

**CROSS/
ROADS**
LINKING MOBILITY SOLUTIONS



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Use of Fly Ash in Low Volume Roads

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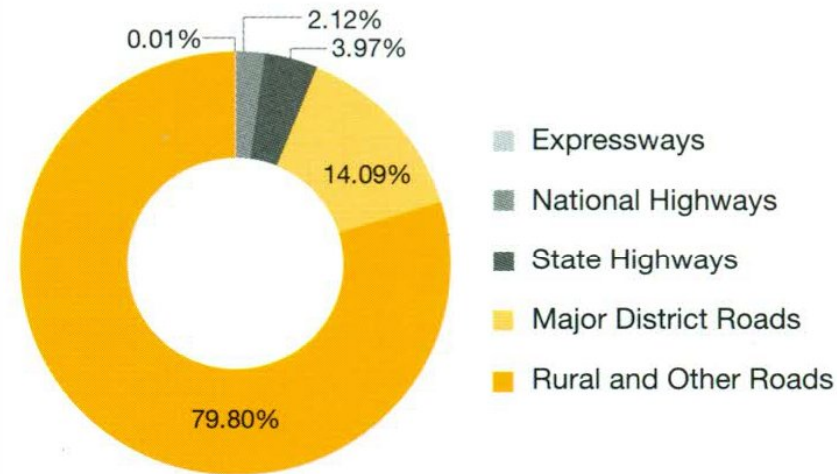


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BACKGROUND

- ❑ Efficient transport system needed for growth of economy
- ❑ India has extensive road network of 5.6 plus million kms
- ❑ 80% comprise rural and other low volume roads
- ❑ National highways are only about 2%, but carry 40% of the road traffic



Source: NHAI

- ❑ No. of vehicles growing at more than 10% per annum
- ❑ Stressed road infrastructure using aggregates largely
- ❑ Road network for all terrains and environment
- ❑ Conventional construction materials depleting fast
- ❑ Need of the high performance/new/alternate materials





Introduction

- **Design options(IRC:37-2012) provide 2-150 MSA, CBR varying 3%- 15%. Use of foamed bitumen, Reclaimed Asphalt Pavement, Cement Treated base and Sub-base course with aggregate Interlayer and stress Absorbing Membrane Interlayer recognised, needs strong database**
- **Design for ≤ 2 MSA is done as per IRC: SP-72(Low Volume Rural Roads) considered in the present work**
- **MDR, ODR and VR make above 90% of road network**
- **To minimize the cost and usage of natural aggregates, waste materials/ industrial by- products(Blast furnace slag, Pulverized fuel ash, Gypsum and Cement kiln dust, Copper slag, Fly ash, Tin slag, Zinc slag etc.) can potentially be used in road construction**
- **Result in sustainable road development in the long run**

Flyash-Scenario in India

- **Fly ash, a by-product of burning coal during power generation in thermal power plants(India generates its 70% of power in TPPs)**
- **Indian coals have 30-45% ash content (against imported 10-15%)**
- **Large quantity of ash thus requires large area of land for disposal. Also, major sources of pollution of both air and water**
- **Flyash has limited use in roads; filling, embankment and cement constituent**
- **Present study considered the use of fly ash in pavement base and sub-base**
- **145 thermal power stations generate 184 m t(million tons) fly ash**

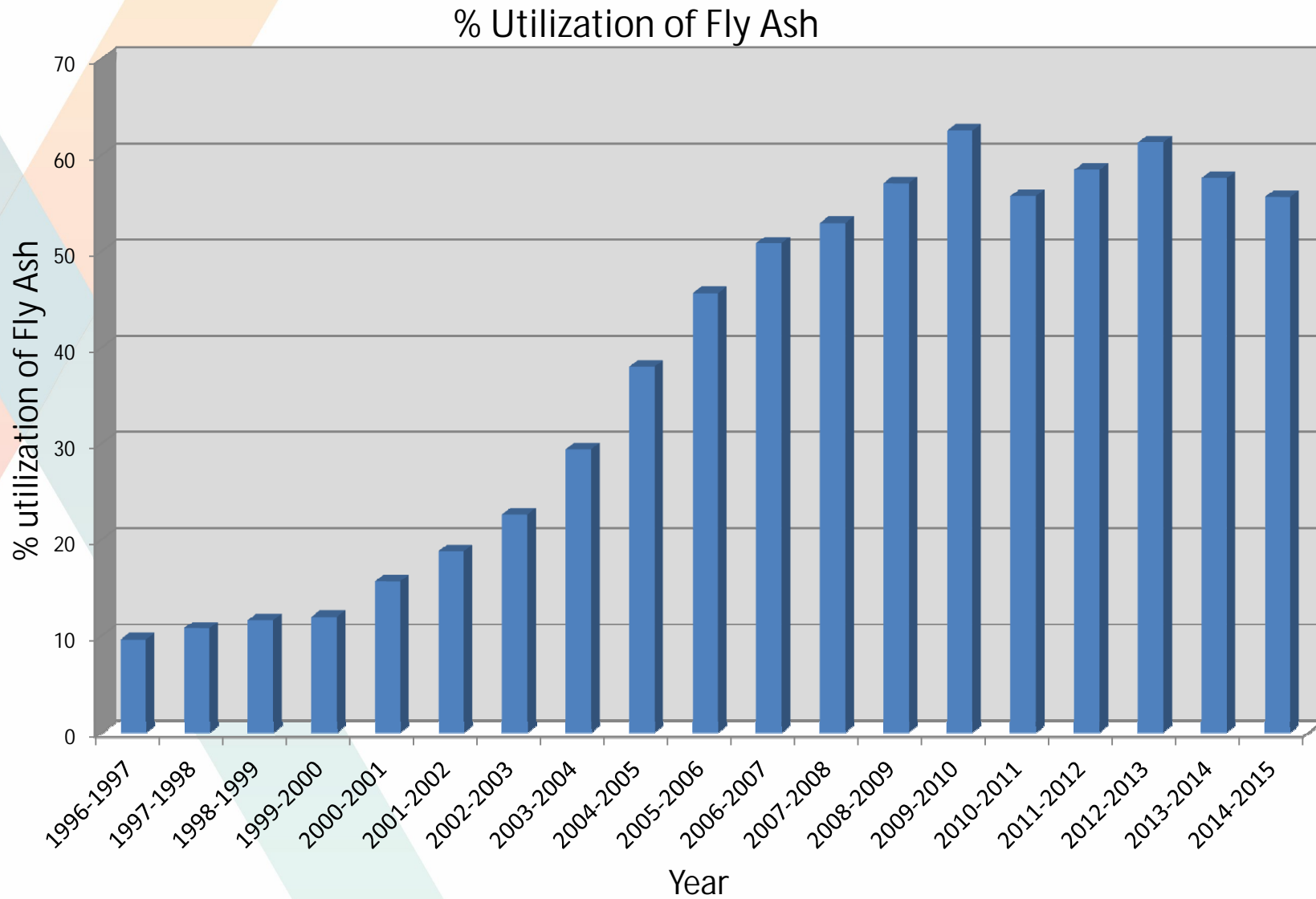
Flyash-Scenario in India(..contd.)

