glass & cullett		P				P	P	
	tyres and rubber					E	P		
	waste oils								
Agricultural and Forestry Wastes									
wood wastes	a. bark and sawdust								E
	b. lignin		P						
	c. paper mill mud		P						

† E Established Use (accepted practice in road construction)

* P Potential Use (research and development have indicated technical feasibility)

MoRD Specifications

- **Low Grade Aggregates as,**
  - Water bound macadam – section 405
  - Granular layer for sub-base – section 401
  - Soil-aggregate mix for sub-base, base and surfacing – section 402
- **Stabilised soil**
  - Mechanical Stabilisation – Section 401 (sands, moorums & gravels)
  - Lime Stabilisation – Section 403 (Medium & heavy clays with PI>10)
  - Cement Stabilisation – Section 404 (Granular soils, organic content <2%)
  - Lime-Fly ash Stabilisation – Section 409 (Clays of medium plasticity)
  - Two Stage (Lime-Cement Stabilisation) – Section 404 (Heavy clays of PI > 30)

Reason for Poor Performance of MM

There are many reasons causing poor performance of materials, which can further result in the materials failing to meet a 'premium' specification and could then be classified as marginal.

Potential Use of MM in Road Construction

Index Property	Material Description	Property Causing Material Marginality	Effects of Marginal Materials on the as-constructed Pavements of Marginal Materials to Pavements	Selected Reference
Plasticity	New Zealand local available fine grained aggregate with a particularly **High swelling clay content**	**High plasticity**	Motorway road base constructed with the aggregate failed.	(Black,2004;Buckland ,1967; Reed,1967)
	03 types of clayey sandy gravel from Ghana **Not meeting local specifications**	3 Soils had a High degree of PI	These materials had a potential for breakdown under mechanical stress. Premature pavement failures occurred when using these materials.	(Frempong and Tsidzi, 1999)
	A marginal granular material from Canada	High fines content was mistakenly placed on a highway.	Localized failures began to appear on asphalt concrete which was a layer over the high fines base course.	(Berthelot et al., 2010; Berthelot et al., 2004)
	Dolomite and limestone from USA	Materials were moisture-susceptible- they contain high plastic fines	N/A	(Santamarina and Cho, 2004)
Strength/ Stiffness	Material used from an existing road. The material consisted of an old poorly cemented base, a multiple-seal surfacing	Not meeting CBR of local specification.	Considered of sub base quality and Its use as a base layer would not be considered.	(Liebenberg and Visser, 2003)
	Lightweight aggregates Tanzania	CBR< 80which could not meet the requirement of local specifications	This material was considered to be used in road base after	(Mfinanga & Kamuhabwa, 2008)

Potential Use of MM in Road Construction

Index Property	Material Description	Property Causing Material Marginality	Effects of Marginal Materials on the as-constructed Pavements of Marginal Materials to Pavements	Selected Reference
Durability	02 aggregates laterite aggregate and pit run gravel.	LAAs could not meet the local specification in India.	These marginal aggregates would break down due to the crushing during the rolling	(Majumder et al.,1999)
	Greywacke, andesite, basalt from four quarries in New Zealand	Partly weathered. All of the rocks contain a small proportion of swelling clays.	Not available	(Bartley et al., 2007)
Particle Characteris	Local Roorkee soil from India	Soil was classified as poor graded fine sand which was used as a subbase of a rural road.	Not available	(Kumar and Singh, 2008)
	Texas- Poorly graded	Materials both had high fines		
Other Recycled and Waste Materials	RCA and masonry aggregates base course- Netherlands	Problems in regards to particle grading and particle shape with these materials. Stabilizers are always used to modify.	RCA and RMA can be very successfully used in unbound courses. Over 80% of the material used for road bases in the Netherlands are RMA and RCA	(Molenaar & Van Niekerk, 2002; Van Niekerk, 2002; Xuan et al., 2012)
	Recycled crushed clay masonry (RCM) recycled concrete aggregate (RCA) from Australia	Investigated basic engineering properties and CBR. LAA of all mixes out of local specification.	It was recommended that the recycled products should be restricted to sub base applications.	(Azam et al., 2012)

Tests on MM in Road Construction

Index	Testing Methods	Description of the Material Property
Plasticity of Fine fractions	Sand Equivalent	Amounts of silt or clay size particles in fine aggregates or fine fractions (i.e. less than 4.75mm)
	Clay index	Particles smaller than 0.075mm to absorb methylene blue. This method is actually a chemical test, not an engineering test.
	Atterberg Limits	Particles smaller than 0.425mm to behave as a plastic/ cohesive material at different moisture contents
Strength or stiffness of Compacted Materials	UCS and Soaked CBR test	Materials to support imposed loads under saturated/unsaturated conditions
	Repeated load tri axial test	Resistance of materials to Permanent deformation
Durability	Los Angles abrasion and Deval	The dry abrasion resistance of aggregates
	Durability and soak Test	Aggregate to the effects of wetting, drying, heating and cooling
	Crushing Resistance	The crushing strength of individual particles by measuring the quantity of fines given a standard crushing load
Particle Characterist	Particle Size Distribution	Proportions of each size fraction from gravel to clay size and their effect on load-bearing properties of rocks and soils
	Particle shape FI +EI and	The angularity and flakiness of the aggregate particles and their ability to interlock together

Table 4.2: **Preferred properties of Type 4 Western Queensland materials**

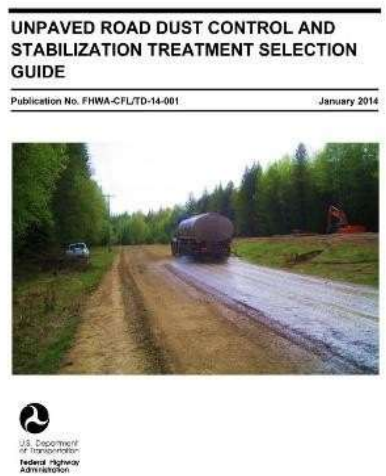
Properties		Base		Subbase
		Alternative 1	Alternative 2	
Per cent passing 53 mm sieve (% < 53 mm)		100	100	100
Per cent passing 9.5 mm sieve (% < 9.5 mm)		65–100	65–100	65–100
Per cent passing 2.36 mm sieve (% < 2.36 mm)		40–70	40–100	40–100
Per cent passing 0.425 mm sieve (% < 0.425 mm)		24–40	24–80	24–100
Per cent passing 0.075 mm sieve (% < 0.075 mm)		12–22	12–30	12–40
Linear shrinkage (LS)%		1.5-4.5	1.5–5.5	1.5–7.0
LS x per cent passing 0.425 mm sieve		75–120	75–275	75–350
$\frac{\% < 0.075\, mm}{\% < 0.425\, mm}$	Mainly uncrushed material	0.32–0.50		0.32–0.55
	Mainly crushed material	0.32–0.55		0.32–0.60
$\frac{\% < 0.075\, mm}{\% < 2.36\, mm}$	(if less than 50% < 0.425 mm)	0.15–0.45		0.15–0.45
$\frac{\% < 0.075\, mm}{\% < 0.300\, mm}$	(if greater than 95% < 0.425 mm)	Not applicable		Minimum 45

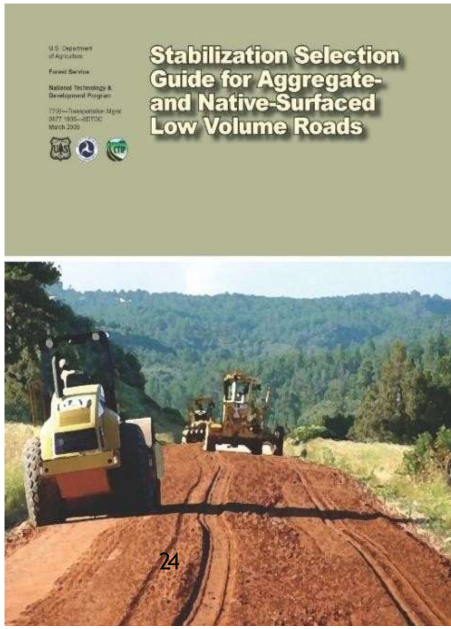
Note: Alternate 2 and subbase requirements refer to the original WQ35 guidelines, whereas as Alternative 1 is closer to conventional materials.

Source: Queensland Department of Transport and Main Roads (2000d) and Wills and Christensen (2017).

