International Conference on New Technologies and Innovations in Rural Roads

24-26 May 2022, New Delhi

Paneled Concrete Pavement – Design, Construction and Performance

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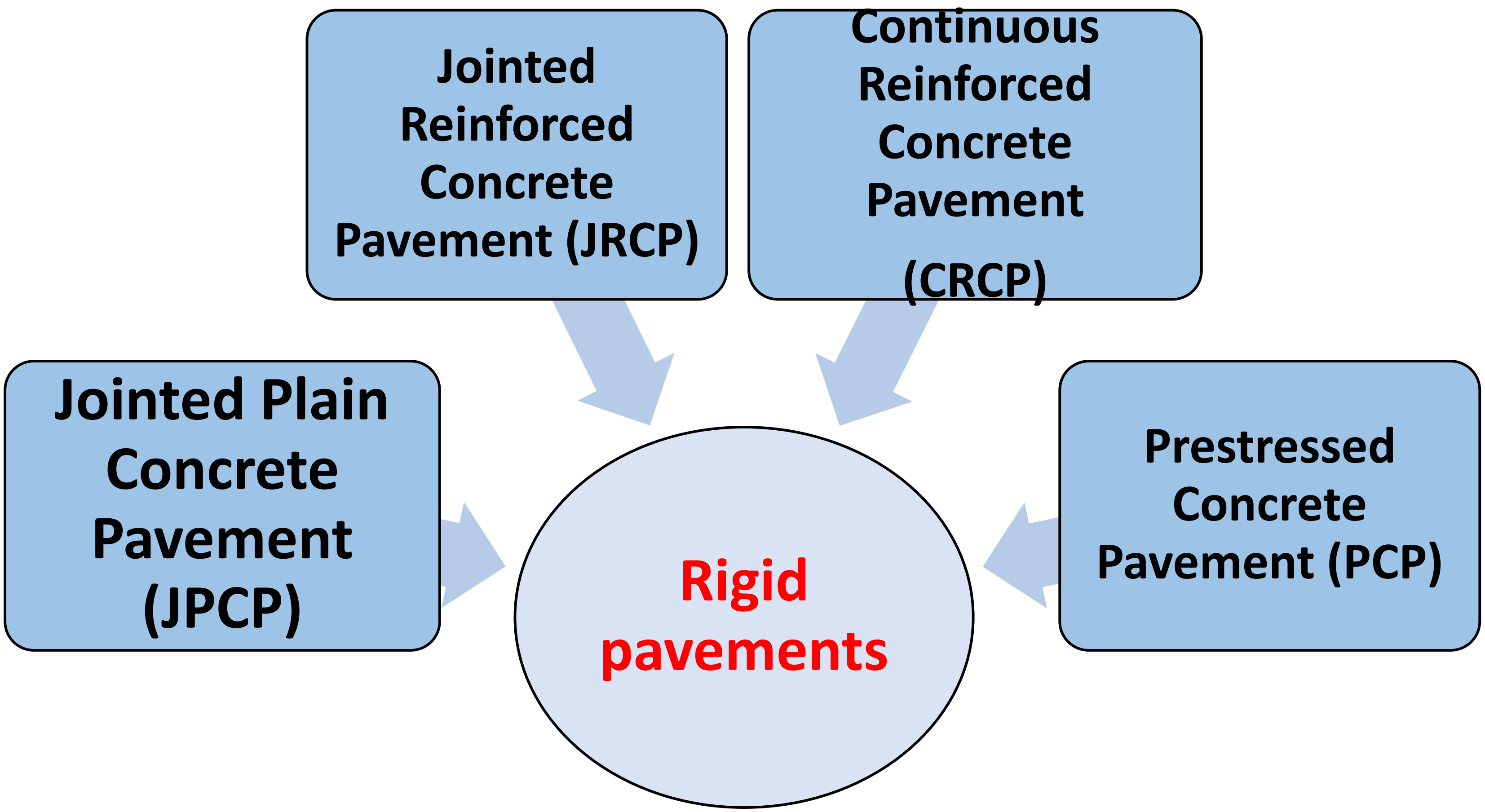
 # Presenting author