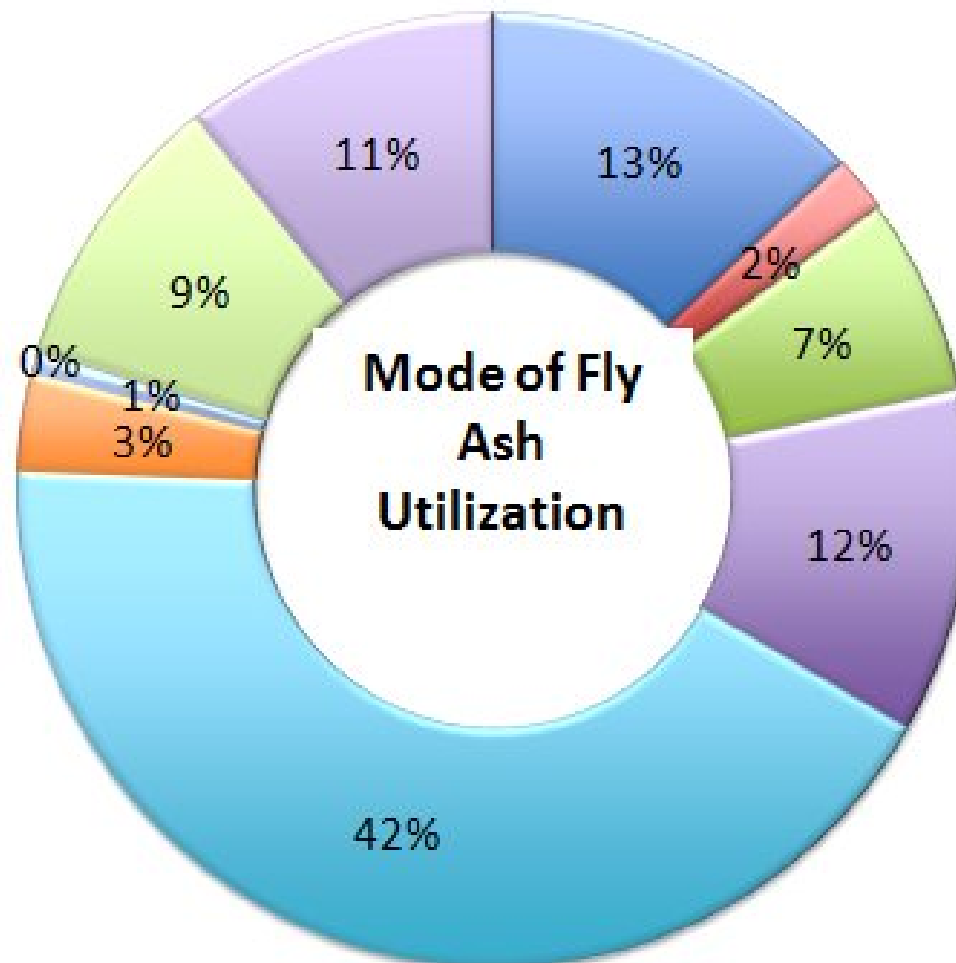
- **The Fly ash utilisation is about 102 m t; about 56 % of the generation The average ash content is about 33 %**
- **The Fly Ash utilization is still less 60% in about 34 % of the thermal power station and only 24 % thermal power plant are fully utilizing fly ash**
- **There is considerable scope of Fly Ash Utilization in Road Construction**
- **Fly ash, generally considered as a traditional stabiliser**
- **The properties of fly ash can vary significantly depending on the source of the coal and the steps followed in the coal burning process**
- **Fly ash can broadly be classified into class C (self-cementing) and class F (non-self cementing) fly ash based on chemical composition (ASTM C 618)**

Summary of Fly ash Generation and Utilisation

Description	Source, CEA, 2014-15
Number of thermal Power plant reported	145
Installed Capacity (MW)	1,38,915.80
Coal Consumed (Million tons)	549.72
Fly Ash Generation (Million Tons)	184.14
Fly Ash Utilization (Million Tons)	102.54
Percentage Utilization	55.69
Percentage average ash content (%)	33.5

Fly ash Utilisation Pattern Over the Years





- Mine Filling
- Agricultural
- others
- Bricks and Tiles
- Cement
- Road and Fly Over
- Concrete
- Hydro Power Sector
- Ash Dike Raising
- Reclamation of Low Lying Area

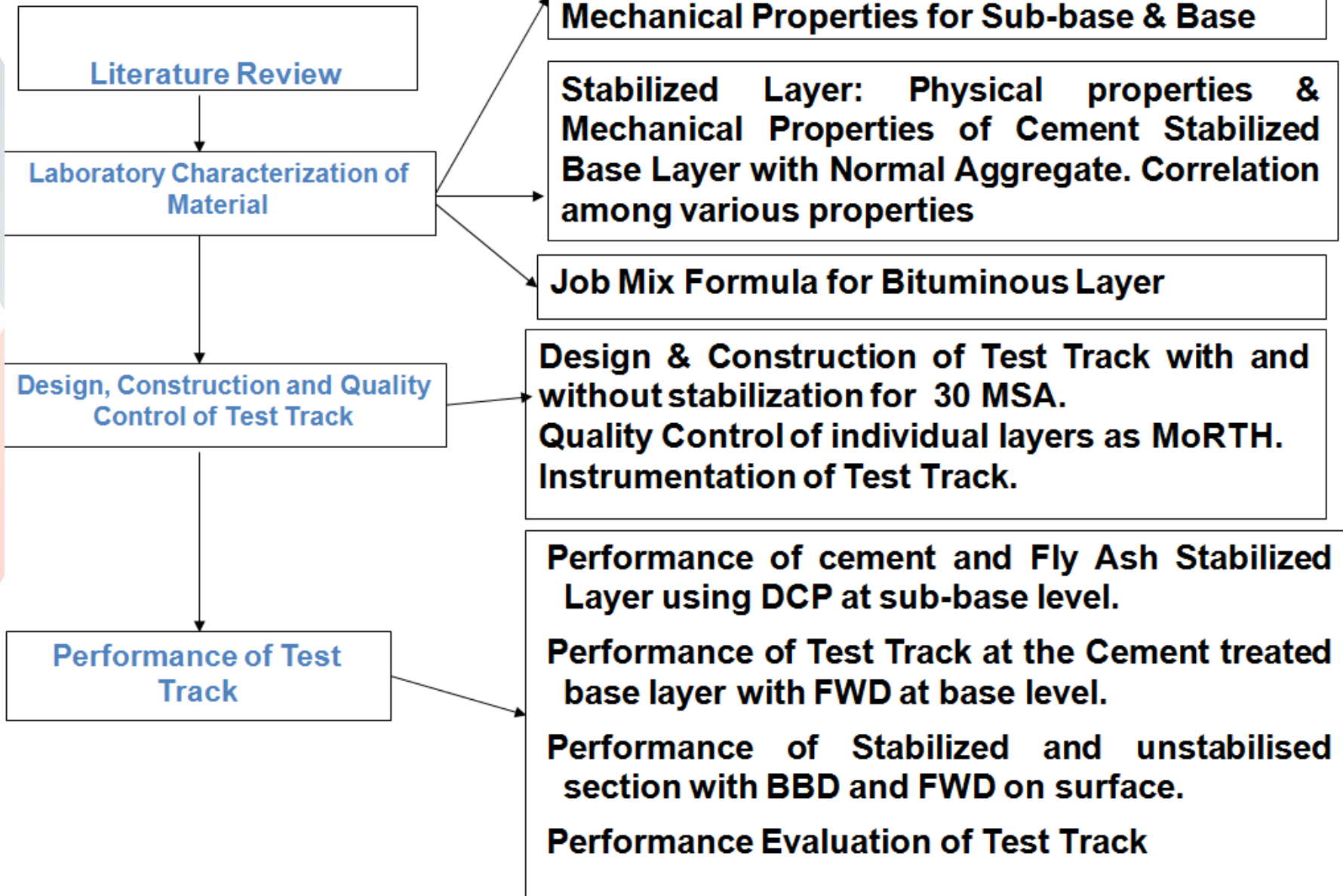
Methodology

- Use of fly ash in bound form in the sub-base/base layers
- Focus on roads catering to low to medium traffic which constitute bulk of our road network
- Designs as per IRC guidelines for subgrade(soil) with CBR 5 % to serve traffic of 30 msa, 2 msa & 0.5 msa
- Conventional granular and cemented control sections
- The mix (fly ash + Cement) to be selected based on strength and durability criteria outlined in IRC and other relevant codes
- Two parameters are variants in cemented layers:
 - Cement content
 - Thickness

Methodology (.....contd)

- M_R to be determined through laboratory testing on stabilised fly ash mixes
- Semi-field evaluation for Fatigue /Rutting characteristics
- Test sections to be adequately instrumented for monitoring pavement responses
- Outline the calibration required in fatigue life estimation of bound base/ sub-base materials and their strength characteristics in terms of M_R
- Interpretations/Analysis for a suitable performance criteria

Methodology



Physical Properties of Fly ash used

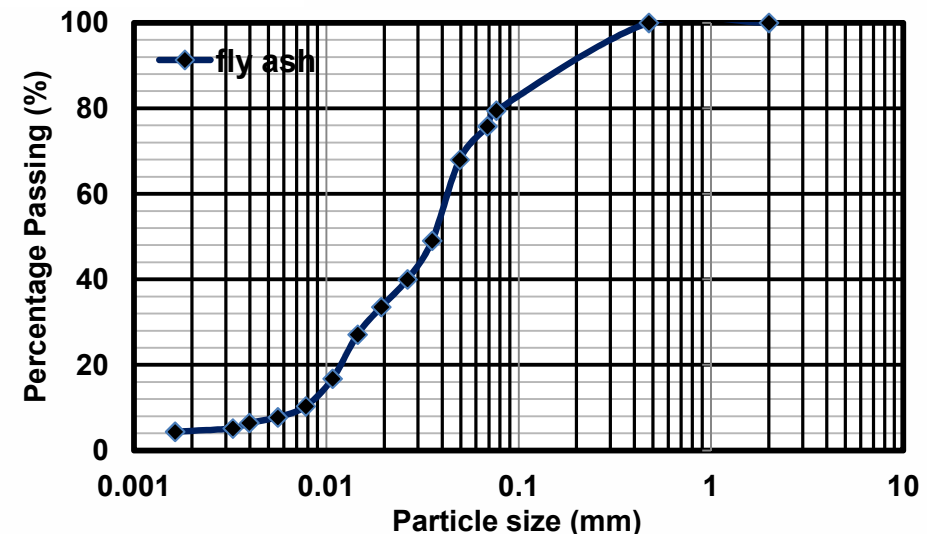
The specific gravity of Fly Ash used is 1.98.