Selection and Evaluation Criteria

- Traditional Stabilizers , the selection process is well documented
- Non-Traditional Stabilizers!! Application rate, Tests and Effectiveness!!
- Enzymes have good potential in clays but in consistency in performance
- New Stabilizers need testing and Evaluation "
- Product Evaluation Criteria
  - Full test Sections
  - Small Scale test Sections
  - Performance based Laboratory tests



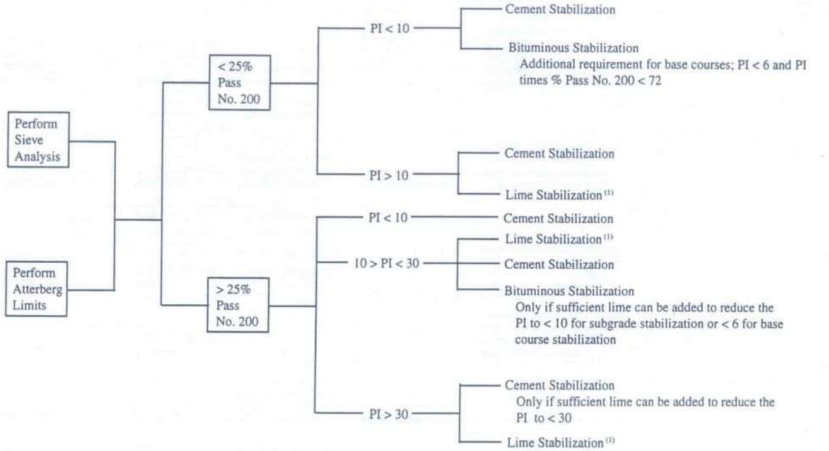


Recommended Stabilization Material

Area	Soil Class.[a]	Type of Stabilizing Additive Recommended	Restriction on LL and PI of Soil	Restriction on Percent Passing No. 200 Sieve[a]	Remarks
1A	SW or SP	(1) Bituminous (2) Portland cement (3) Lime-cement-fly ash	 PI not to exceed 25		
1B	SW-SM or SP-SM or SW-SC or SP-SC	(1) Bituminous (2) Portland cement (3) Lime (4) Lime-cement-fly ash	PI not to exceed 10 PI not to exceed 30 PI not to exceed 12 PI not to exceed 25		
1C	SM or SC or SM-SC	(1) Bituminous (2) Portland cement (3) Lime (4) Lime-cement-fly ash	PI not to exceed 10 --[b] PI not less than 12 PI not to exceed 25	Not to exceed 30% by weight	
2A	GW or GP	(1) Bituminous (2) Portland cement (3) Lime-cement-fly ash	 PI not to exceed 25		Well-graded material only Material should contain at least 45% by weight of material passing No. 4 sieve
2B	GW-GM or GP-GM or GW-GC or GP-GC	(1) Bituminous (2) Portland cement (3) Lime (4) Lime-cement-fly ash	PI not to exceed 10 PI not to exceed 30 PI not less than 12 PI not to exceed 25		Well-graded material only Material should contain at least 45% by weight of material passing No. 4 sieve
2C	GM or GC or GM-GC	(1) Bituminous (2) Portland cement (3) Lime (4) Lime-cement-fly ash	PI not to exceed 10 --[b] PI not less than 12 PI not to exceed 25	Not to exceed 30% by weight	Well-graded material only Material should contain at least 45% by weight of material passing No. 4 sieve
3	CH or CL or MH or ML or OH or OL or ML-CL	(1) Portland (2) Lime	LL less than 40 and PI less than 20 PI not less than 12		Organic and strongly acid soils falling within this area are not susceptible to stabilization by ordinary means

[a] Soil classification corresponds to MIL-STD-619B. Restriction on liquid (LL) and plasticity index (PI) is in accordance with Method 103 in MIL-STD-621A.

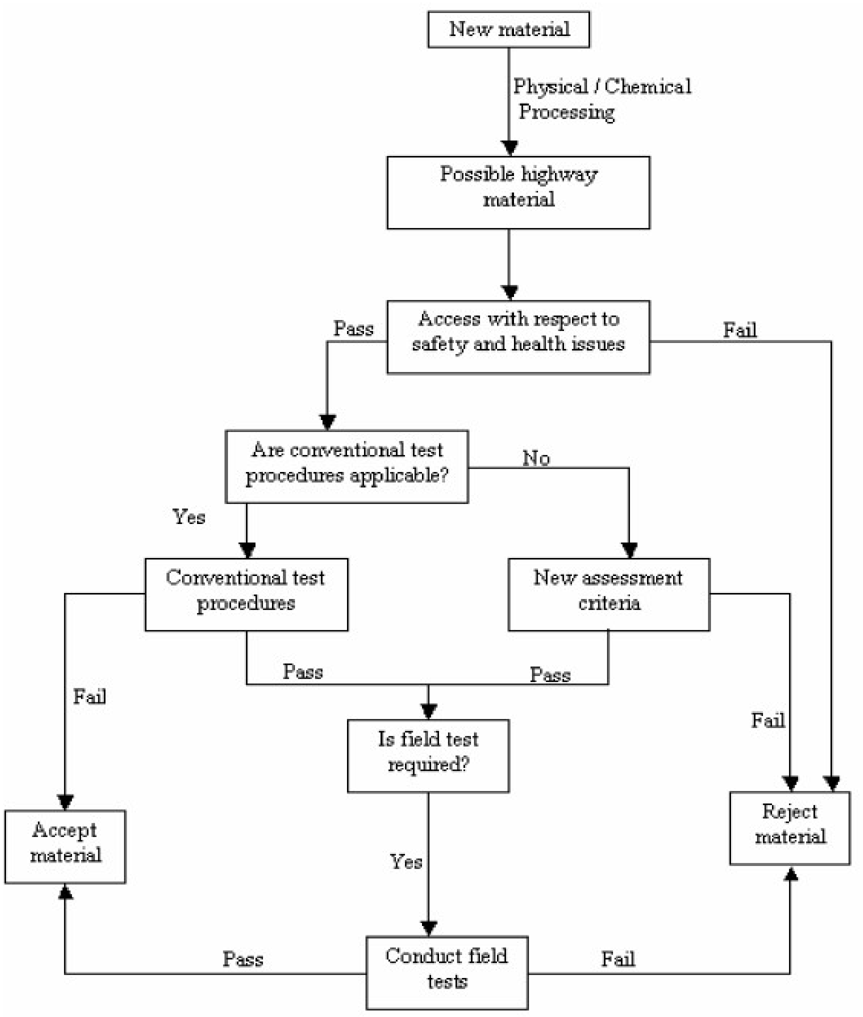
[b] $PI \leq 20 + \frac{50 - \text{percent passing No. 200 sieve}}{4}$



Type of stabilization	Soil Properties					
	>25%p 75 μm sieve			<25%p75 μm sieve		
	PI < 10	10 < PI < 20	PI > 20	PI <6, PI< 60	PI < 10	PI>10
Cement	Yes	Yes	-	Yes	Yes	Yes
Lime	-	Yes	Yes	No	-	Yes
Lime-Pozz	Yes	-	No	Yes	Yes	-

Research Works at NIT Warangal

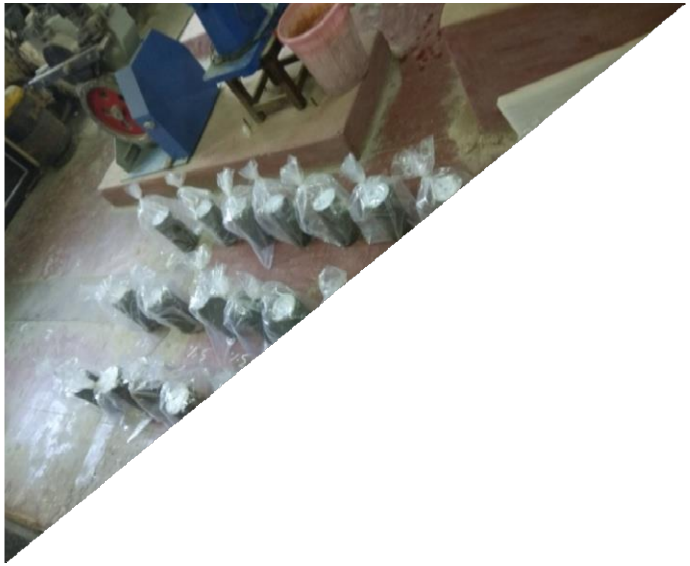
Evaluation of MM for Suitability of Construction



Sieve Size (mm)	Limits (MoRD) (Table 400.2A)(Base layer)
53	100
37.5	100
26.5	100
19	97-100
9.5	67-79
4.75	47-59
0.425	12-21
0.075	4-15

Moorum	stack1	stack2	stack3
60%	18%	0	22%
50%	23%	3%	24%
40%	26%	9%	25%

Contd...



