# New Technology Initiatives in Rural Roads and Use of Marginal Materials

## White topping, Short Panel Concrete Pavements and Cell filled concrete pavements

National Rural Infrastructure Development Agency

Ministry of Rural Development

National Institute of Technology

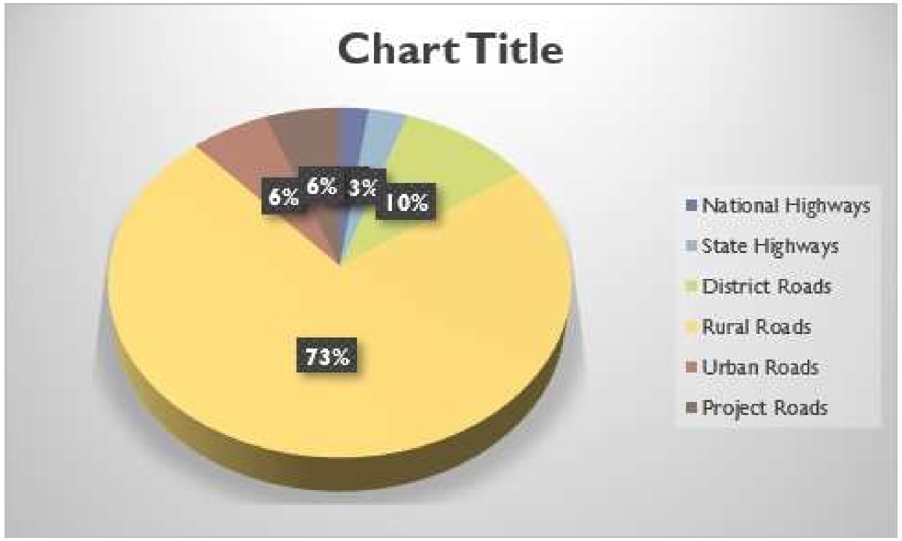
Warangal, Hyderabad

# Lecture 1

## White topping, Short Panel Concrete Pavements and Cell filled concrete pavements

# Road infrastructure in India

- India is having the second largest road network
  - Total length of Road network – 6, 215,797 km

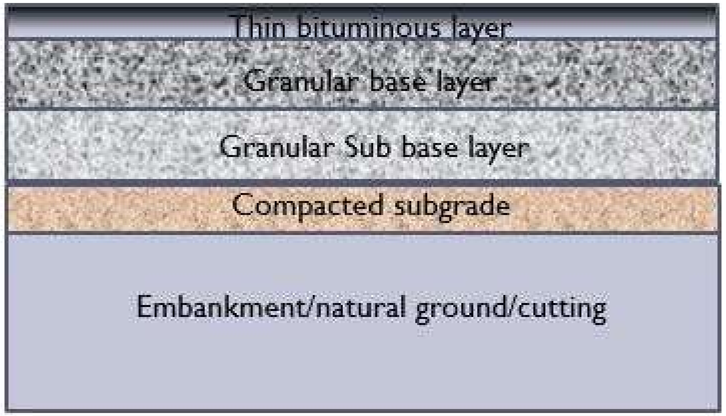


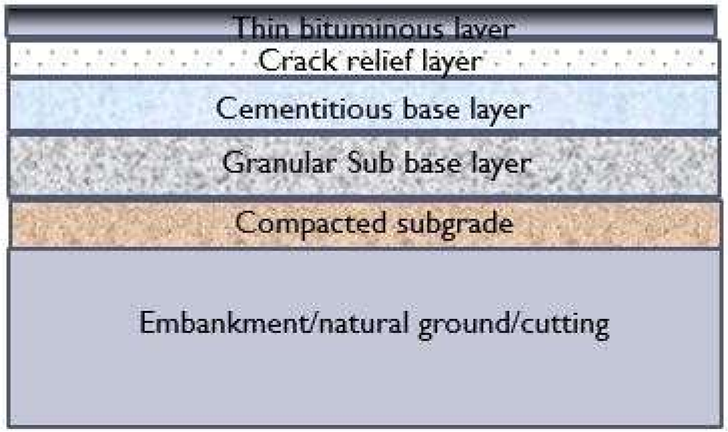

**Administrating authorities**

- MoRTH
- MoRD
  - Panchayat raj
  - PMGSY
- State PWD
- Municipal corporation and municipalities
- Different Govt organisations such as BRO, SAIL, Irrigation etc

Nearly 90% of the pavements in India are constructed as flexible pavements

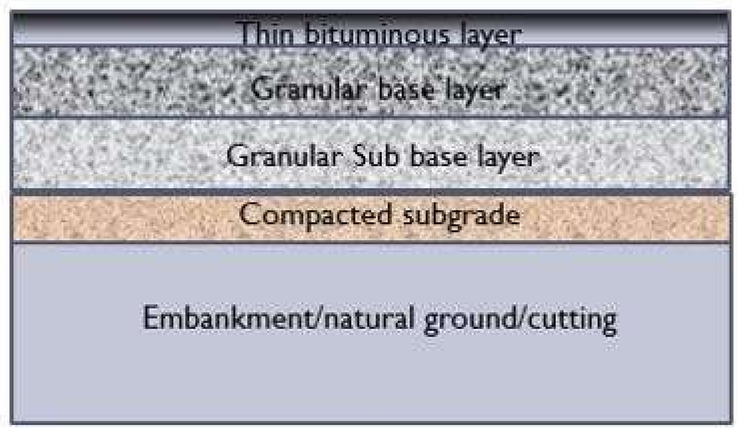
# Typical cross sections of flexible pavements in LVR



# Premature failures of flexible pavements in LVR

- Edge breaks
- Rutting along wheel path (granular layers, subgrade)
- Raveling of bituminous layers, potholes




- Lack of maintenance funds and inappropriate construction practices results in premature failure of bituminous surface, and the road creates discomfort to the passengers