Sl. No.	Characteristics	Requirements	Obtained
1.	Fineness-specific surface in m^2/kg by Blaine's permeability test, min	250	349
2.	Particles retained on 45 micron IS sieve, max	40	21
3.	Lime reactivity in N/mm^2 , Min	3.5	4.6
4.	Soundness by autoclave test expansion of specimen in per cent Max	0.8	0.02

Aggregate Properties

(Source: Western U.P)

1. Impact Value- 11.23%
2. Water Absorption – 0.2%
3. Specific Gravity
 - Coarse- 2.61
 - Medium- 2.68
 - Fine- 2.48



Chemical Composition of Fly Ash

Thermal power plant	Chemical Composition (%)										
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Sx	CaO	MgO	Na ₂ O	P ₂ O ₅	SO ₃	C	LOI
Chandrapur, Maharashtra	66	23	4	93	2	0.4	0.85	0.5	0.2	0.1	0.4
Badarpur, New Delhi	60	25	6	91	1	0.5	1.3	1	0.4	0.9	2
Tuticorin, Tamil Nadu	65	20	5	90	1	0.5	1.2	0.5	0.4	0.9	2
Simhadri, Andhra Pradesh	63	25	6	94	1	0.7	1.2	0.7	0.2	0.2	3
Singrauli, Madhya Pradesh	66	22	6	94	1	0.6	1.3	0.3	0.2	0.2	0.5
Dadri, Uttar Pradesh	62.5	28	4.98	95.5	1.5	0.85	Others= 1.52				0.6

Requirements of Cement Bound Materials for Base/Sub-Bases/Capping Layer

Sieve Size, mm	Rural Roads Specifications 2014	
	Sub-base/Base	
53.0	100	
37.5	95-100	
19.0	45-100	
9.5	35-100	
4.75	25-100	
0.600	8-65	
0.300	5-40	
0.075	0-10	
7 days UCS(Mpa)	1.7(sub-base)	3.00(Base)
	(Compressive Strength)	
* Average of a batch of 5 cubes ** Minimum strength of individual cube within the batch		

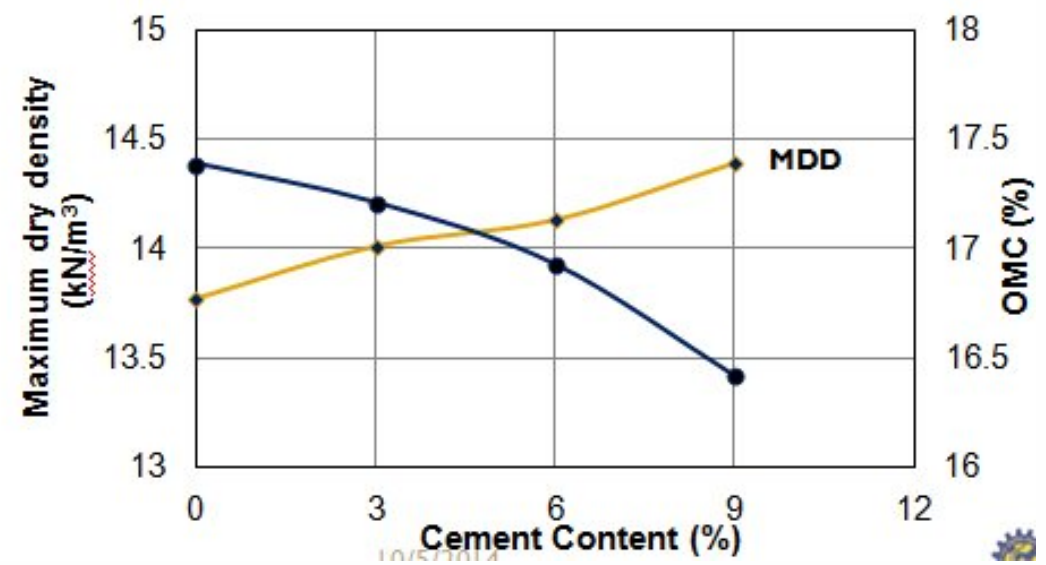
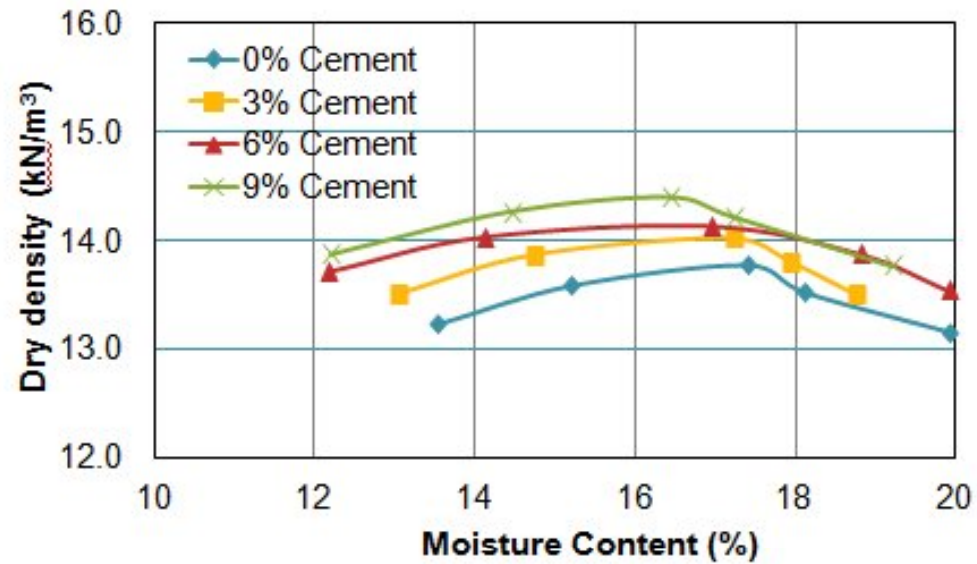
Envisaged Tests on Cement-Flyash Stabilised Courses

1	Compaction Properties	Sub-Base/ Base
2	UCS/Compressive Strength	Sub-Base/ Base
3	Durability	Sub-Base/ Base
4	Flexural Strength	Sub-Base/ Base
5	Indirect Tensile Strength	Sub-Base/ Base
6	Repeated Triaxial(M_R)	Sub-Base/ Base

Stabilized Sub-base layer

- **A combination of cement and fly ash chosen at Cement : Fly ash :: 3%:97%, 6%:94% and 9%:91%**
- **A series of test were conducted on these blends, which includes compaction test, unconfined compressive strength test, indirect tensile strength, modulus of resilience test, durability test**
- **The unconfined compressive strength and durability criteria was fixed to optimize the percentage of cement in the mixture**
- **Based on strength and durability criteria the cement content of 7% percent was chosen as the optimum cement content for the construction of pavement with maximum utilization of fly ash in this layer, which is approximately 93%.**