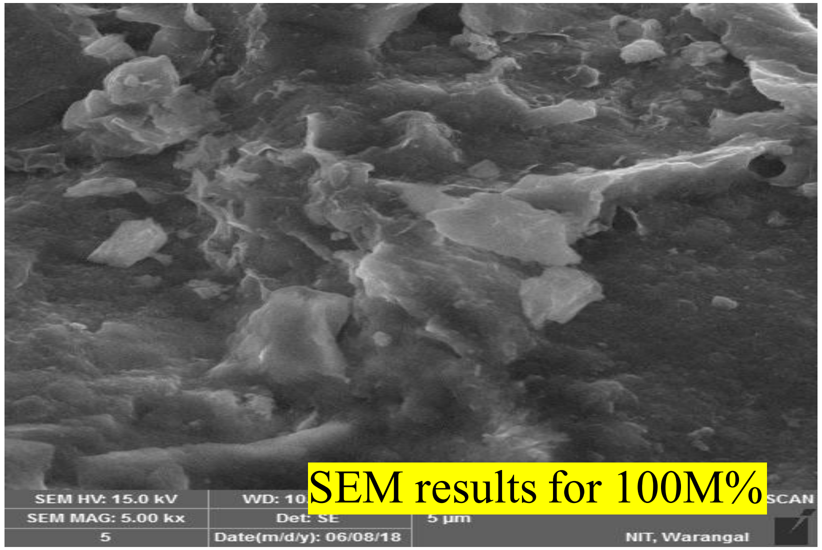
Combination- Stabilization

ID	Terrasil, 0.6kg/m^3 Zycobond & Cement	Terrasil, 0.3kg/m^3 Zycobond & Cement	Cement	ID	RBI Grade 81
C1	100%M+1%C	100%M+1%C	100%M+1%C	R1	100%M+1%RBI
C2	100%M+2%C	100%M+2%C	100%M+2%C	R2	100%M+2%RBI
C3	100%M+3%C	100%M+3%C	100%M+3%C	R3	100%M+3%RBI
C4	100%M+4%C	100%M+4%C	100%M+4%C	R4	100%M+4%RBI
C5	60%M+40%V+1%C	60%M+40%V+1%C	60%M+40%V+1%C	R5	60%M+40%V+1%RBI
C6	60%M+40%V+2%C	60%M+40%V+2%C	60%M+40%V+2%C	R6	60%M+40%V+2%RBI
C7	60%M+40%V+3%C	60%M+40%V+3%C	60%M+40%V+3%C	R7	60%M+40%V+3%RB
C8	60%M+40%V+4%C	60%M+40%V+4%C	60%M+40%V+4%C	R8	60%M+40%V+4%RBI
C9	50%M+50%V+1%C	50%M+50%V+1%C	50%M+50%V+1%C	R9	50%M+50%V+1%RBI
C10	50%M+50%V+2%C	50%M+50%V+2%C	50%M+50%V+2%C	R10	50%M+50%V+2%RBI
C11	50%M+50%V+3%C	50%M+50%V+3%C	50%M+50%V+3%C	R11	50%M+50%V+3%RBI
C12	50%M+50%V+4%C	50%M+50%V+4%C	50%M+50%V+4%C	R12	50%M+50%V+4%RBI
C13	40%M+60%V+1%C	40%M+60%V+1%C	40%M+60%V+1%C	R13	40%M+60%V+1%RBI
C14	40%M+60%V+2%C	40%M+60%V+2%C	40%M+60%V+2%C	R14	40%M+60%V+2%RBI
C15	40%M+60%V+3%C	40%M+60%V+3%C	40%M+60%V+3%C	R15	40%M+60%V+3%RBI
C16	40%M+60%V+4%C	40%M+60%V+4%C	40%M+60%V+4%C	R16	40%M+60%V+4%RBI

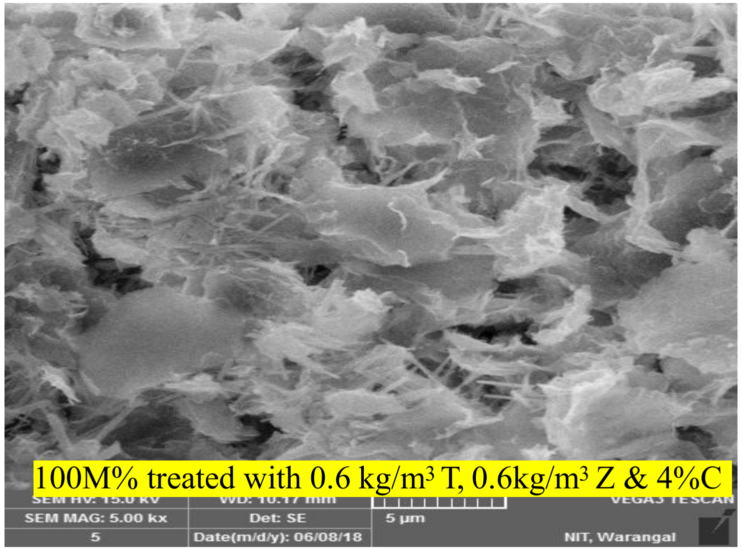
M= Moorum, V=Virgin aggregate, C= Cement, RBI= RBI Grade 81

With out Stabilization
100%M
60%M+40%V
50%M+50%V
40%M+60%V

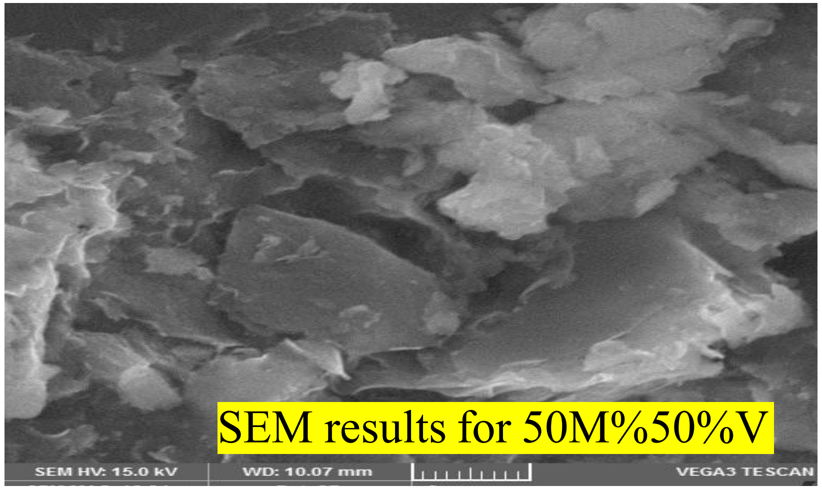
Scanning Electron Microscopy



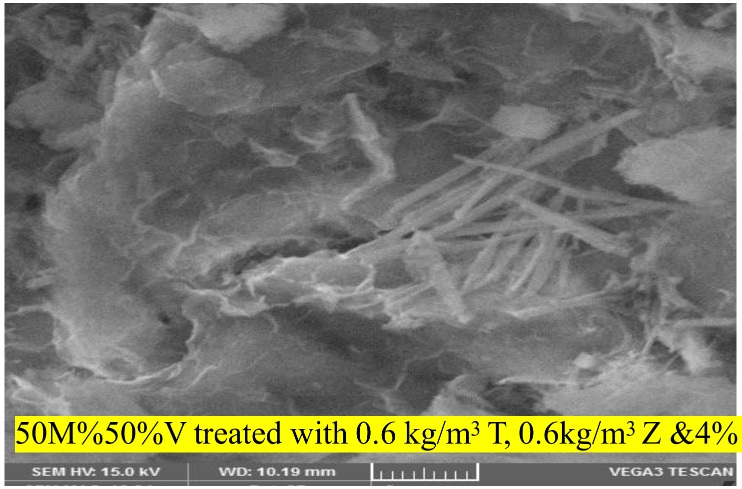
SEM results for 100M%



100M% treated with 0.6 kg/m³ T, 0.6kg/m³ Z & 4%C



SEM results for 50M%50%V



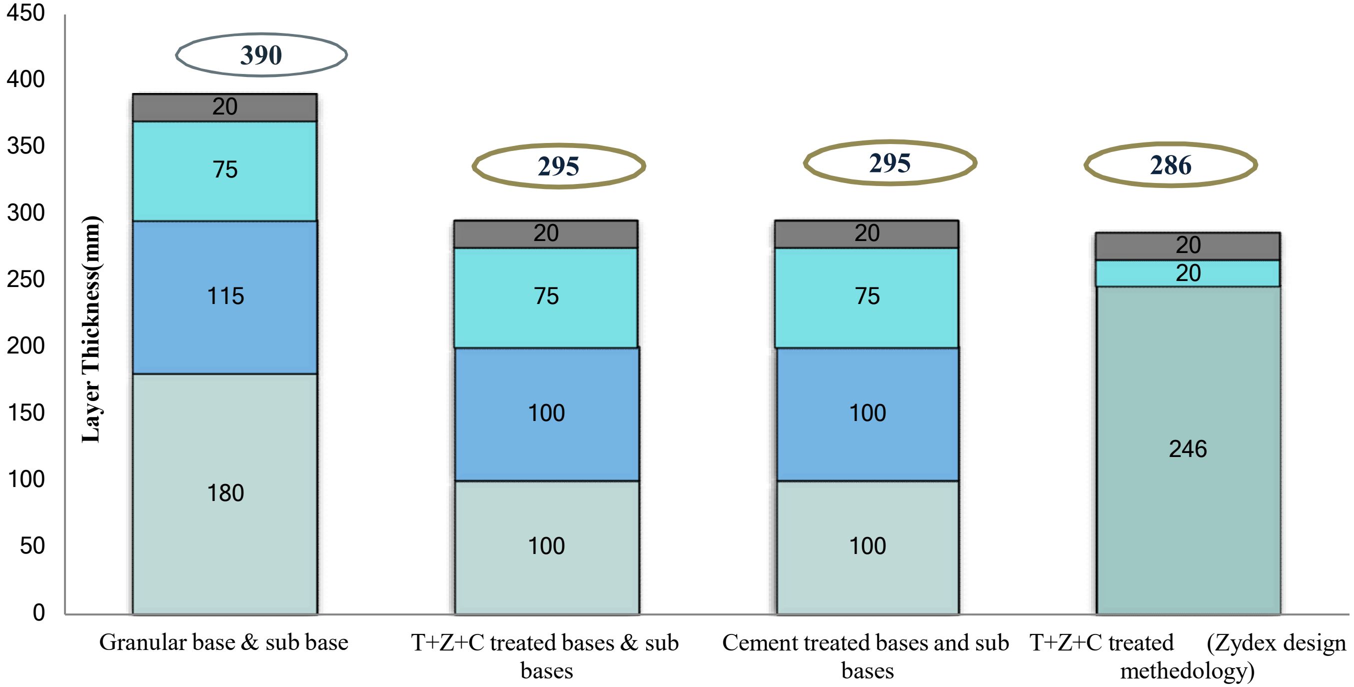
50M%50%V treated with 0.6 kg/m³ T, 0.6kg/m³ Z &4%