Presentation Outline

- Introduction
- Concept of Panel Concrete Pavement :Cast-in-situ Short Paneled Concrete Pavement (CiSPCP)
- Review of Literature
- Design of CiSPCP for Low Volume Roads (LVR)
- Construction of CiSPCP- LVR and High Volume Roads
- Evaluation of CiSPCP
- Conclusions

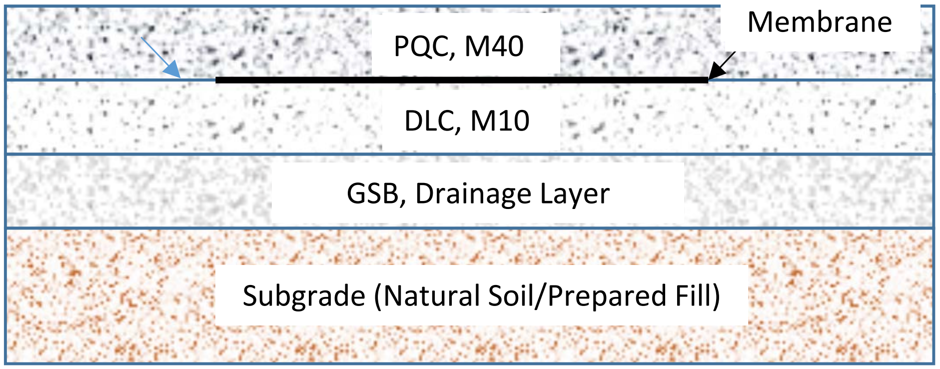
Introduction

Different types of rigid pavements



Introduction

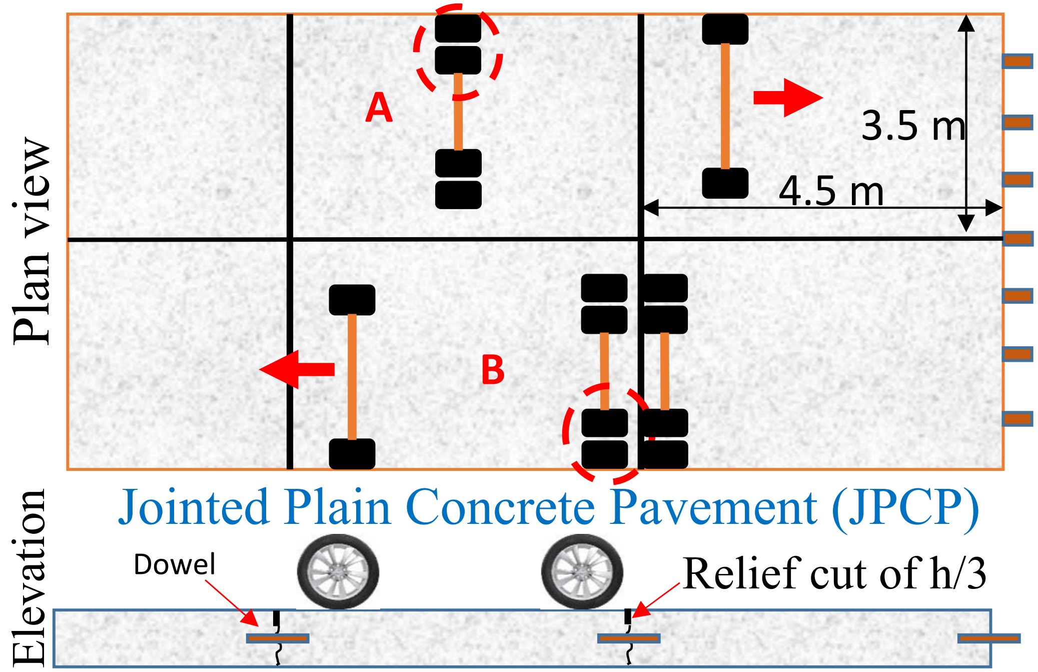
Jointed Plain Cement Concrete Pavements (JPCP)