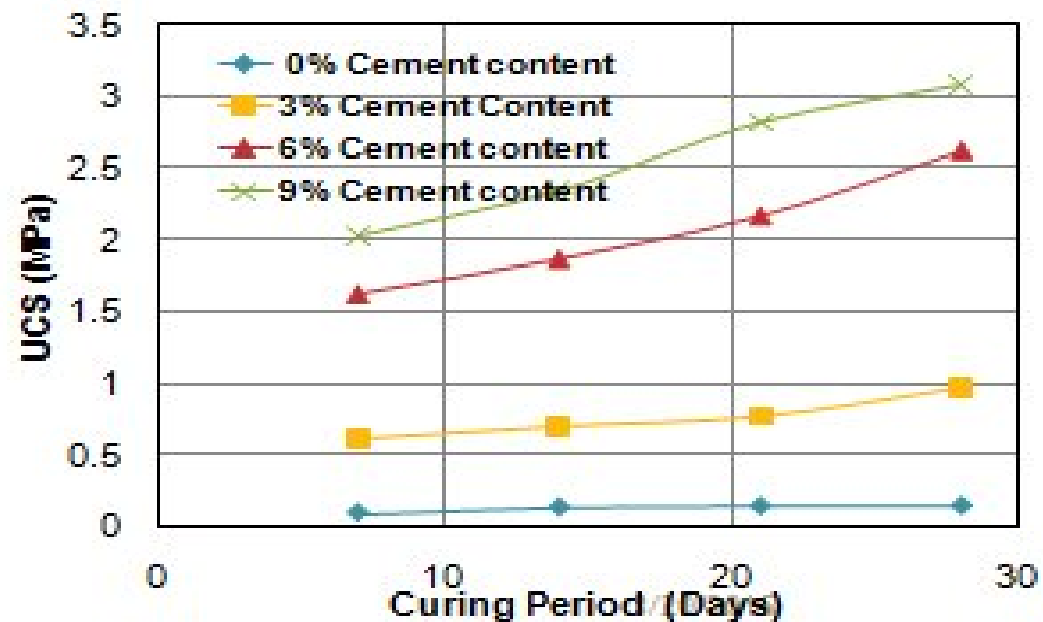
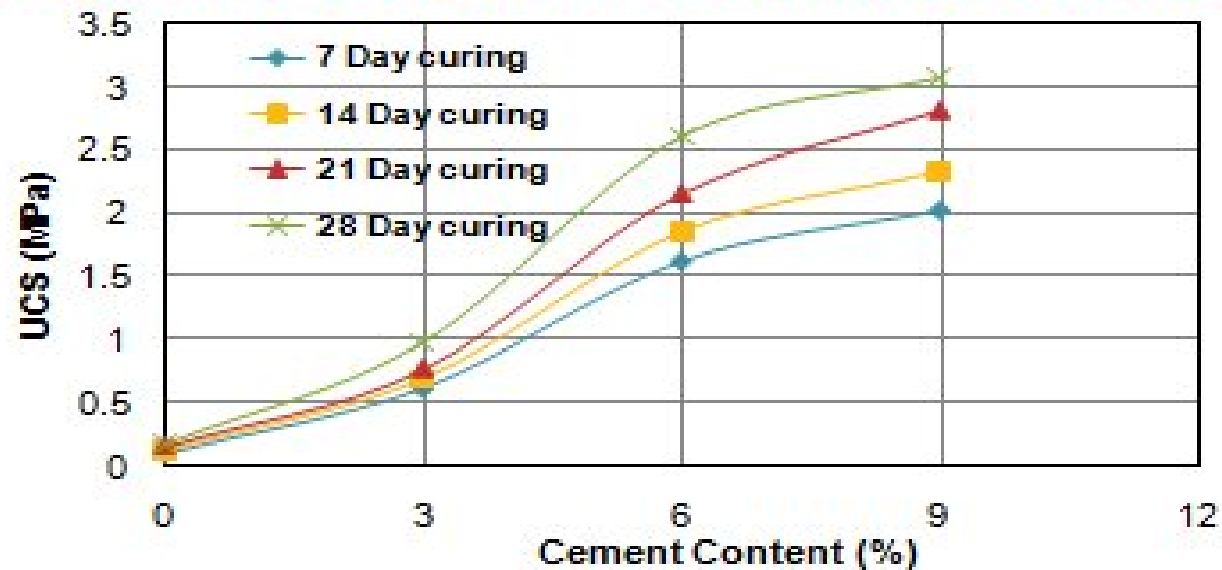
MODIFIED PROCTOR TESTS



10/5/2014



UNCONFINED COMPRESSION TESTS



DURABILITY TESTS

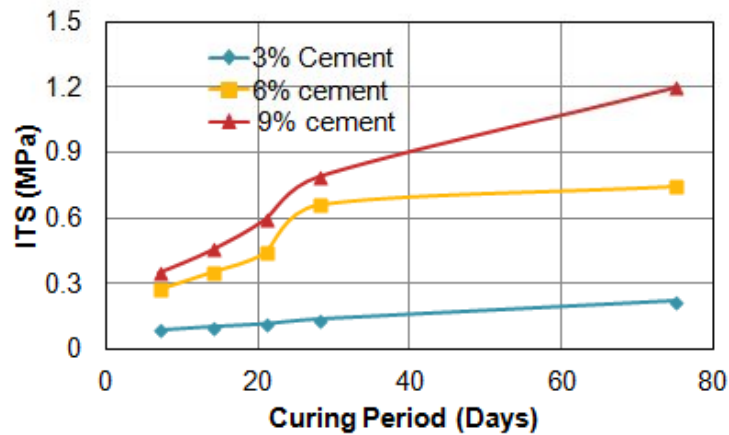
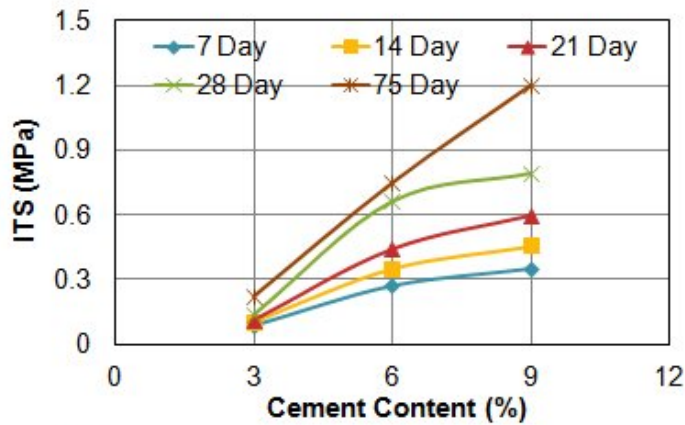


View of 3% cement
stabilized samples after
12 cycles

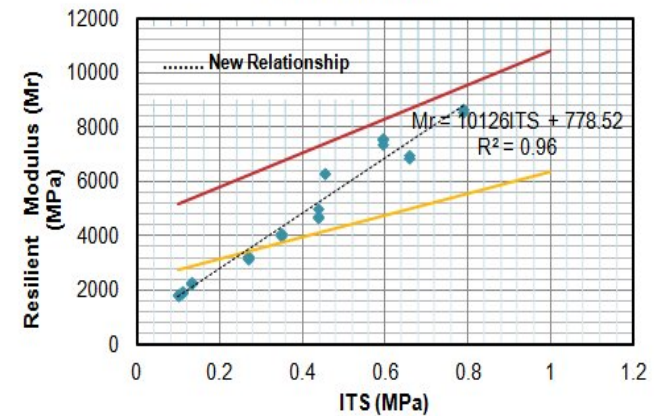
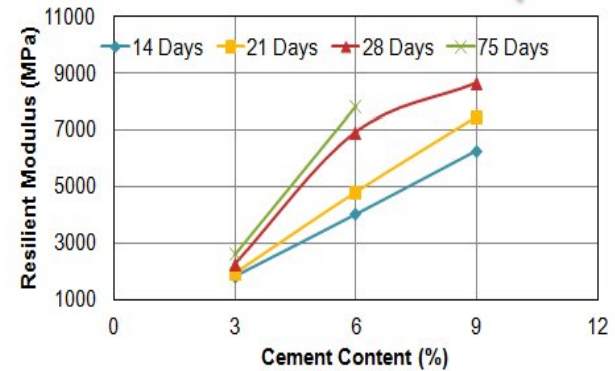


View of 6% cement
stabilized samples after
12 cycles

INDIRECT TENSILE STRENGTH (ITS) TEST



RESILIENT MODULUS TEST (Contd.)