Pavement design (IRC SP 72 2015)

For Traffic 1msa and subgrade CBR 7% to 9%		
Conventional design for granular Base and sub base layers (IRC 72-2015)	Terrasil ,Zycobond & Cement treated bases and sub bases (IRC 72-2015)	Cement treated bases and sub bases (IRC 72-2015)
OGPC	OGPC	OGPC
WBM Grading 3 Graded Metal)	Crack Relief Aggregate layer(WMM)	Crack Relief Aggregate layer(WMM)
WBM Grading 2 (Graded Metal)(Base layer)	60% Moorum 40%Virgin aggregate, 0.3kg/m3Terrasil, 0.3kg/m3 Zycobond and 4%Cement(base layer)	50%Moorum 50%Virgin aggregate,6%Cement (base layer)
Granular Sub-base with Well Graded Material (Table 400.1)	100%Moorum, 0.3kg/m3 Zycobond and 3%Cement(Sub base layer)	100%Moorum, 4%Cement (Sub base layer)

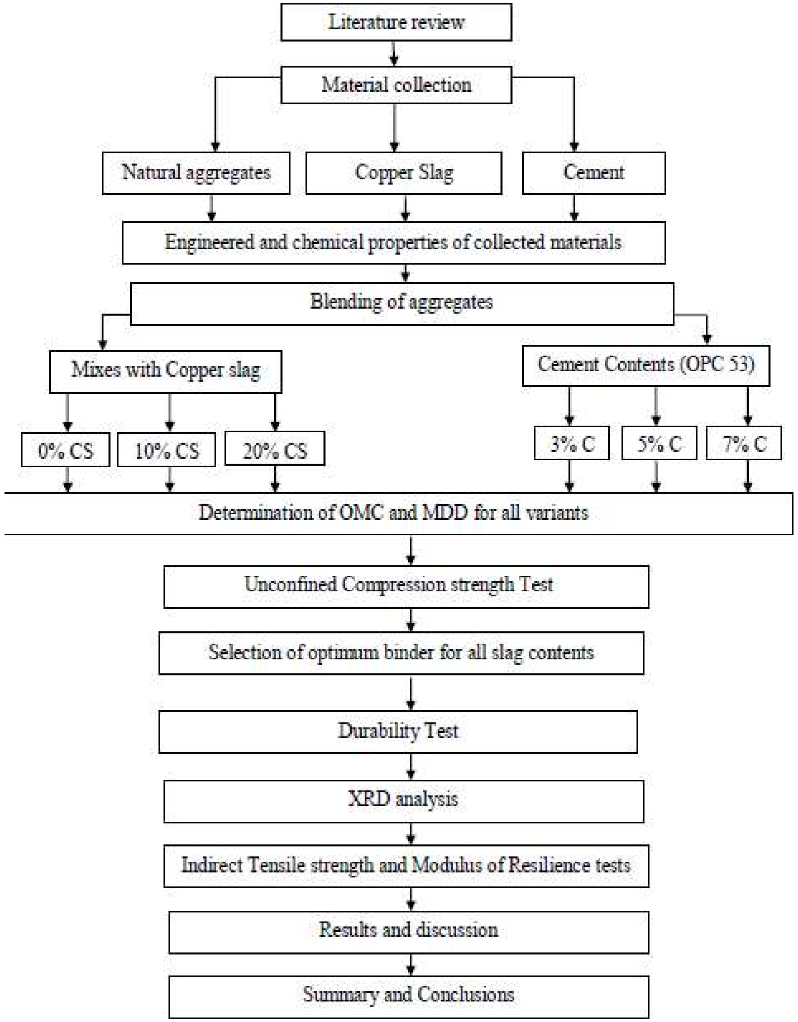
Cement treated base and sub base as design based on the UCS value

Pavement Design Cross Section



Granular base and sub base	T+Z+C treated bases and sub bases	Cement treated bases and sub bases	T+Z+C treated (Zydex design methodology)

Copper Slag



- Copper slag is a glassy, black granular material and an industrial waste produced as a byproduct during the manufacturing of copper.
- Every 1-ton production of copper, the generation of copper slag is nearly about 2.5-3 tons. It is considered a non-hazardous and inert material for its use.

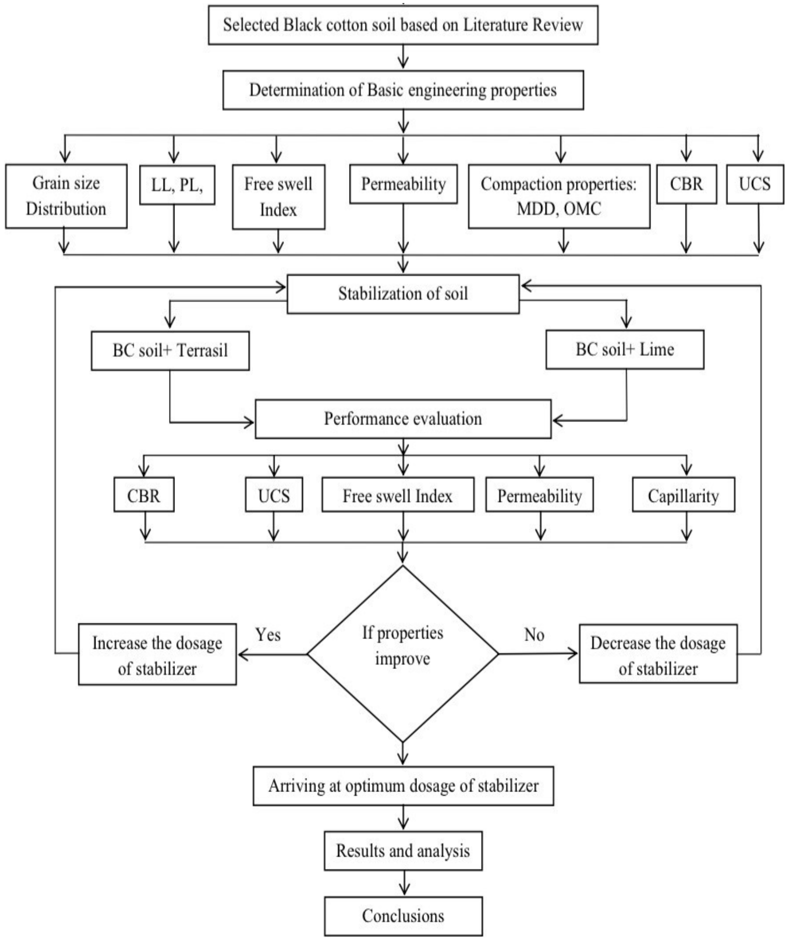
Chemical Parameters	Composition (%)	IRC SP 121 2018
Iron Fe_2O_3	50.8	40-45
Silica SiO_2	30.7	28-35
Aluminum Al_2O_3	4.5	3-5
Sulphur S	0.74	0.5-1.5
Calcium CaO	0.81	2-5
Cobalt Co	4.30	-
Copper Cu	0.7	0.4-0.5
Loss on Ignition	<1	-
Zinc Zn	0.6	-
Chlorine Cl	0.54	-
Chromium Cr	1.35	-
Minor oxides	<4	-

Copper Slag- Pavement Design

			0CS	10CS	20CS	10CS	
BC	40	BC	40	40	40	40	40
DBM	110	DBM	110	110	110	110	110
Crack Relief	0	Crack Relief	100	100	100	100	100
GB	250	CTB	250	250	250	200	150
GSB	200	GSB	200	200	200	200	200
Total Thickness	600	Total Thickness	700	700	700	650	600
		Reduction in thickness	**0**	**0**	**0**	**50**	**100**
Tensile Strainsat bottom of bituminous layer (μ ε)	109.3		109.4	104.4	105.4	105.9	109.3
Tensile Strainsat bottom of CTB(μ ε)			56.2	37.3	42.13	45.45	55.69
Compressive strains on top of subgrade(μ ε)	176.1		143.1	113.2	121.3	139.9	176.1

Terrasil Soil Stabilization

Property of black cotton soil	Value
Specific gravity	2.68
Atterberg limits	
Liquid limit	61%
Plastic limit	27%
plasticity index	34%
Grain size distribution	
Gravel	11%
Sand	27%
Silt	27%
clay	35%
Soil classification	CH
Free swell index %	45.7%
Compaction properties	
MDD	1.91 gm/cm3
OMC	20%
Soaked &Unsoaked CBR	1 and 5%
UCC	3.57 kg/cm^2