# Premature failure of flexible pavements

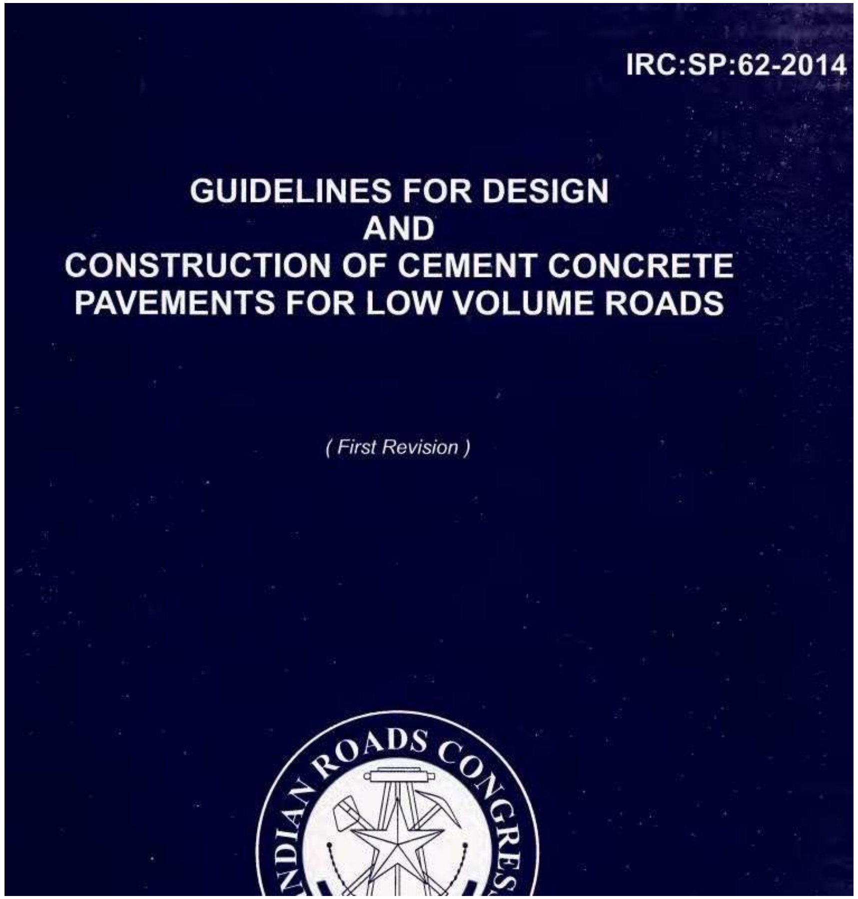
- Unexpected increase in traffic loading, poor maintenance, improper drainage conditions aggravate the rate of deterioration of flexible pavements

# Concrete Pavements

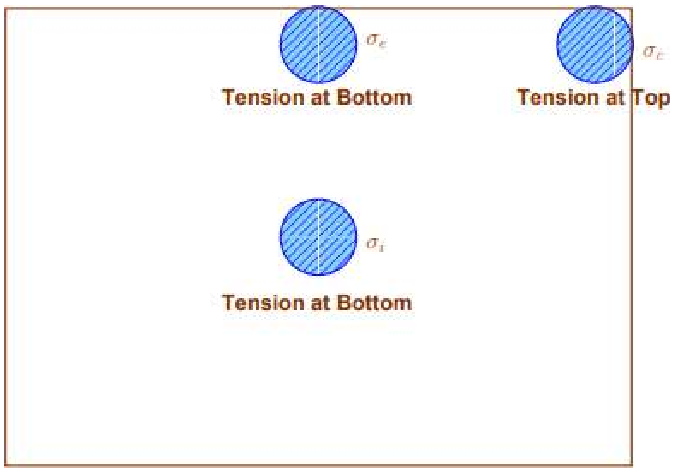
- Generally provided in areas
  - Having poor subgrade strength
  - Drainage issues (such as in built up areas)
  - In places where aggregate haul distances are higher, and are costly
  - Places subjected to severe rainfall
- Relatively higher initial cost of construction
- However, these pavements requires very less maintenance, and hence Life cycle cost of concrete pavements are much lesser when compared to flexible pavements

# Design of low volume concrete roads

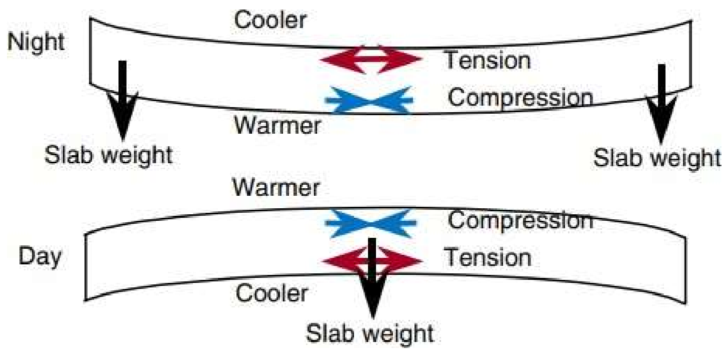
- For conventional concrete pavement, the slab thickness is governed by
  - Traffic load repetitions
  - Modulus of subgrade reaction
  - Flexural strength of concrete
  - Wheel load stresses
  - Temperature stresses
- In rural roads – the typical slab dimension can be 3 to3.75 m X 2.5 to 4 m
- The minimum slab thickness of 150 mm is recommended even for higher modulus of subgrade reaction



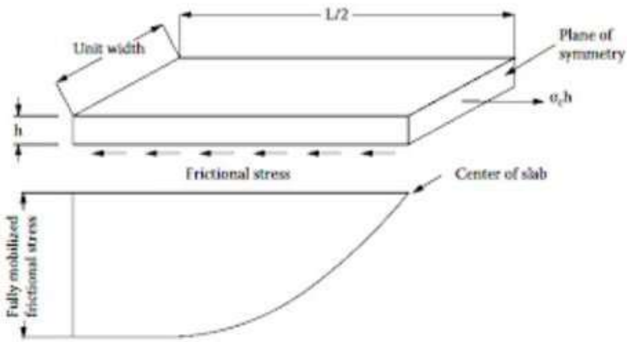
# Stresses in concrete pavement




Stresses due to wheel load




Stresses due to daily variation in temperature




Stresses due to seasonal variation in temperature

# Concrete pavement design

- Case 1: When traffic less than 50 CVPD – wheel load stresses are considered
- Case 2: When traffic is in between 50 to 150 CVPD – Wheel load and temperature stresses are considered
- Case 3: When traffic is greater than 150 CVPD and less than 450 CVPD – Combined Wheel load and temperature stresses, and fatigue analysis

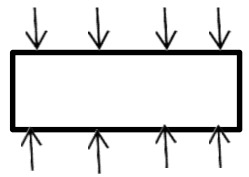
For a selected concrete mix, panel dimensions and slab thickness, the stresses arising from the above conditions <u>shall not exceed the flexural strength of concrete</u>

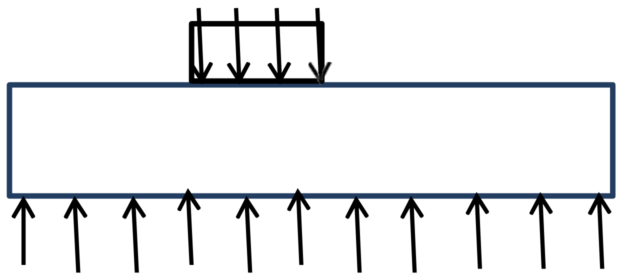
- As the minimum thickness of concrete slab recommended by IRC SP 62-2014, is 150 mm, cost comparison of rigid pavements, with flexible pavements will always result higher initial cost of construction
- How can we still construct concrete pavements? Are there any options?