Summary of Cement-Fly ash Mix Properties(Completed)

Compaction Characteristics

Cement Content, %	MDD, (kN/m ³)	OMC, (%)
0	13.77	17.3
3	14.0	17.2
6	14.1	16.9
9	14.3	16.4

Strength(UCS) Characteristics, MPa

Cement Content, %	Curing Period, Days			
	7	14	21	28
0	0.15	0.18	0.22	0.25
3	0.55	0.60	0.75	1.00
6	1.55	1.80	2.10	2.55
9	2.00	2.35	2.80	3.05
Specified(MoRD)	1.7			

ITS Characteristics, MPa

Cement Content, %	Curing Period, Days			
	7	14	21	28
3	0.12	0.14	0.15	0.16
6	0.28	0.35	0.43	0.65
9	0.32	0.45	0.60	0.78

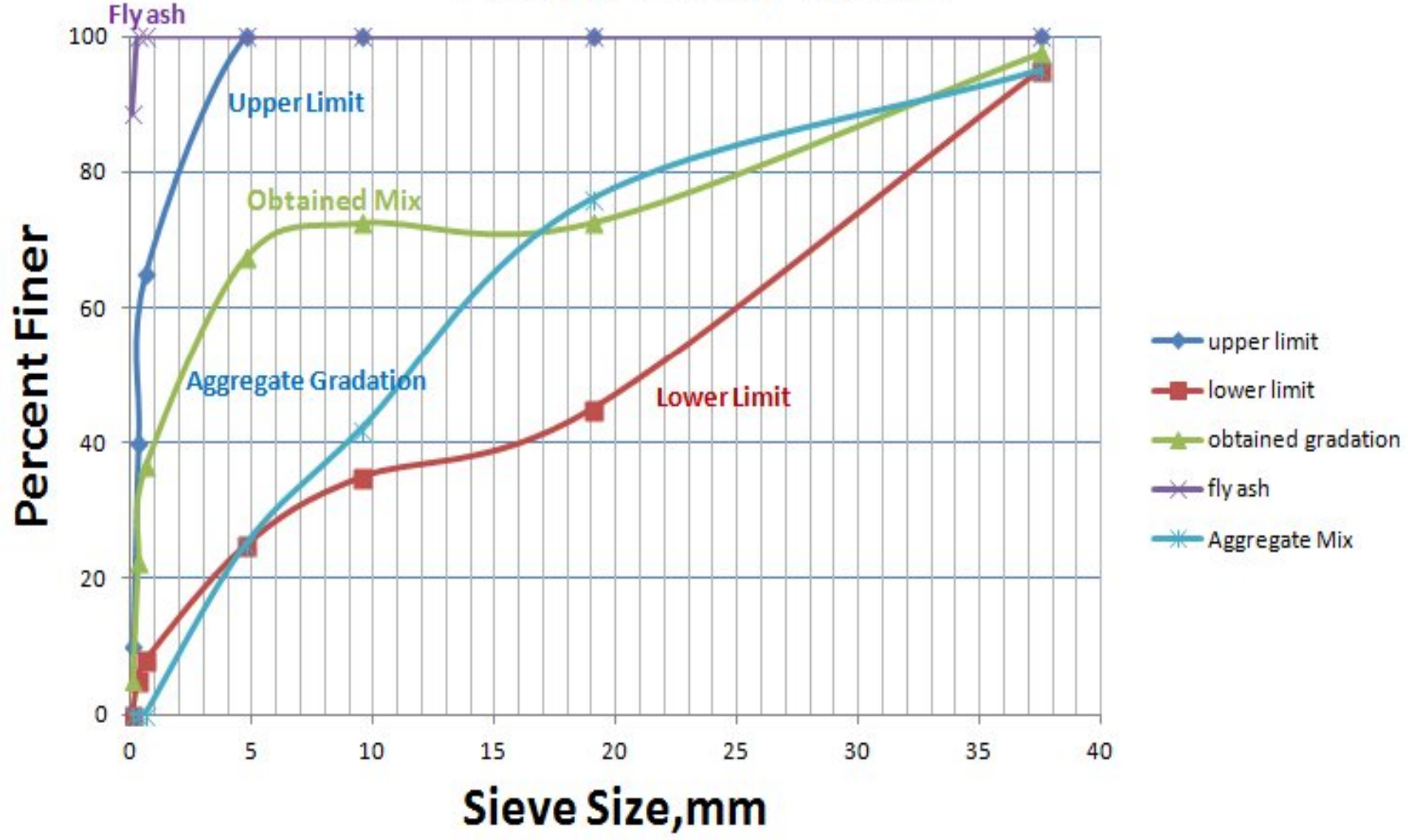
Modulus(M_R) Characteristics, MPa

Cement Content, %	Curing Period, Days			
	7	14	21	28
3	2000	2100	2270	2500
6	4500	4650	4950	6950
9	6100	6180	7250	8500

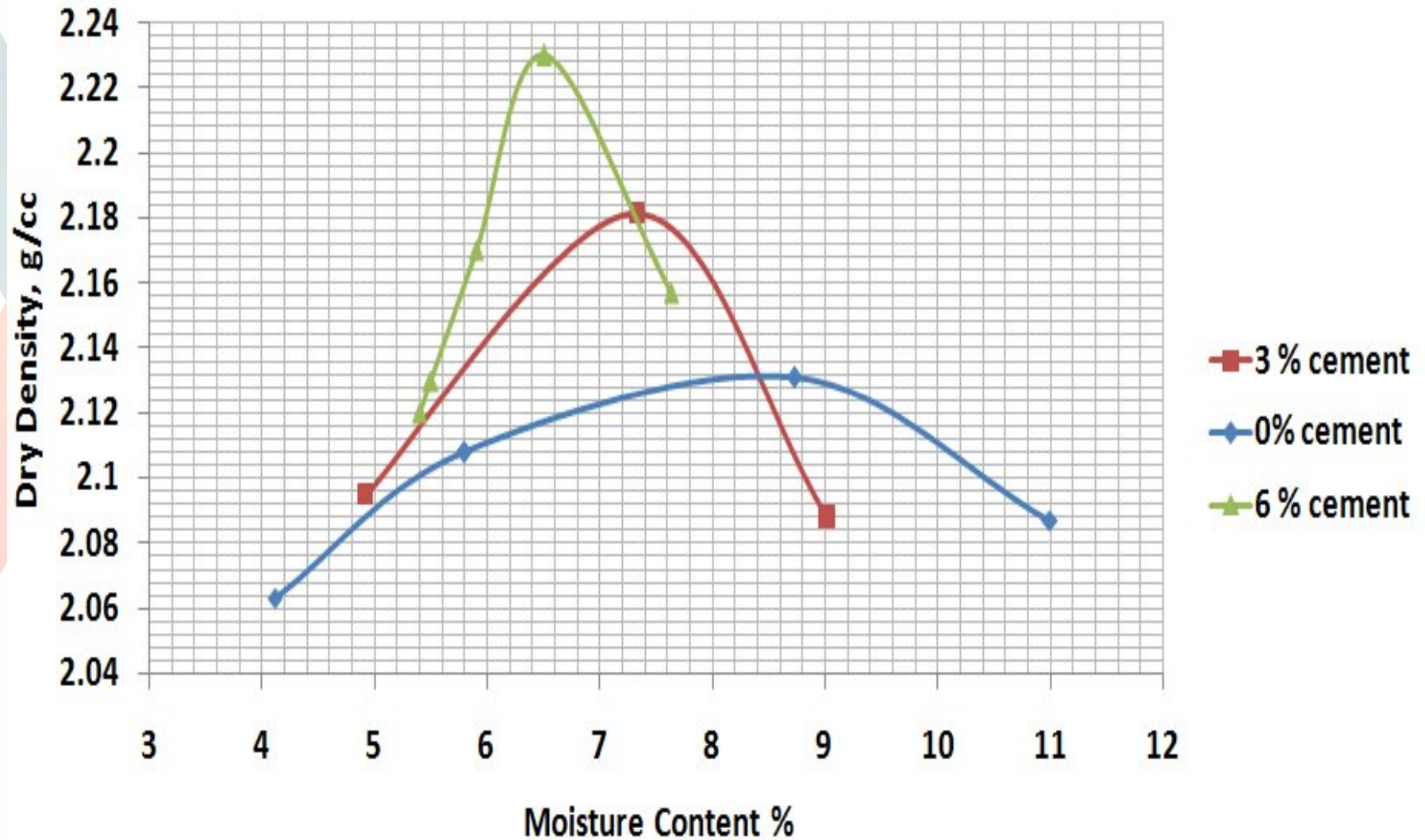
Cement Stabilized base Layer

- **The base layer of the pavement was stabilized with cement, fly ash and aggregate.**
- **Optimising of the particle size arrangement of fly ash and aggregate was done in line with IRC SP-89:2010. The optimum percentage of fly ash and aggregate was found to be 22% fly ash and 78% aggregate.**
- **The cement content was varied from 3,6 and 9% respectively.**
- **The targetted minimum strength of unconfined compressive strength of the base layer was 4.5 MPa and the minimum durability of mix above 80%.**