Performance Evaluation of Four Roads Constructed using TerraZyme One Each in the Chennur Block (AP04131405) and Pendlimarri Block (AP04131406) of YSR Kadapa District, Andhra Pradesh, and Chillakur Block (AP141402) and Doravarisatram Block (AP141403) of Nellore District, Andhra Pradesh

Contd…

20 mm BT layer

75 mm WBM layer

75 mm WBM layer

Subgrade

Cross-section of control section on Kadapa road-1 (5/840 – 6/8)

25 mm BT layer

75 mm WMM layer

100 mm TerraZyme layer

75 mm WBM layer

100 mm Gravel layer

Subgrade

Cross-section of TerraZyme section on Kadapa road-1 (3/1 – 4/2)

Overall, based on the roughness, Benkelman beam deflection, and rutting survey, it is observed that that the performance of TerraZyme sections in Nellore road-1 is similar to that of the performance of the control sections and the entire road is observed to be in good condition. In Nellore road-2, the performance of TerraZyme sections is comparable to that of the performance of the control sections in spite of the poor drainage conditions prevailing at 2/0 to 3/4 stretch of the road and the entire road is observed to be in good condition. In Kadapa road-1, the performance of control section is relatively better than the performance of the TerraZyme section. However, the riding quality on TerraZyme section is in fair condition as could be observed from roughness and rut depth measurements. It is important to note here that there is significant movement of caged-wheel tractors on this road as could be observed from its imprints on the entire stretch of this road and thin wearing courses of bituminous mixtures deteriorate at a much faster rate due to movement of cage-wheeled tractors. In Kadapa road-2, the performance of control section is relatively better than the performance of the TerraZyme section. However, the riding quality on TerraZyme section is in fair condition as could be observed from roughness and rut depth measurements.

RCA- Pointers from Literature Review

RCA - specific gravity is relatively lower and water absorption is relatively high

100%
RAP performs well with softer grade bitumen

20% RAP performs better than virgin mix in terms of moisture susceptibility, rutting, and retained Marshall stability.

A few research work has been done without using chemical additive for bituminous mixtures with RAP.

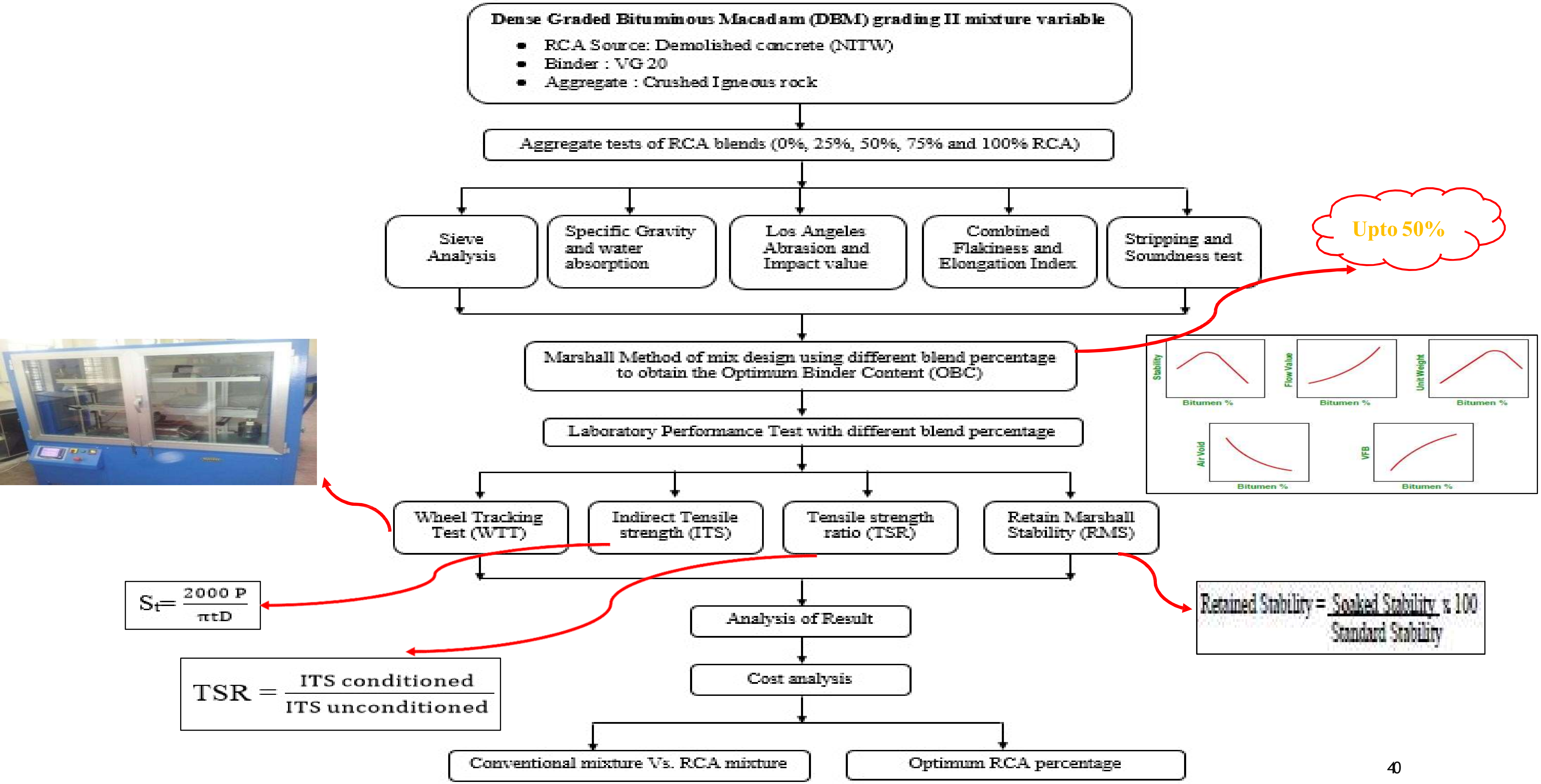
Limited research work has been done on DBM mixes using RCA and RAP

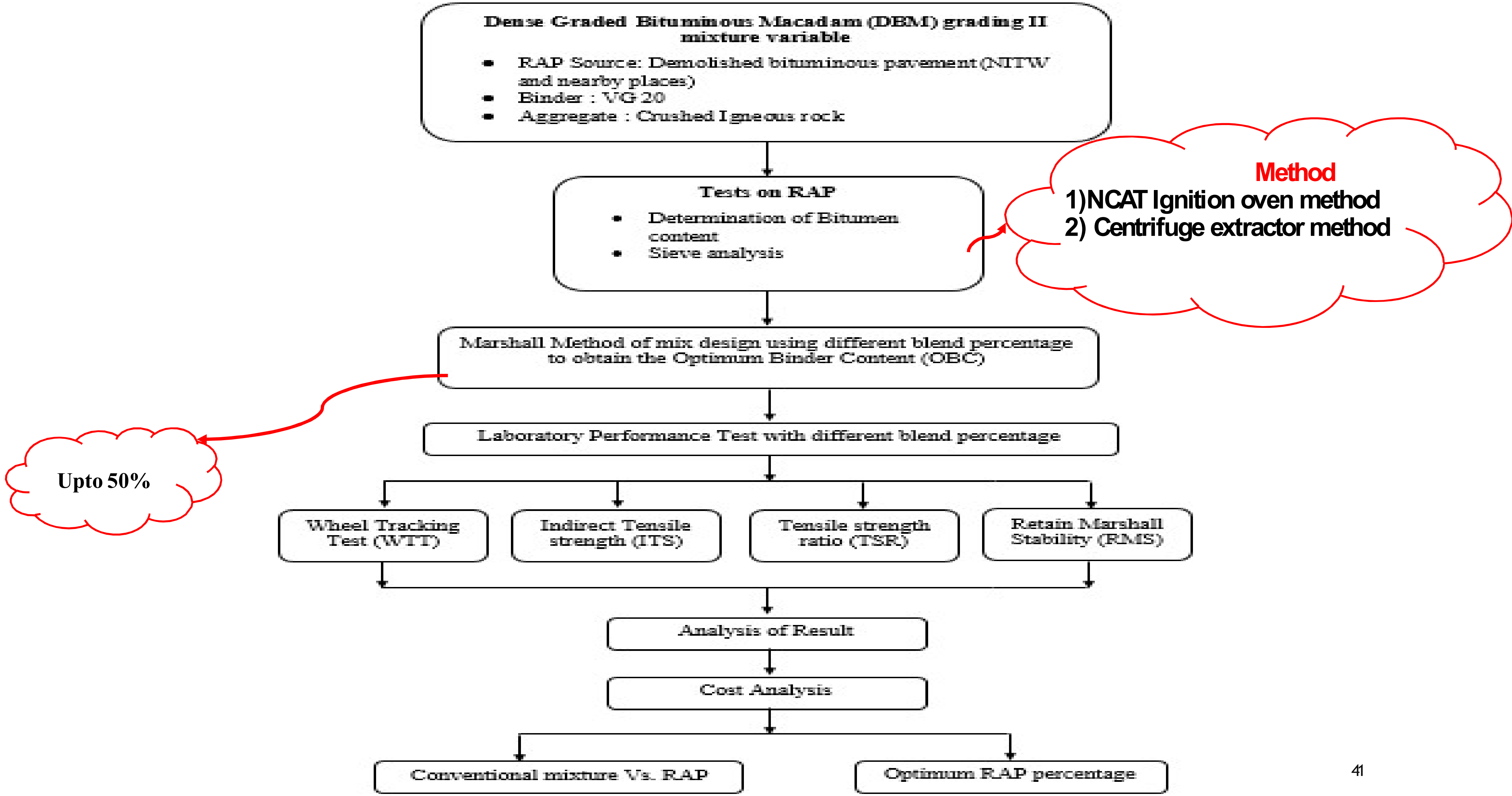
RCA
Improvement- Chemical Treatment

- **RECYCLING** Means recovery and subsequent utilization of a material for manufacture and fabrication of similar product from which the waste was originated
- The Aggregates obtained after the Recycling Process are termed as **RECYCLED AGGREGATES**