- As the minimum thickness of concrete slab recommended by IRC SP 62-2014, is 150 mm, cost comparison of rigid pavements, with flexible pavements will always result higher initial cost of construction
- How can we still construct concrete pavements for low volume roads? Are there any options?
  - Short Paneled concrete pavements
  - Cell filled concrete pavements
  - Interlocking concrete pavements

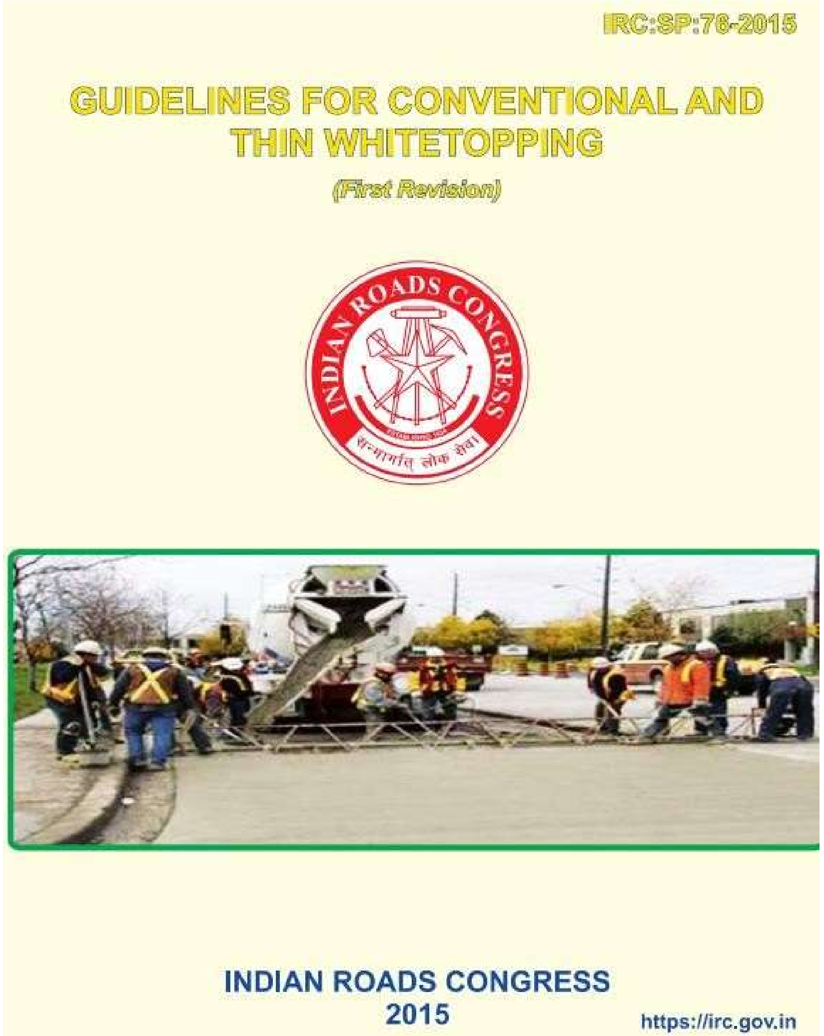
# Benefit of reducing the panel dimension

- When panel dimensions becomes smal (such as in the case of block pavements),no flexural stresses are developed
- W hen the slab dimensions increases, tensile stresses starts to occur at the bottom of the slab due to bending moment (resulting from the reaction offered by the foundation, which is at lever-arm distance away from the axis of loading)
- Hence an efective way of reducing the load induced bending stresses is by reducing the slab dimension
- BENEFIT:
  - Temperature stresses are reduced
  - Slab thicknesses can be reduced





# White topping pavements



# White topping

- White topping is defined as a PCC overlay placed above an existing bituminous pavement

  Benefits of White topping

  - Compared to bituminous overlays, white topping have lower rate of loss of serviceability
  - Deformation (Rutting) is eliminated
  - Conventional white topping tends to increase the structural capacity of existing bituminous layer, if build on a strong base course
  - Reduces urban heat island effect
  - Reduced fuel consumption

# Types of White topping

- Conventional White topping
  - PCC overlay of thickness 200 mm or more, without consideration of bond between concrete overlay and underlying bituminous layer
- Thin white topping
  - PCC overlay of thickness greater than 100 mm and less than 200 mm
  - Bond between PCC and underlying bituminous layer is considered, however not mandatory in design
- Ultra thin white topping
  - PCC overlay layer thickness less than 100 mm
  - Bonding between the PCC overlay and underlying bituminous layer is mandatory

# Materials used

- Concrete grade used: M40
- Fibers – steel/polypropylene/polyester/polyethylene/nylon fibers
  - Length 30-60mm; Dosage 0.5 to 1.5%

# Surface preparation before placing PCC overlay

- Direct placement
- Milling
- Placement of leveling course
- DLC/PCC leveling course

# Conventional white topping - Thickness design

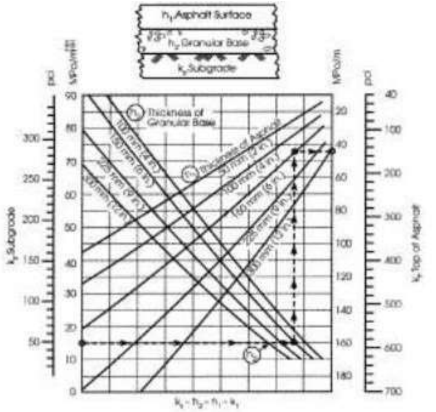



Fig. 1: Chart for Determination of Modified "k" value on top Bituminous Pavement atop of Granular Base