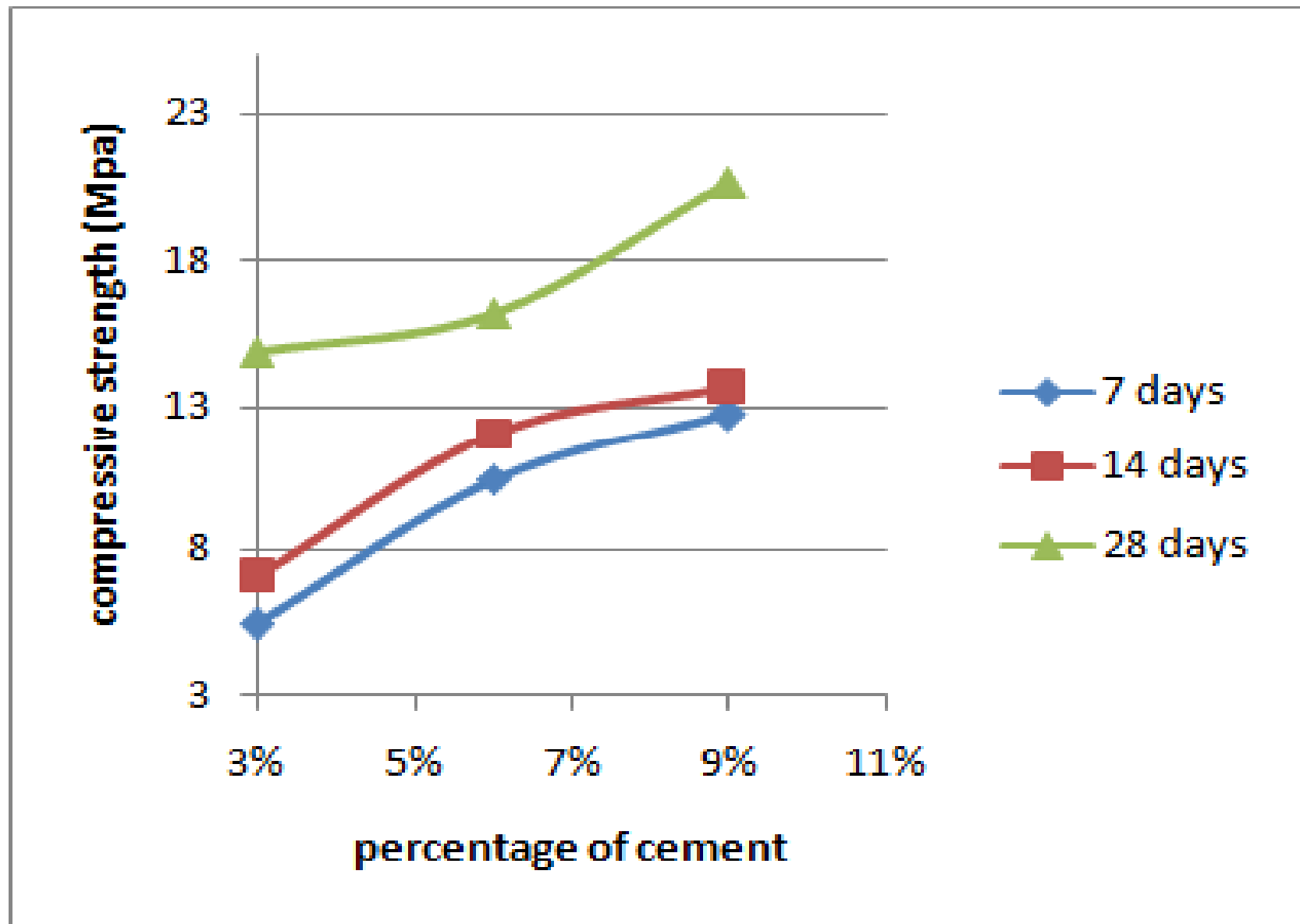
78% agg. :22 % fly ash mix



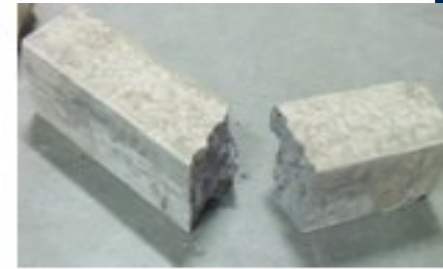
Compaction Properties **Aggregate:fly ash::78:22**



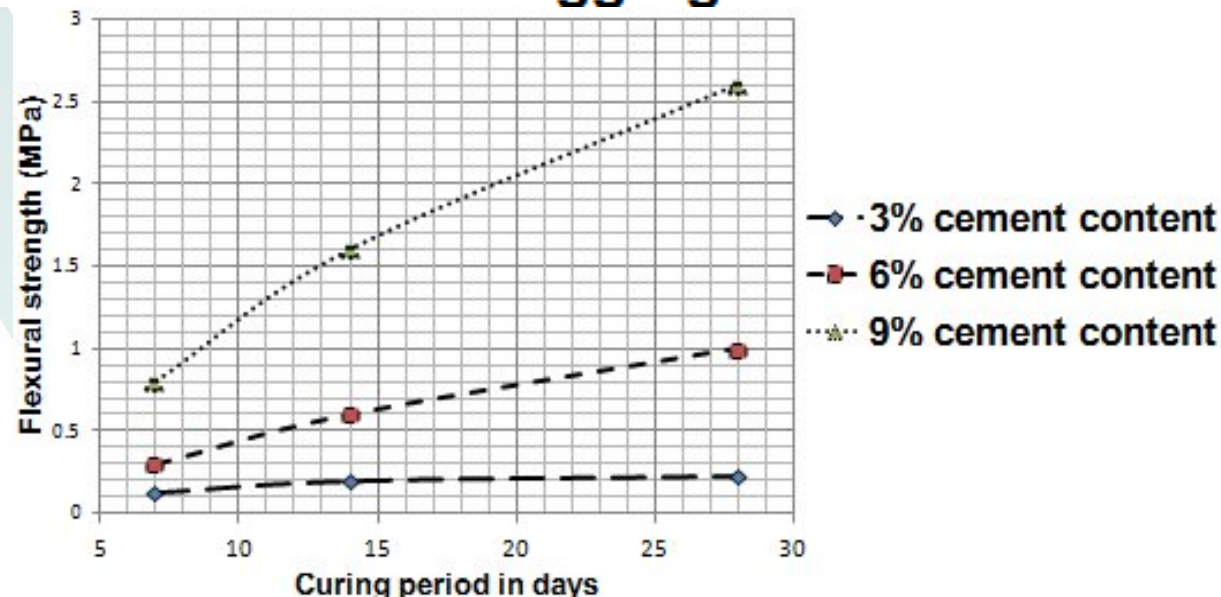
COMPRESSIVE STRENGTH TEST



Flexural Strength



- Flexural strength is one of the measures of the tensile strength of the concrete. It is a measure of a beam or slab to resist failure in bending.
- The flexural strength is expressed as Modulus of Rupture (M_R). Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used.



Summary of Cement-Fly ash-Aggregate Mix Properties(FA:A::22:78)

Compaction Characteristics

Cement Content, %	MDD, (kN/m ³)	OMC, (%)
3	21.81	9.0
6	22.31	10.0
9	22.06	12.0

Strength(UCS) Characteristics, MPa

Cement Content, %	Curing Period, Days		
	7	14	28
3	5.4	7	14.9
6	10.4	12	16.2
9	12.7	13.59	20.67
Specified	3(Rural Roads)		

ITS Characteristics, MPa

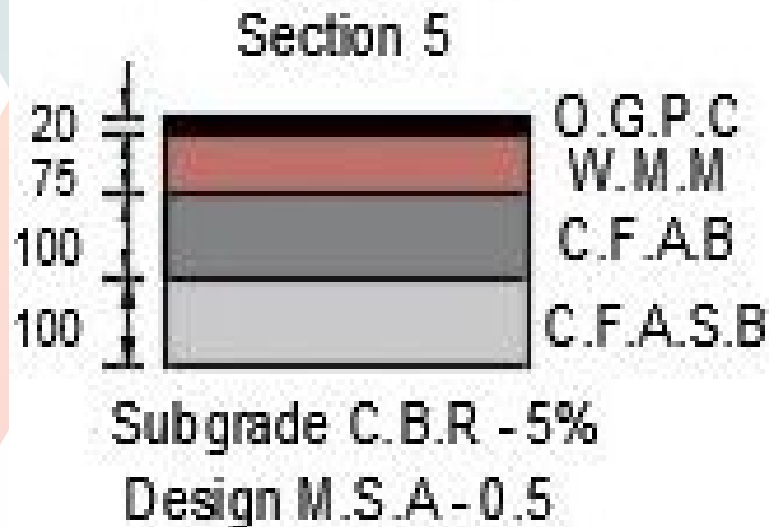
Cement Content, %	Curing Period, Days		
	7	14	28
3	4.45	5.02	6.07
6	5.82	10.43	12.68
9	9.22	12.84	14.31