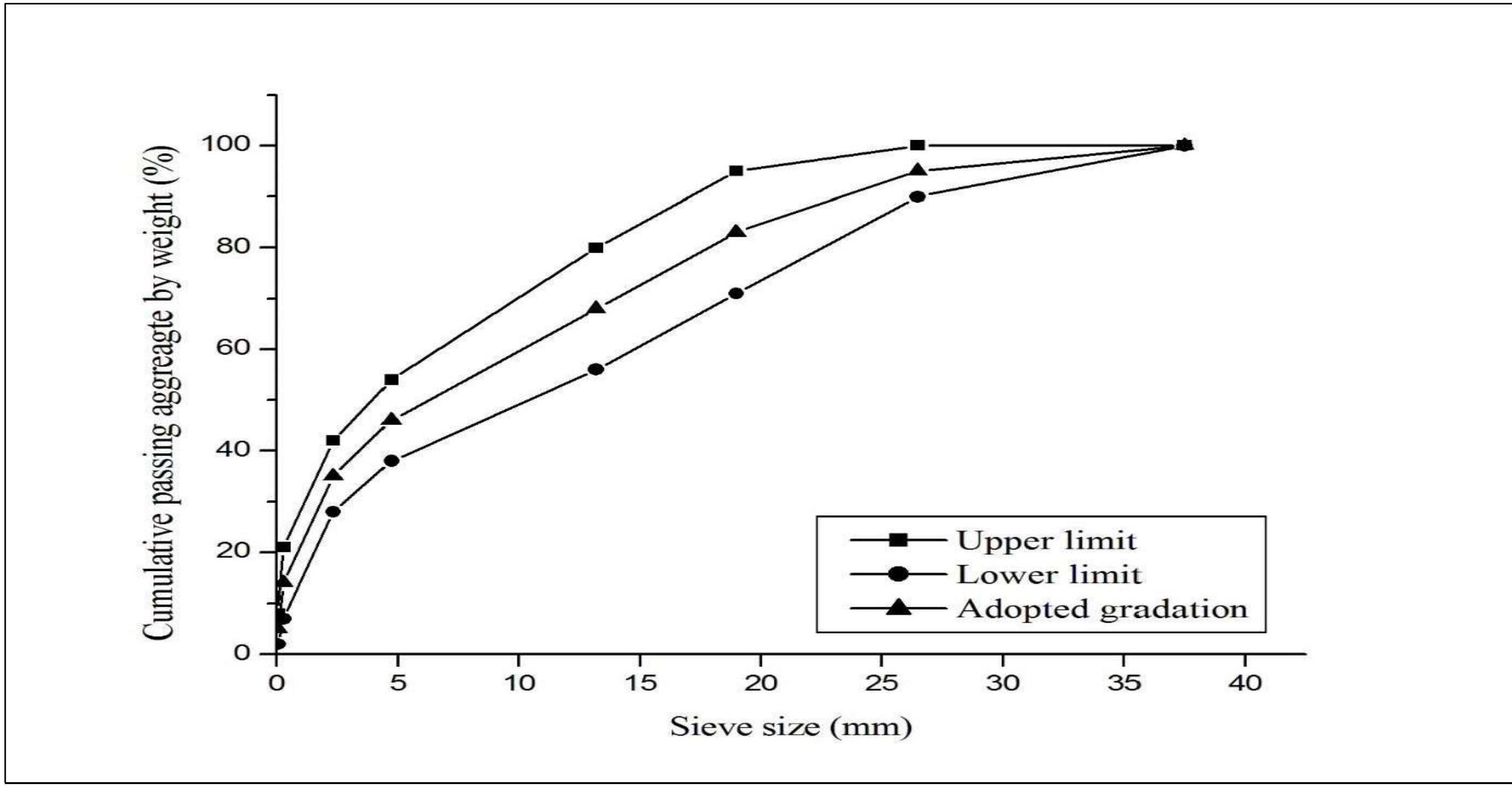
Source of RCA

Source of RAP


Dense Graded Bituminous Macadam (DBM) grading II mixture variable
RCA Source: Demolished concrete (NITW)
Binder : VG 20
Aggregate : Crushed Igneous rock
Aggregate tests of RCA blends (0%, 25%, 50%, 75% and 100% RCA)
Sieve Analysis
Specific Gravity and water absorption
Los Angeles Abrasion and Impact value
Combined Flakiness and Elongation Index
Stripping and Soundness test
Upto 50%
Marshall Method of mix design using different blend percentage to obtain the Optimum Binder Content (OBC)
Stability
Flow Value
Unit Weight
Air Void
VFB
Bitumen %
Laboratory Performance Test with different blend percentage
Wheel Tracking Test (WTT)
Indirect Tensile strength (ITS)
Tensile strength ratio (TSR)
Retain Marshall Stability (RMS)
St = 2000 P / πtD
TSR = ITS conditioned / ITS unconditioned
Retained Stability = Soaked Stability / Standard Stability x 100
Analysis of Result
Cost analysis
Conventional mixture Vs. RCA mixture
Optimum RCA percentage

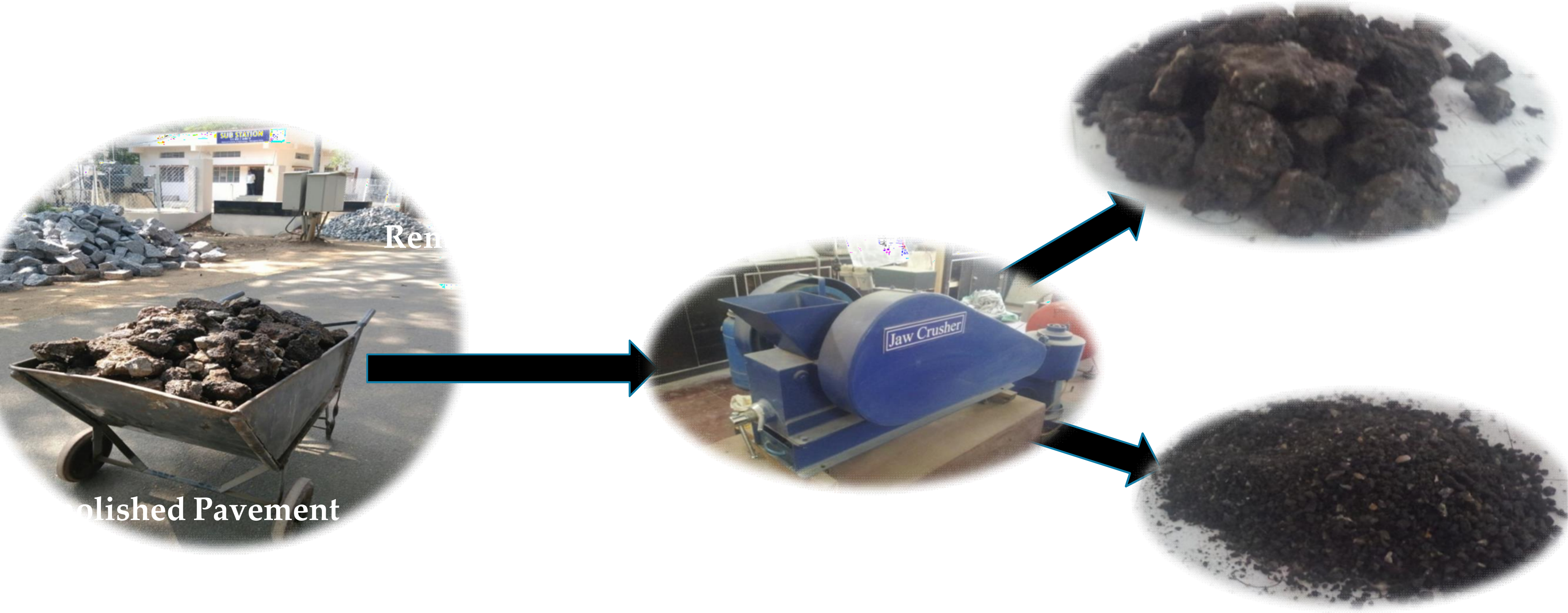

Dense Graded Bituminous Macadam (DBM) grading II mixture variable
RAP Source: Demolished bituminous pavement (NITW and nearby places)
Binder : VG 20
Aggregate : Crushed Igneous rock
Tests on RAP
Determination of Bitumen content
Sieve analysis
Method
1)NCAT Ignition oven method
2) Centrifuge extractor method
Marshall Method of mix design using different blend percentage to obtain the Optimum Binder Content (OBC)
Upto 50%
Laboratory Performance Test with different blend percentage
Wheel Tracking Test (WTT)
Indirect Tensile strength (ITS)
Tensile strength ratio (TSR)
Retain Marshall Stability (RMS)
Analysis of Result
Cost Analysis
Conventional mixture Vs. RAP
Optimum RAP percentage