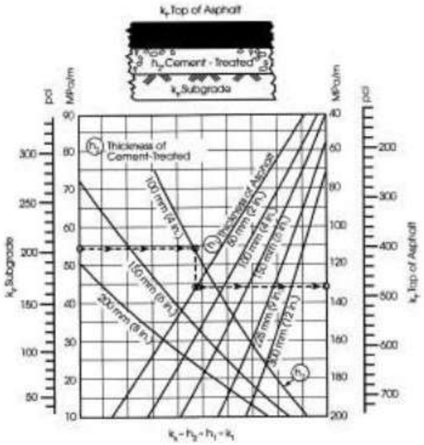
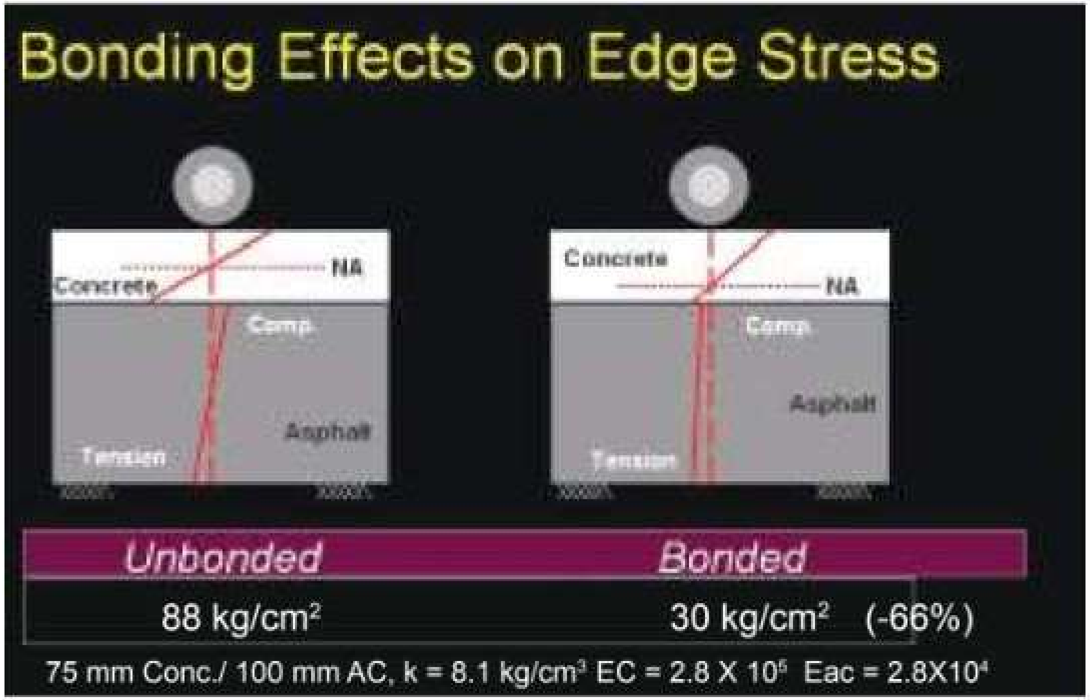



Fig. 2: Chart for Determination of Modified "k" value (modulus of support) on the top Bituminous Pavement atop of Cement Treated Base

- The main effort is to determine the modified 'k' value, which is given as a function of 'k' value of subgrade, granular layer thickness and bituminous layer thickness
- Once modified 'k' values are determined, remaining design can be taken as per conventional IRC 58 method
- Joint spacing 4 to 4.5 m

# Thin White Topping (TWT)




Effective bonding between concrete overlay and existing asphalt layer, lowers the location of neutral axis, and reduces the tensile stresses coming in the bottom fiber of concrete slabs

# Thin white topping

- Development of an effective bond between the existing bituminous pavement and concrete overlay is desirable
- Extensive surface preparation (milling, or sometimes chiseling) is required to promote significant bonding between the concrete overlay and bituminous pavement
- Use of short joint spacing is recommended (1 m to 1.5 m)
- The minimum thickness of hot mix bituminous pavement is 75 mm (net excluding the milled thickness for Thin white topping

# Thin White Topping - Thickness design

- Critical stress location: Due to shorter panel size, corner stresses due to loading, as well as curling is considered to be critical
- Stresses due to temperature curling
  - Negative temperature gradient produces tensile curling stresses on the top of the slab

$$\sigma_T = 1.933\text{-}241000(\alpha\,\Delta T) + 1.267(L/l_e).$$

    - Recommended value for ΔT is 0.15$^o$C/cm
- Stresses due to wheel load

$$Log(\sigma_8) = 3.6525 - 0.465log(k) + 0.686log(L/l_e) - 1.291log\,(l_e)$$

$$Log(\sigma_{16}) = 3.249 - 0.559log(k) + 1.395log(L/l_e) - 0.963log\,(l_e) - 0.088\,(L/l_e)$$

    - If panel size is smaller than 1.3 m then only single axle would be considered as both the axles cannot come on the same panel

Pl Note: The equations given above are only for 8T and 16T, single and tandem axle load groups, whereas while estimating wheel load stresses from an axle load survey, linear interpolation has to be carried out to estimate wheel load stresses due to any other load magnitude

# Thin White Topping - Thickness design

- Fatigue analysis is also done for the axle loads considered (single 8T and tandem 16T) using Miner's hypothesis (IRC 58, 2015)
- As the concrete used in Thin white topping incorporates fibers, stress ratio considers residual strength in fiber reinforced concrete