Very common type

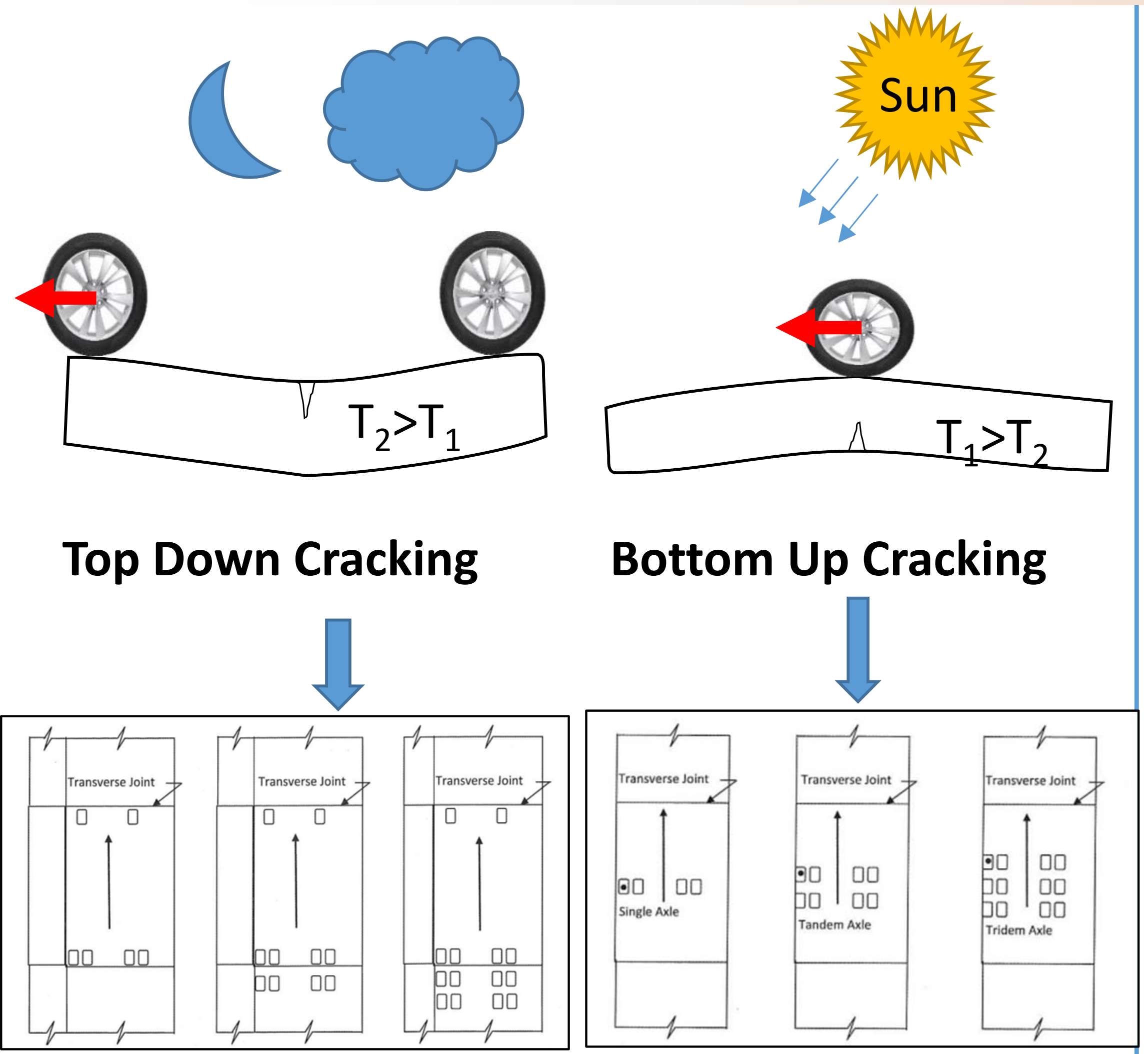
Size: 3.5 x 4.5 m

A Typical Concrete Pavement System



Jointed Plain Concrete Pavement (JPCP)

JPCP: Performance based design



Specifications and Guidelines-
IRC:58-2015 - JPCP

Salient Features:

Fatigue Damage Analysis by Miner's Approach:

Cumulative Fatigue Damage $_{BUC}$
\+
Cumulative Fatigue Damage $_{TDC}$
= **Cumulative Fatigue Damage $_{Total}$ < 1, Safe**

Design is limited to single sized slabs:
4.5 m x 3.5 m

Concept of Panel Concrete Pavement
Cast-in-situ Short Paneled Concrete Pavement (CiSPCP)

- Concept of concrete slabs with smaller slab sizes started with the design of thin concrete overlays over asphalt (white toppings).