RCA


Cumulative passing aggreagte by weight (%)
Sieve size (mm)
Upper limit
Lower limit
Adopted gradation
0
20
40
60
80
100
0
5
10
15
20
25
30
35
40

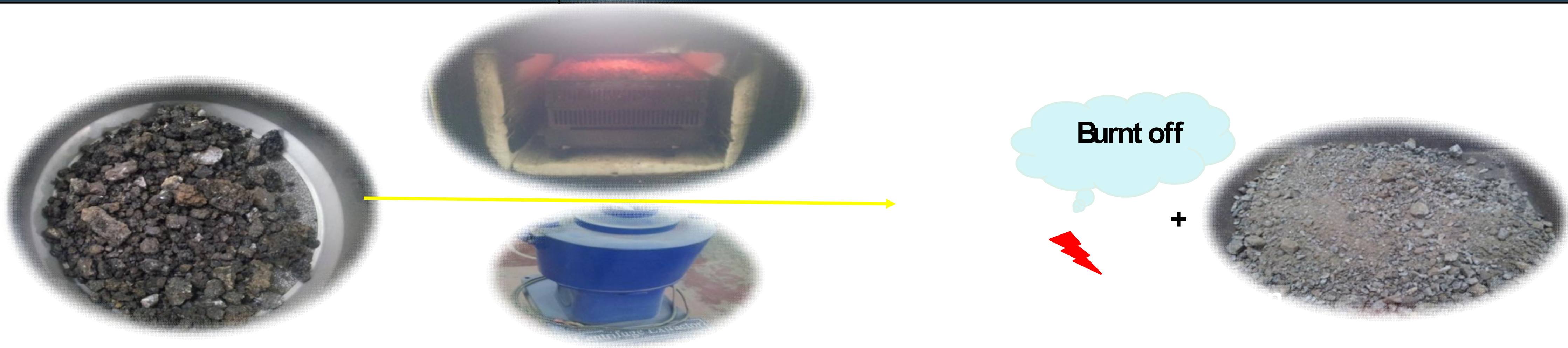
PHYSICAL PROPERTIES OF RCA

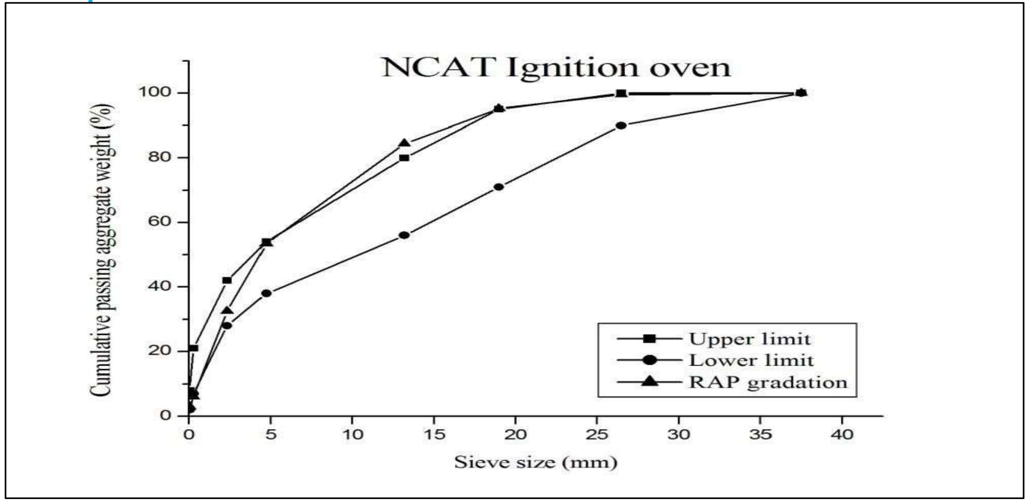
S. No.	Material Property	RCA (%)					MoRTH, 2014 Limits
		0	25	50	75	100	
1	Eff.Specific gravity	2.61	2.59	2.58	2.58	2.43	-
2	Specific gravity	2.56	2.53	2.51	2.38	2.25	-
3	Water absorption (%)	**0.64**	**0.72**	**1.76**	**3.18**	**3.35**	Max 2%
4	Bitumen absorption (%)	0.66	0.95	1.81	3.27	3.45	-
5	Agg. Impact value (%)	18.44	26.38	29.44	31.8	33.6	Max27%
6	LOS A Abrasion (%)	27.18	33.35	35.50	38.0	42.4	Max 35%
7	Combined FI+EI (%)	17.38	17.74	19.31	19.0	21.0	Max 30%

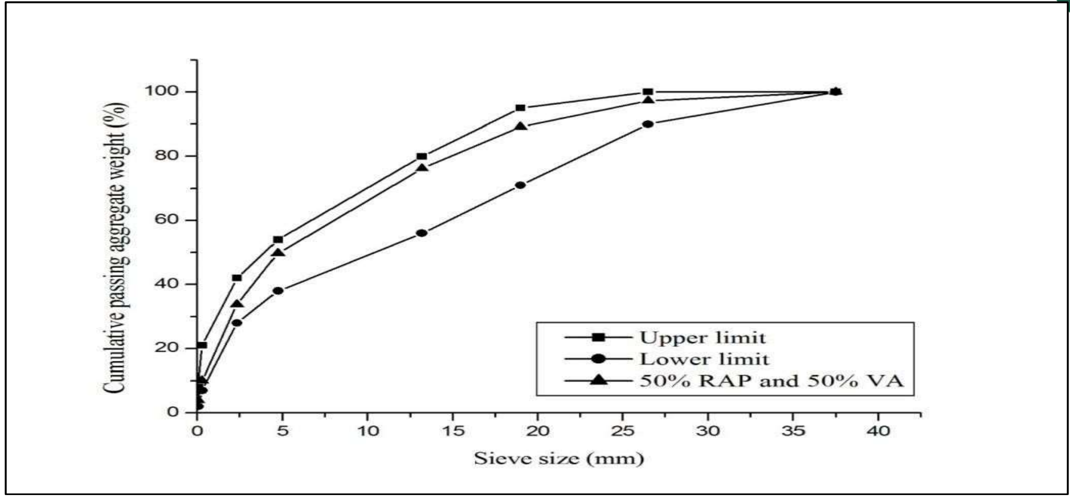

Ren
Jaw Crusher
olished Pavement

Binder in the RAP

S. No.	Bitumen content (%)	
	NCAT Ignition Oven	Centrifuge extractor
1	3.6	3.5
2	4.2	3
3	3.48	4.5
Mean	3.76	3.67
Adopted	3.72	