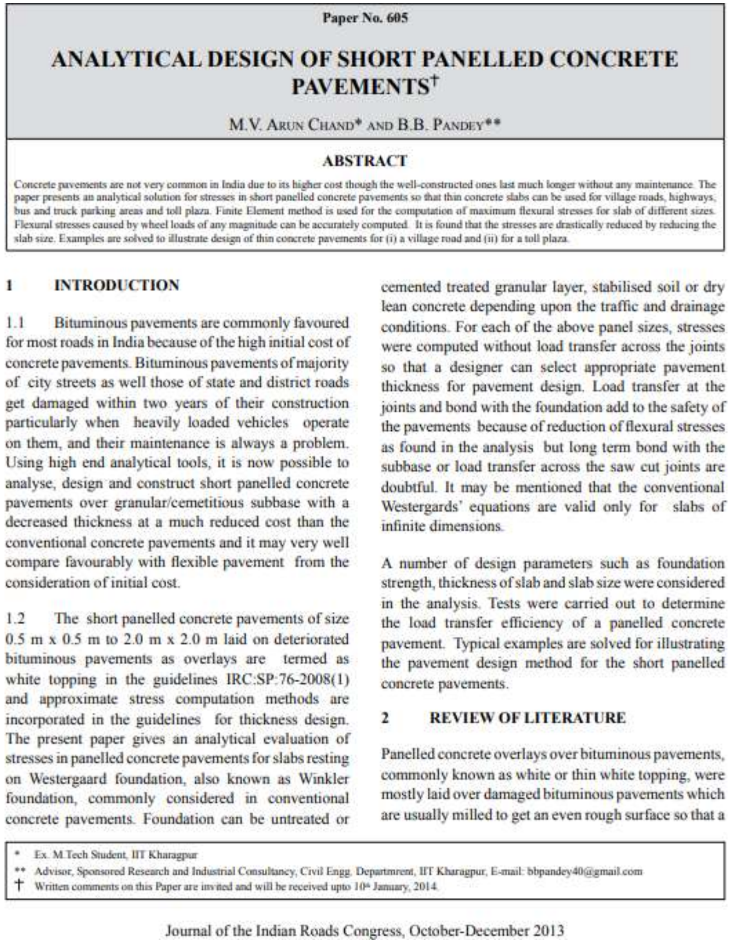
$$\text{Stress ratio} = \text{Flexural stress} / MOR\ (1 + R_{150})$$

<u>Design steps</u>

- Obtain the axle load spectrum of traffic loads in terms of cvpd
- Obtain subgrade CBR/k value, and modified k value considering granular/cementitious base thickness, and bituminous layer thickness
- Consider trial thickness, and joint spacing
- Estimate temperature and wheel load stresses, the sum of these stresses have to be less than flexural strength of concrete
- For wheel load stresses due to each axle load group, estimate stress ratio, and use IRC 58 fatigue equations to estimate damage due to each load group. For the selected thickness and axle load groups, the cumulative fatigue damage shall be less than 1

# Short panel concrete pavements

- Short paneled concrete pavement design was proposed by Arun Chand and Prof B B Pandey (2013)
- Short panel concrete of size 0.5 m x 0.5 m to 2 x 2 m was proposed, over untreated/cement treated/stabilized/ lean concrete base layers
- Simple design charts were proposed in the paper for different panel sizes and subgrade conditions



Paper No. 605

## ANALYTICAL DESIGN OF SHORT PANELLED CONCRETE PAVEMENTS†

M.V. Arun Chand* and B.B. Pandey**


### ABSTRACT

Concrete pavements are not very common in India due to its higher cost though the well-constructed ones last much longer without any maintenance. The paper presents an analytical solution for stresses in short panelled concrete pavements so that thin concrete slabs can be used for village roads, highways, bus and truck parking areas and toll plaza. Finite Element method is used for the computation of maximum flexural stresses for slab of different sizes. Flexural stresses caused by wheel loads of any magnitude can be accurately computed. It is found that the stresses are drastically reduced by reducing the slab size. Examples are solved to illustrate design of thin concrete pavements for (i) a village road and (ii) for a toll plaza.


### 1 INTRODUCTION

1.1 Bituminous pavements are commonly favoured for most roads in India because of the high initial cost of concrete pavements. Bituminous pavements of majority of city streets as well those of state and district roads get damaged within two years of their construction particularly when heavily loaded vehicles operate on them, and their maintenance is always a problem. Using high end analytical tools, it is now possible to analyse, design and construct short panelled concrete pavements over granular/cemetitious subbase with a decreased thickness at a much reduced cost than the conventional concrete pavements and it may very well compare favourably with flexible pavement from the consideration of initial cost.

1.2 The short panelled concrete pavements of size 0.5 m x 0.5 m to 2.0 m x 2.0 m laid on deteriorated bituminous pavements as overlays are termed as white topping in the guidelines IRC:SP:76-2008(1) and approximate stress computation methods are incorporated in the guidelines for thickness design. The present paper gives an analytical evaluation of stresses in panelled concrete pavements for slabs resting on Westergaard foundation, also known as Winkler foundation, commonly considered in conventional concrete pavements. Foundation can be untreated or cemented treated granular layer, stabilised soil or dry lean concrete depending upon the traffic and drainage conditions. For each of the above panel sizes, stresses were computed without load transfer across the joints so that a designer can select appropriate pavement thickness for pavement design. Load transfer at the joints and bond with the foundation add to the safety of the pavements because of reduction of flexural stresses as found in the analysis but long term bond with the subbase or load transfer across the saw cut joints are doubtful. It may be mentioned that the conventional Westergards' equations are valid only for slabs of infinite dimensions.

A number of design parameters such as foundation strength, thickness of slab and slab size were considered in the analysis. Tests were carried out to determine the load transfer efficiency of a panelled concrete pavement. Typical examples are solved for illustrating the pavement design method for the short panelled concrete pavements.