Modulus(M_R) Characteristics, MPa

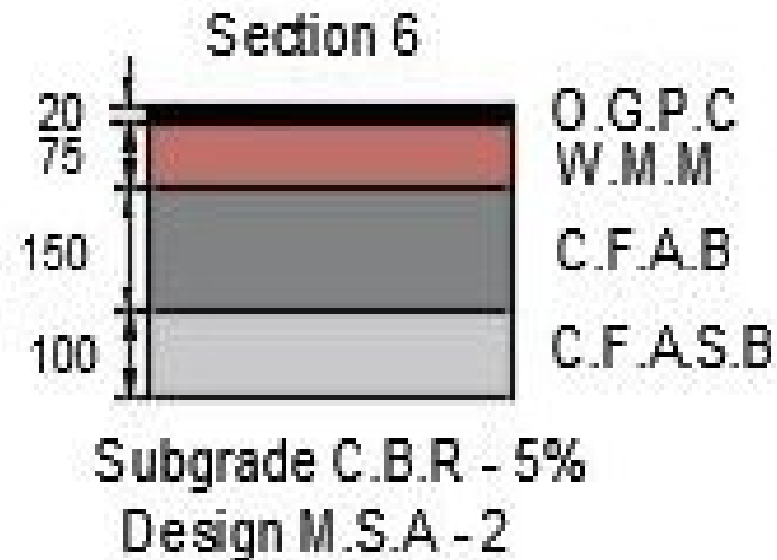
Cement Content, %	Curing Period, Days			
	7	14	21	28
3	32000	35100	40659	46949
6	34500	42122	43878	49538
9	37610	45628	51786	59450

Design Cross-Sections(IRC SP 72:2015)

Stabilised Pavement for Rural Roads



Stabilised Pavement for Rural Roads



Note: - All dimensions are in mm

C.F.A.B - Cement Stabilised Flyash Base

C.F.A.S.B - Cement Stabilised Flyash Sub-Base

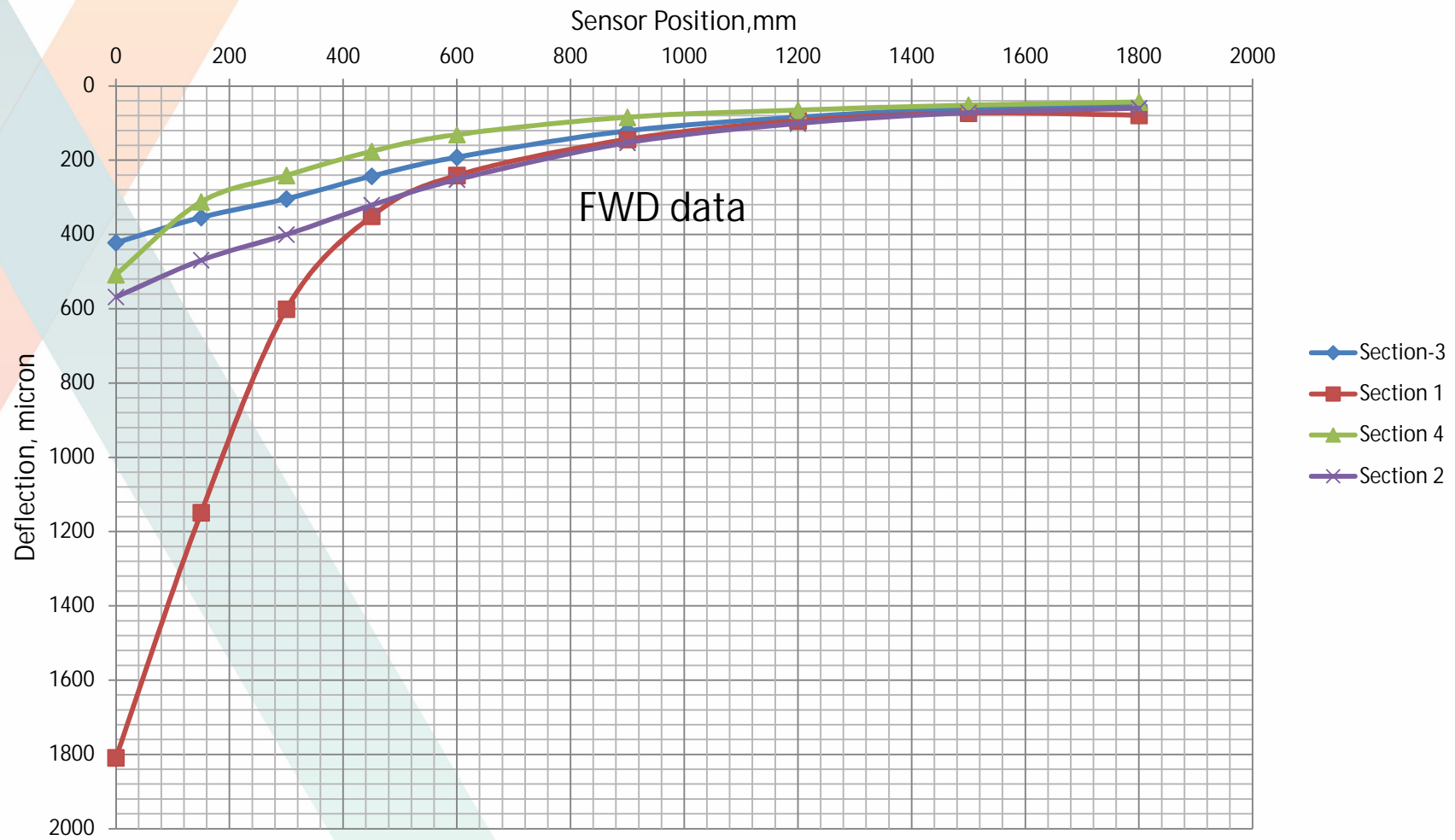
Construction of test section

- **After optimizing the aforesaid percentage of Cement: Fly Ash: Aggregate, the base layer of the test section was finalized.**
- **The sub-base was constructed with a cement content of 7% and fly ash content of 93% composition after getting the desired strength and durability criteria.**
- **The layer was laid in 100-125mm thickness for better compaction.**
- **The aggregate and sub-grade were compacted at OMC and MDD**
- **The bituminous layer was constructed after obtaining Job Mix Formula of Bituminous concrete (16:23:15:44:2::20mm:10mm:6mm:stone dust:lime) with 5.2 percentage OBC and dense bituminous concrete (50:15:33:3::20mm:6mm: stone dust:lime) at 4.7 % OBC by total weight of mix.**
- **The asphalt strain gauges were installed in bottom of bituminous layer and static pressure cell in the granular layer**