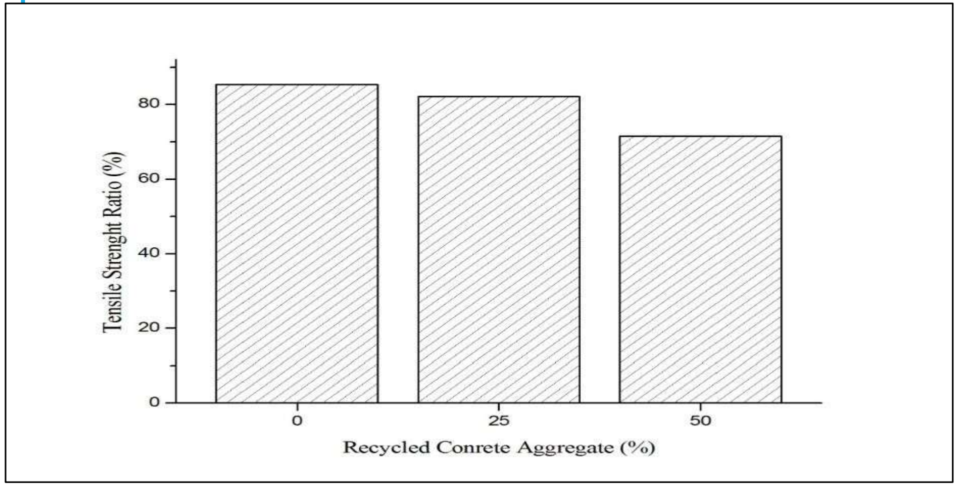


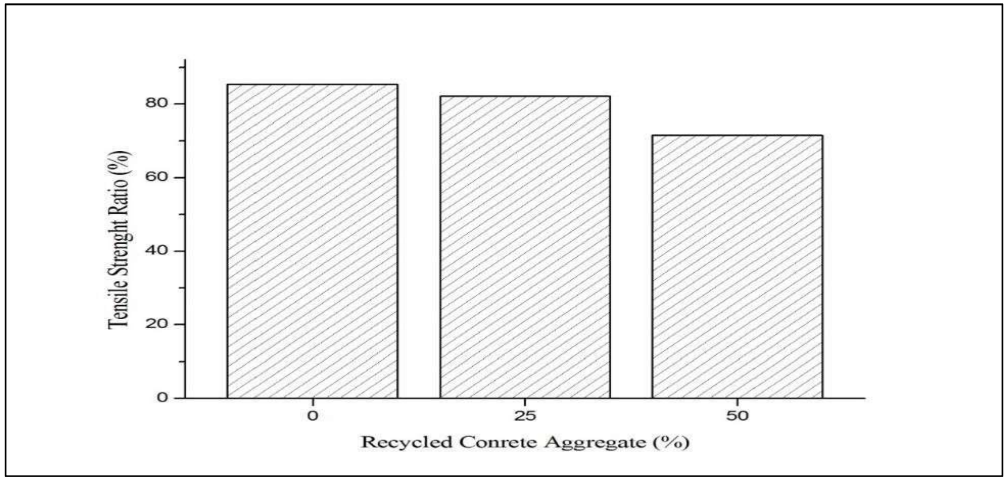


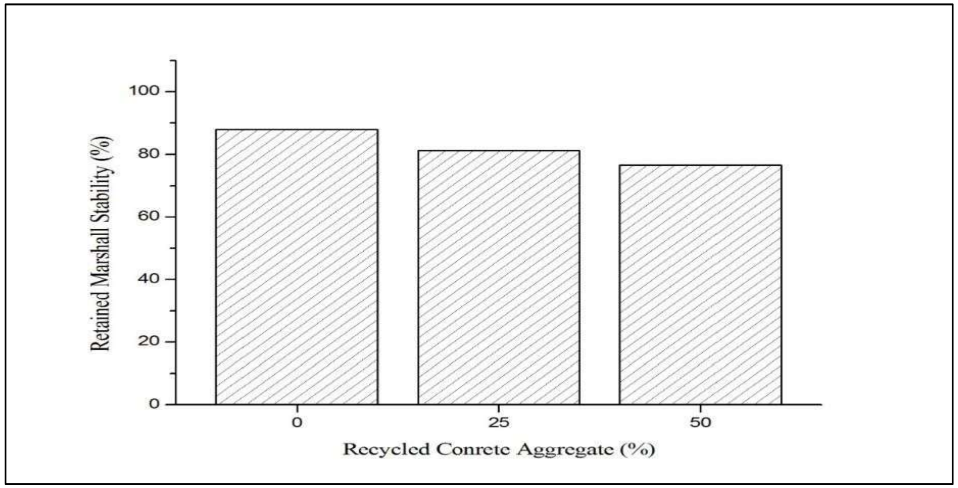
S. No.	Mix	OBC (%)	Specifications
1	Control mix	4.9	Minimum 4.5% for DBM Grading-II
2	RCA-25	5.1	
3	RCA-50	5.2	
4	RAP-25	4.8	
5	RAP-50	4.9	

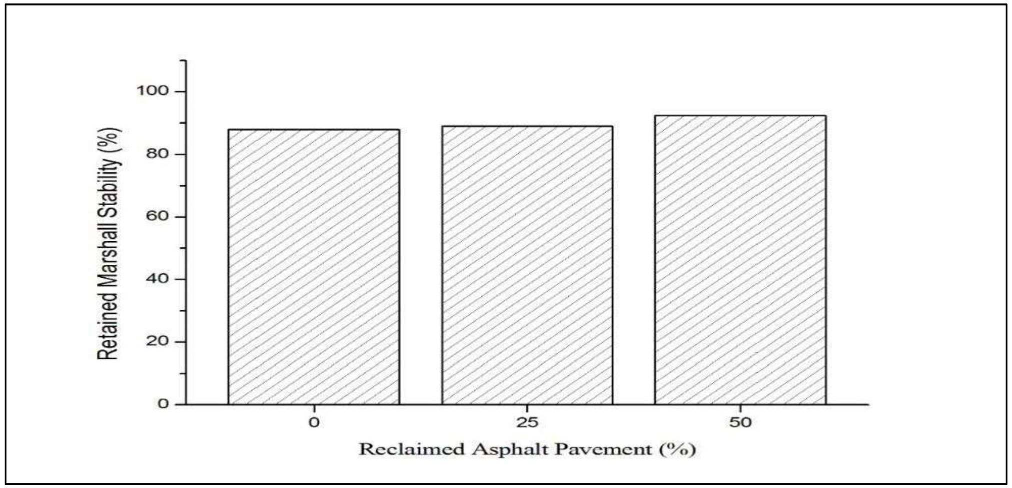
S. No.	Marshall Property	Obtained value					Specifications
		Controll ed mix	Uncontrolled mix				
			RCA-25	RCA-50	RAP-25	RAP-50	
1	Stability, (kN)	19.09	18.5	17.87	22.36	21.37	09 (min)
2	Flow, (mm)	2.60	2.65	2.51	2.44	2.46	2-4
3	Air void, (%)	2.84	3.19	3.35	3.72	3.20	3-6
4	VFB, (%)	80.51	78.97	77.75	74.43	76.65	65-75
5	VMA, (%)	14.66	15.88	15.94	15.28	14.91	13 (min)

ITS and TSR-RCA : AASHTO T 283

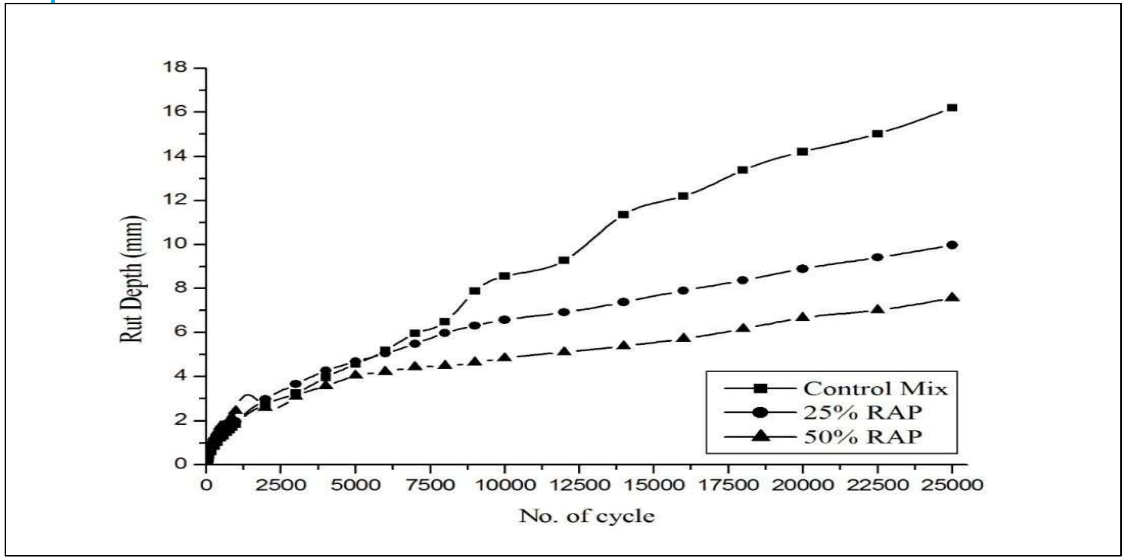








Wheel Tracking Test



Mix Type	Rut Depth (mm)
Control Mix	16.20
25% RCA	21.35
50% RCA	24.52
25% RAP	9.97
50% RAP	7.57

Cost Comparison

Items	Cost Incurred (Yes or No)					
	Virgin Aggregate	Virgin Bitumen	Carriage of Virgin Aggregate and Bitumen	Demolishing	Crushing or Milling	Extra transportation
Conventional material	Y	Y	Y	N	N	N
RCA	Y	Y	Y	N	Y	Y
RAP	Y	Y	Y	Y	Y	Y

Contd..

S. No.	RCA (%)	Material cost (Rs./cum)	Saving (Rs./cum)	Savin g (%)
1	0	6560.47	0.00	0.00
2	25	6503.80	56.67	0.86
3	50	6261.25	299.22	4.56
4	75	6018.69	541.78	8.26
5	100	5776.13	784.34	11.96

S. No.	RAP (%)	Material cost (Rs./cum)	Saving (Rs./cum)	Saving (%)
1	0	6560.47	0.00	0.00
2	25	5288.88	1271.59	19.38
3	50	4017.30	2543.17	38.77
4	75	2745.72	3814.75	58.15
5	100	1474.13	5086.34	77.53

Conclusions

- Specific gravity, water absorption, AIV for 100 and 75% RCA and LAAV for 100% RCA were found unsuitable for any bituminous construction as per morth, 2013 specifications.
- The adopted combined gradation of rap and virgin aggregate was found to be under the specified limits for the DBM Grade-II
- DBM mixes with RCA was found to be more susceptible to moisture damage than the control mixes, DBM mixes with rap was found to be more resistive to moisture damage than the control mixes
- DBM with RCA has less rutting than the control mixes, DBM with rap has more rut resistant than the control mixes. RAP and RCA has potential to reduce the material cost for the bituminous mix.

Summary of Lecture

- MM which do not meet current standard highway specifications.
- Use of MM for LVRRs will allow not only economy.
- Conservation of resources use in “premium” pavements.
- Development of new test methods, technology, and specifications
- Overall economics of marginal materials; and
- Good engineering judgment and courage.
- Design issues and Discussions!!