### 2 REVIEW OF LITERATURE

Panelled concrete overlays over bituminous pavements, commonly known as white or thin white topping, were mostly laid over damaged bituminous pavements which are usually milled to get an even rough surface so that a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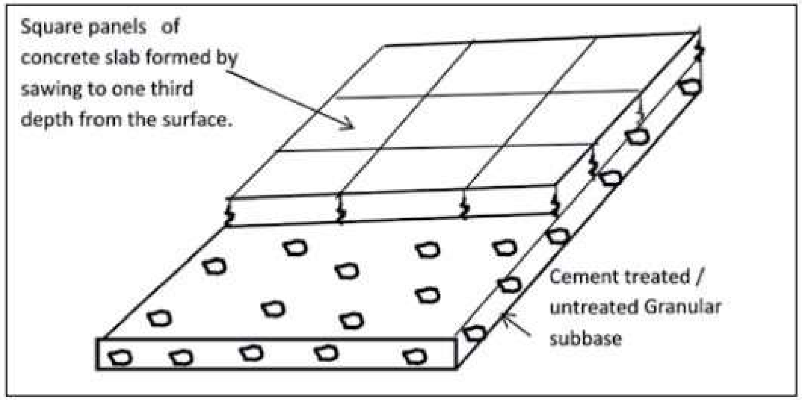
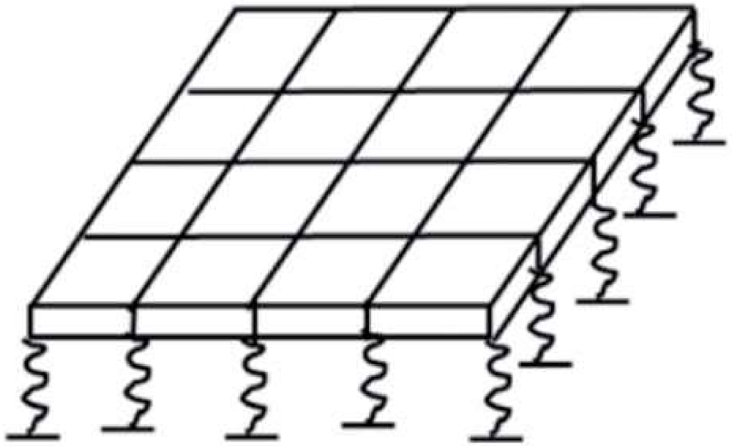
† Written comments on this Paper are invited and will be received upto 10th January, 2014.

# Short paneled concrete pavements



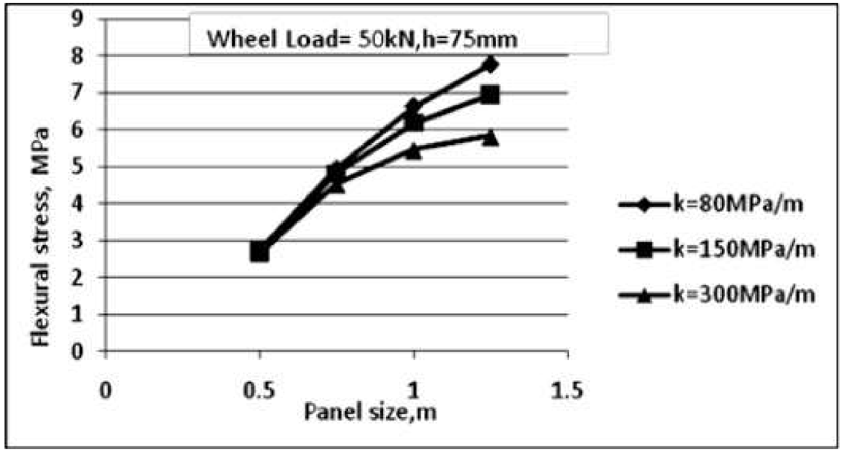
| Soaked subgrade CBR | 2 | 3 | 4 | 5 | 7 | 10 | 15 | 20 | 50 |
|---|---|---|---|---|---|---|---|---|---|
| k Value (MPa/m) | 21 | 28 | 35 | 42 | 48 | 50 | 62 | 69 | 140 |

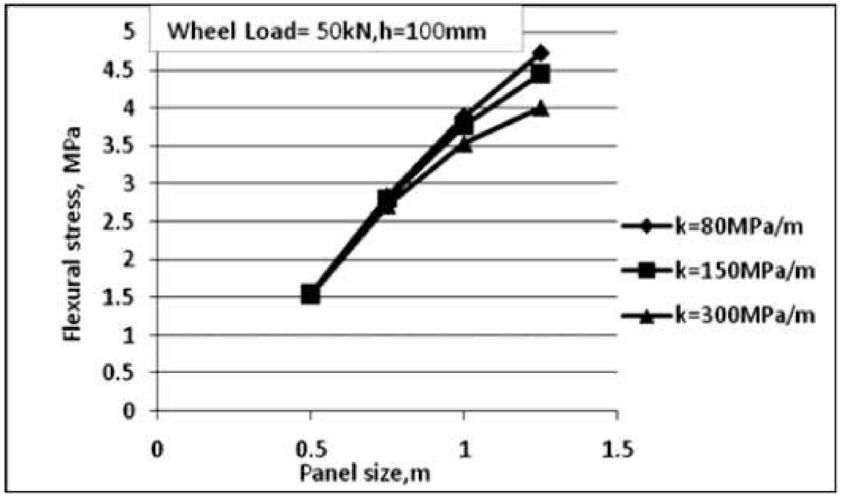
Modulus of subgrade reaction, k, if slab is placed directly above compacted subgrade

| Soaked CBR | 2 | 3 | 4 | 5 | 7 | 10 | 15 | 20 | 50 |
|---|---|---|---|---|---|---|---|---|---|
| k Value over granular subbase (thickness 150 to 250 mm), MPa/m | 25 | 34 | 42 | 50 | 58 | 60 | 74 | 83 | 170 |
| k Value over 150 to 200 mm cementations sub base MPa/m | 42 | 56 | 70 | 84 | 96 | 100 | 124 | 138 | 280 |

Modulus of subgrade reaction, k, if slab is placed directly above granular subbase/cementitious subbase

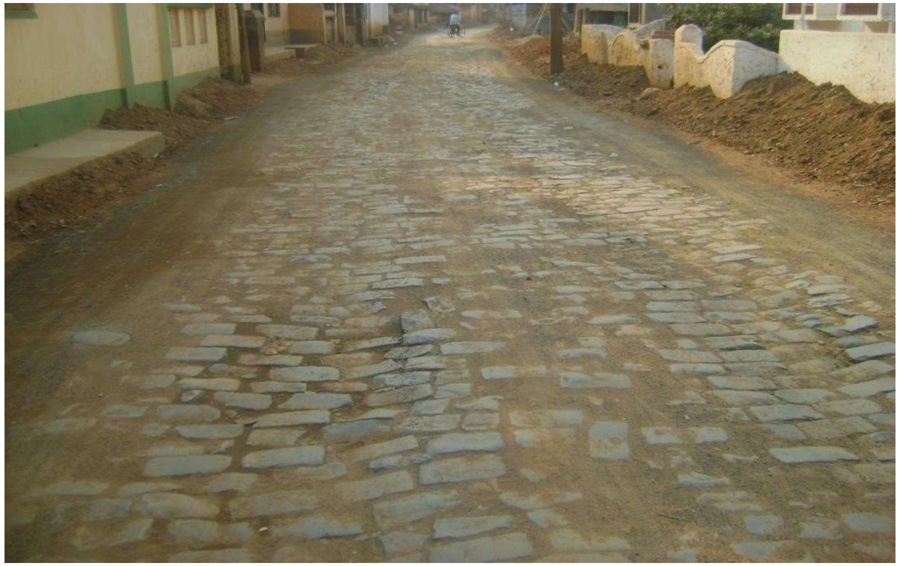
# Design charts




- Flexural stresses reduces drastically by more than 60% when panel size is reduced from 1.25 m to 0.5 m
- A 75 mm thick concrete slab with panel size 0.5 m x 0.5 m will develop only 2.6 MPa flexural stress under dual wheel load of 50 kN and can be a cost effective solution for village roads
- Panel concrete pavements, for a good long term performance require a good non erodible subbase such as DLC over stabilized subgrade
- The design charts are proposed by considering the case that no load transfer occurs across the joints to neighboring panels