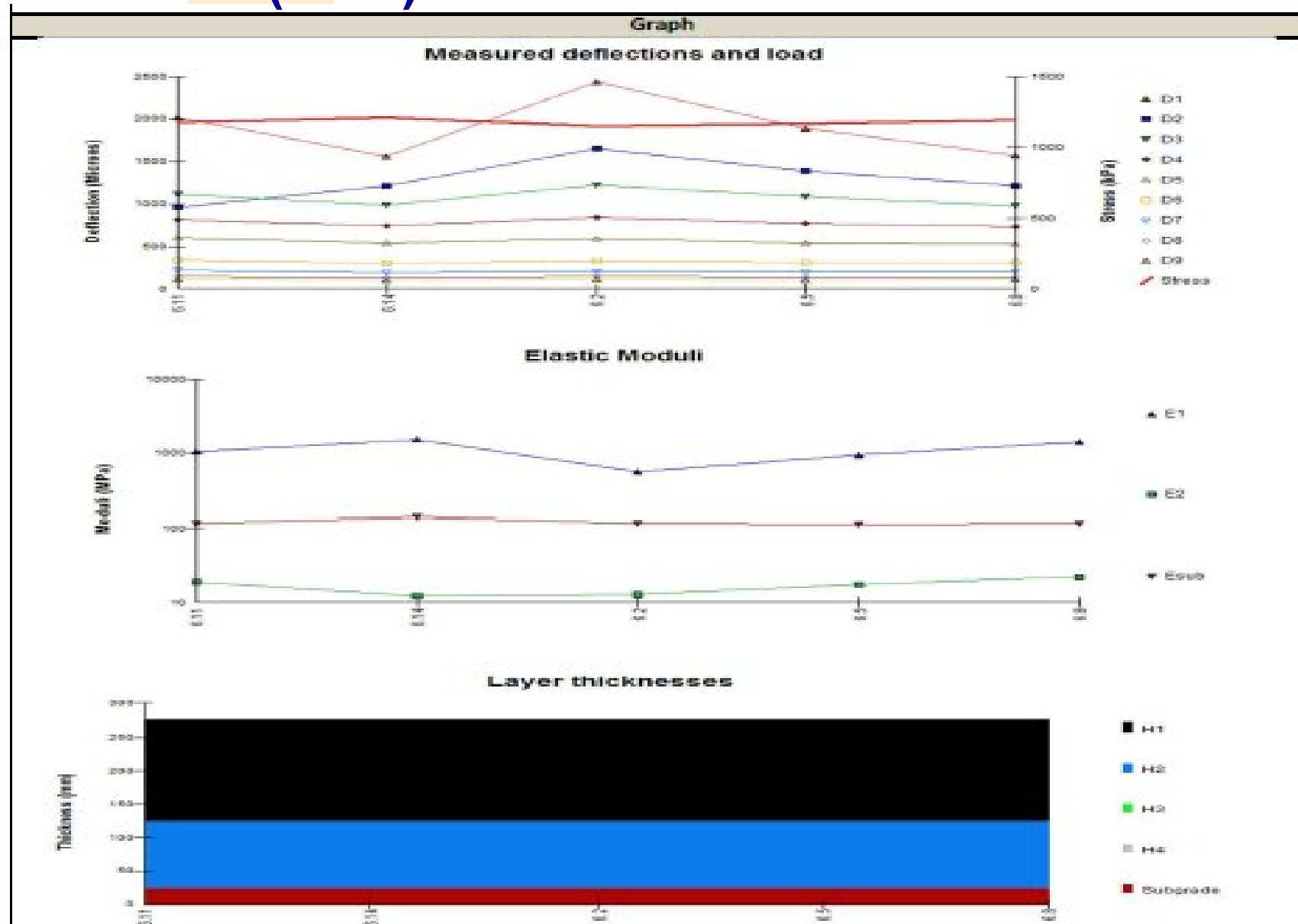




Falling Weight Deflection Test



FWD(NDT) Evaluation– 2 MSA Section



Fatigue Cracking in Cementitious Layers

$$N = RF \times \left[\frac{\left(\frac{113000}{E^{0.0804}} \right) + 191}{\varepsilon_t} \right]^{12}$$

Where,

N = Fatigue life of the cementitious material

RF = Reliability factor for cementitious materials for failure against fatigue

=1 for Expressways/NH/other heavy volume roads

=2 for others carrying < 1500 trucks / day

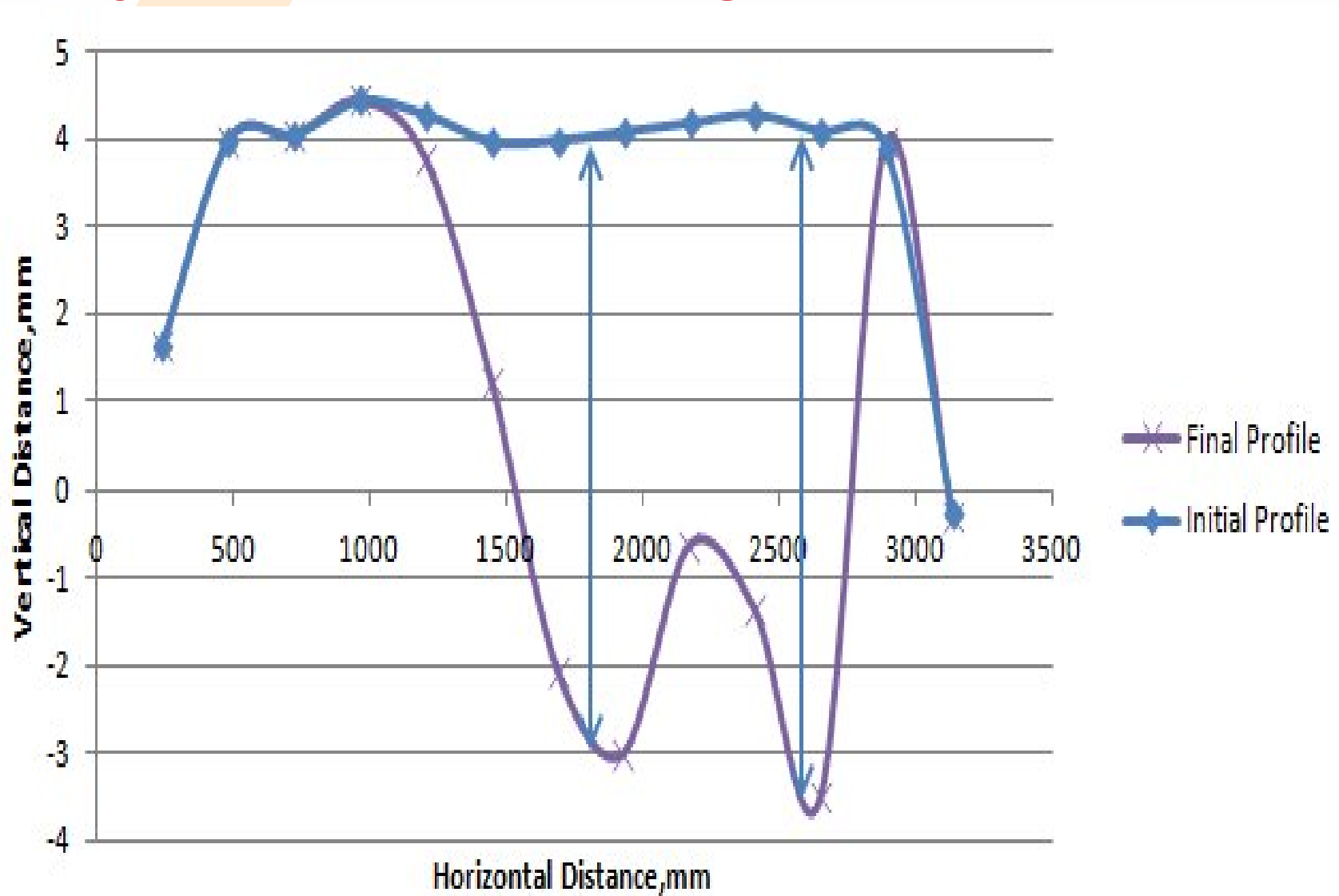
E = Elastic modulus of cementitious material

ε_t = Tensile strain in the cementitious layer (in microstrain)

Analysis by IIT PAVE(For 2 MSA Design)

Modulus(Assumed as per convention)	Poission's Ratio	Thickness (mm)	Load and Tyre Pressure
OGPC -500 MPa	0.4	20	20000 N and 560 KPa
SAMI -450 MPa	0.35	75	
CTB -3200 MPa	0.2	150	
CTSB -700 MPa	0.2	100	
Sub-grade -50 MPa	0.35	-	

Typical Profile Tracking – 2 MSA Section



Concluding Remarks

- **Utilisation of fly ash in different areas of engineering such as embankment construction, cement industry, concrete, as adsorbent in waste water treatment plant, bricks, building materials, as a backfill material etc. is being done**
- **Despite the effort of the Government of India and Researchers, the utilisation of Fly Ash is still around 56% (CEA, 2015).**
- **In order to further amplify the usage of fly ash in other areas, especially in road sector, the stabilisation of base and sub-base layer of pavements with fly ash and cement is a viable option as shown by the present study.**

Concluding Remarks

- **The present study summarises the comprehensive usage of Fly Ash in base and sub-base layer of pavement from laboratory optimization of Fly Ash to design of pavements and construction of pavements through low volume road.**
- **The usage of Fly Ash there will achieve considerable saving of fresh aggregate in sub-base layer and base layer.**
- **Saving is with added benefits of improved performance and quality of the low volume roads as seen in term of laboratory evaluation, design and field construction of the pavements.**
- **This will lead to sustainable development as this utilisation of Fly Ash leads to improved economy, engineering property and social development of the country.**

Further Work

- **The present study, in its scope, covered only one source of fly ash and blending formula, which can be extended**
- **The cement content, especially in base layer and the thicknesses different from the design specified may be verified**
- **Similarly, effects of curing and non-curing with water may be studied**
- **Employing soft/weak aggregates and alternate aggregates like over burnt brick may also be attempted**



Thank You