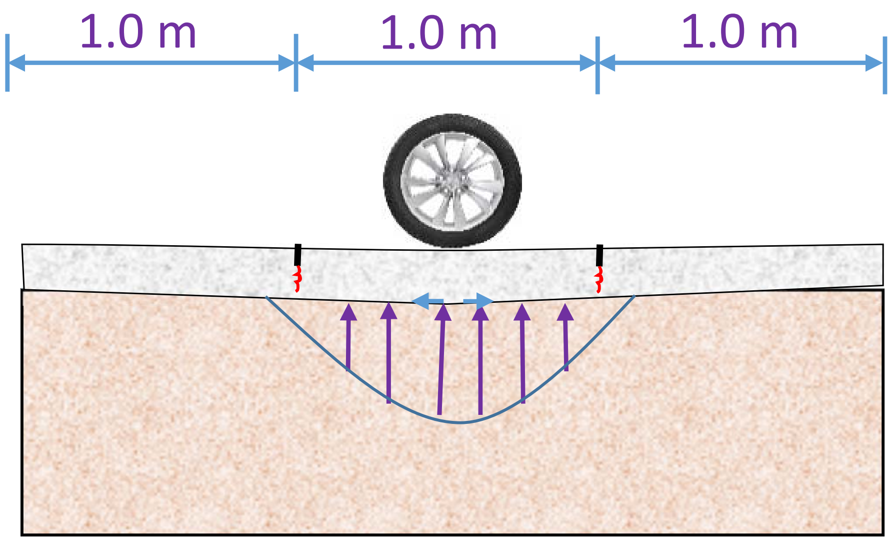
- Key principle is to select the slab size so that not more than one set of wheels is on any given slab at one time, thereby minimizing the critical tensile stresses.

- Short paneled concrete Pavement (SPCP) slabs utilizes the strength of the lower layers (Stiffness of the the layer below the slab is very important in case of thin concrete slabs)

- Curling stresses get reduced by decreasing slab length.

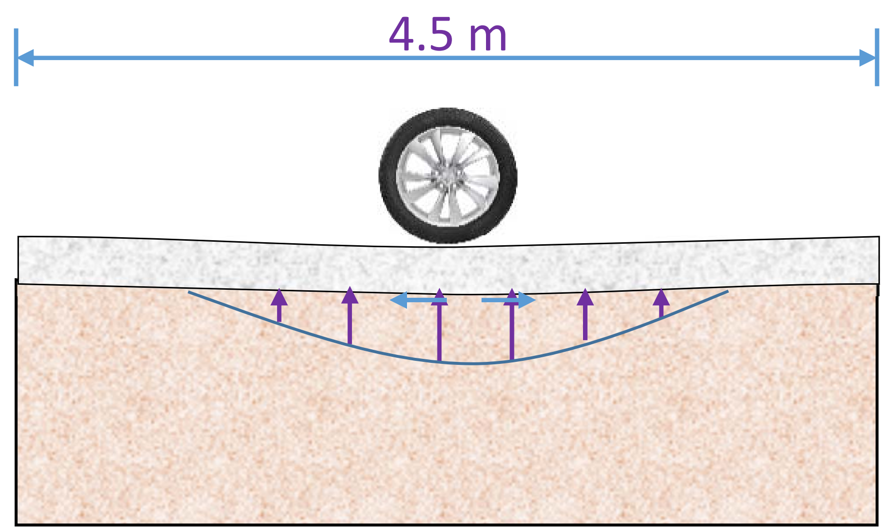
Cast-in-situ Short Paneled Concrete Pavement (Ci-SPCP)

- Closely spaced joints
- Size: 1.0 m x 1.0 m, 1.5 m x 1.5 m and 2.0 m x 2.0 m
- Aggregate interlock across closely spaced joints- 1/3 rd depth



Cast-in-situ Short Paneled Concrete Pavement (CiSPCP)

(Slabs bend with vertical deflection under loading)