# Short Paneled concrete pavement executed in Burdwan district, West Bengal



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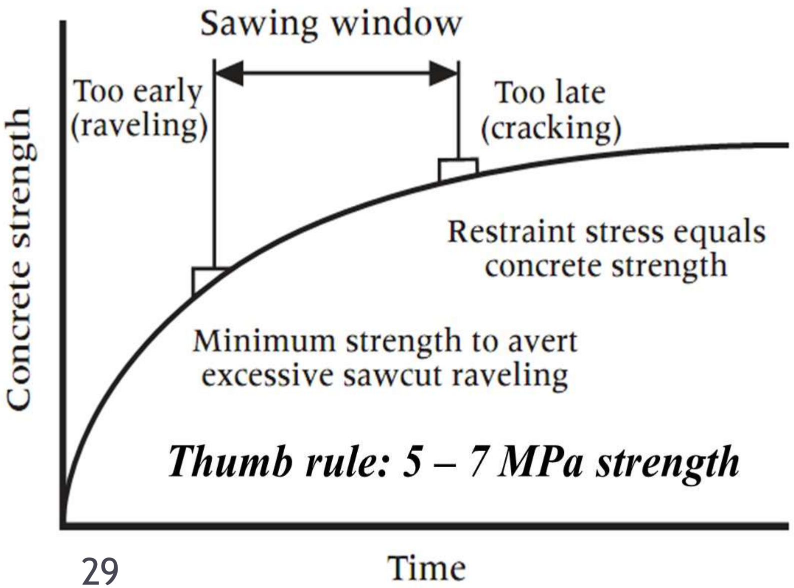



- Within 8 to 9 hrs. of construction of the PQC, 1 mt x 1 mt paneling was formed by saw cutting 3 mm wide groove upto 1/3rd depth
- For cutting grooves on such a small scale work, diamond cutters fitted in hand hold small machines with which marble slabs are cut, were used

# Short Paneled concrete pavement executed in Burdwan district, West Bengal

- Soon after grooving was done on PQC in appropriate panel size, Curing was started and maintained for 28 days.

# Pavement Performance

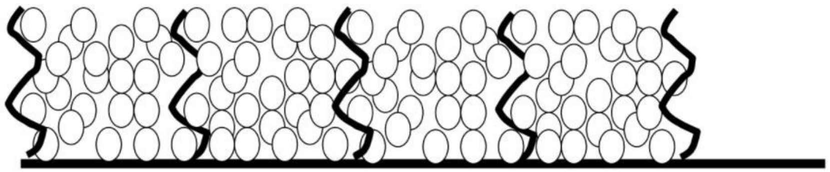



The stretch of SPCP carried the usual traffic of a State Highway with CVPD not less than 750 consisting of a good number of truck traffic and has given an excellent service since April,2012 except one or two locations where a bit of crack was observed.

# Cell filled concrete pavements

- Cell filed concrete pavements consist of a grid of plastic cels in which concrete is placed and compacted
- Has very short joint spacing with unique joint arrangement
- Thinner concrete layers with multiple joints,hence load spread is not by slab action
- Joints are created in slab using Plastic cells

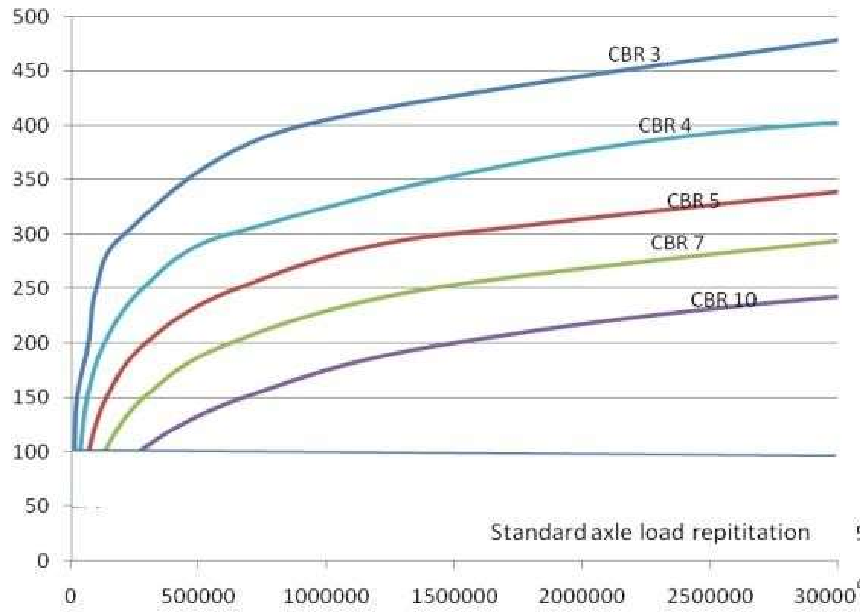
# Cell filled concrete pavements



- As plastic cells are filled with concrete, it forms a flexible layer having rigid material
- Typical depth is between 50-100mm
- Has negligible temperature stresses
- Interlocking between the blocks is crucial for pavement performance
- Non erodible foundation

# Cell filled concrete pavement - Design philosophy

- The 80% reliability rutting criteria can be adopted for cell filled concrete pavement design
- Modulus of cell filled concrete can be taken as 2000 MPa
- Thickness charts for cell filled pavements are provided in 'Do it yourself manual' of NRIDA



# Salient features of Cell filled concrete pavement

- Conventional concrete or zero slump concrete with 28 day characteristic compressive strength of 30 MPa
- For zero slump concrete, a static roller 6 –8 T capacity may be used.For normal concrete,with a slump value of 50 mm,plate vibrators can be used
- During compaction,the plastic cel walls deform due to rolling/vibration,and develop interlocking
- HDPE sheet of thickness 0.2 mm to 0.22 mm (about 1250 kg for 3.75 m width and 1 km length) or LDPE sheet of 0.3 to 0.35 mm thickness is used

# Form work of Cell filled concrete pavements

# Cell filled concrete pavements

- Three approaches
  - Fill the cells with single aggregates, lightly compact it with road roller. Further cement grout of sufficient flow value, is grouted
  - Fill the cells with cement concrete and compact using pan/skid vibrator
  - Fill the cells with low water concrete, and compact using road roller compactor

Edge restraint is advisable

- Three approaches
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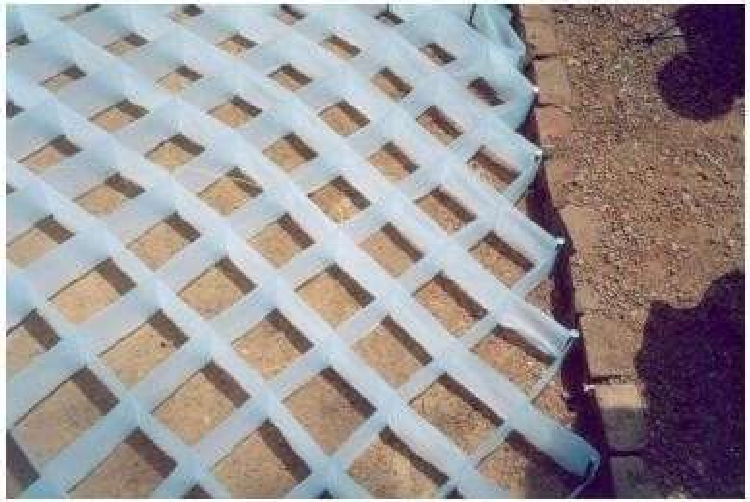
# Cell filled Concrete Pavements

# Cell Filled Concrete road in WB

## Study stretch trials carried in Kerala, by NIT Warangal and StGits College of Engineering, Kottayam

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Bedding layer for the paving block was well compacted and sides were confined after construction. Fine sand was filled into the gaps of the block using a broom.

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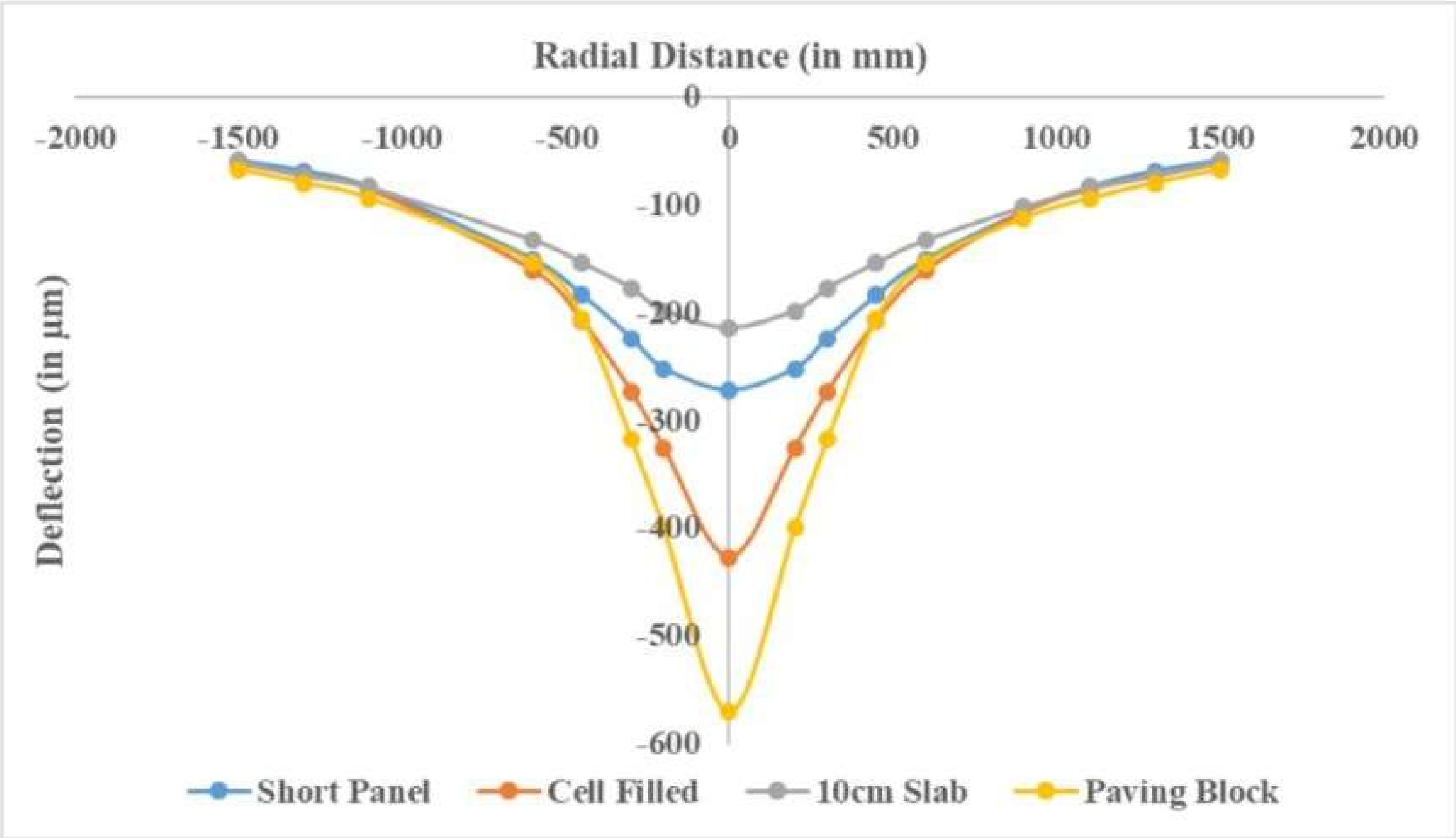

# Way forward..

- Need to adopt sustainable long lasting pavement technologies which are cost effective also