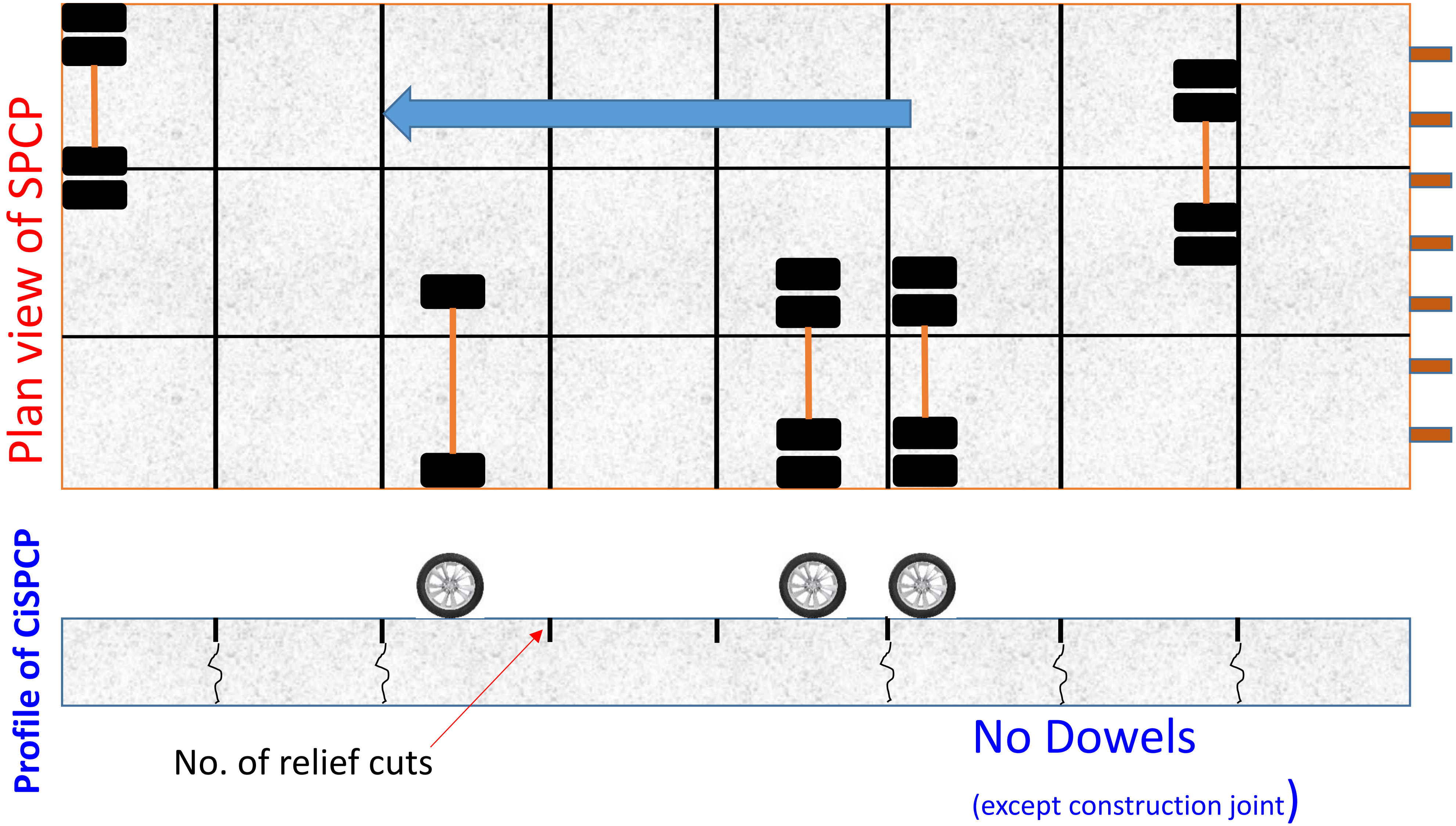
Jointed Plain Concrete Pavement (JPCP)

(Slabs bend under loading)

Ci-SPCP on Low Volume Roads

PMGSY Road, Mankar Village, West Bengal, India

Cast-in-situ Short Paneled Concrete Pavements



Literature Review

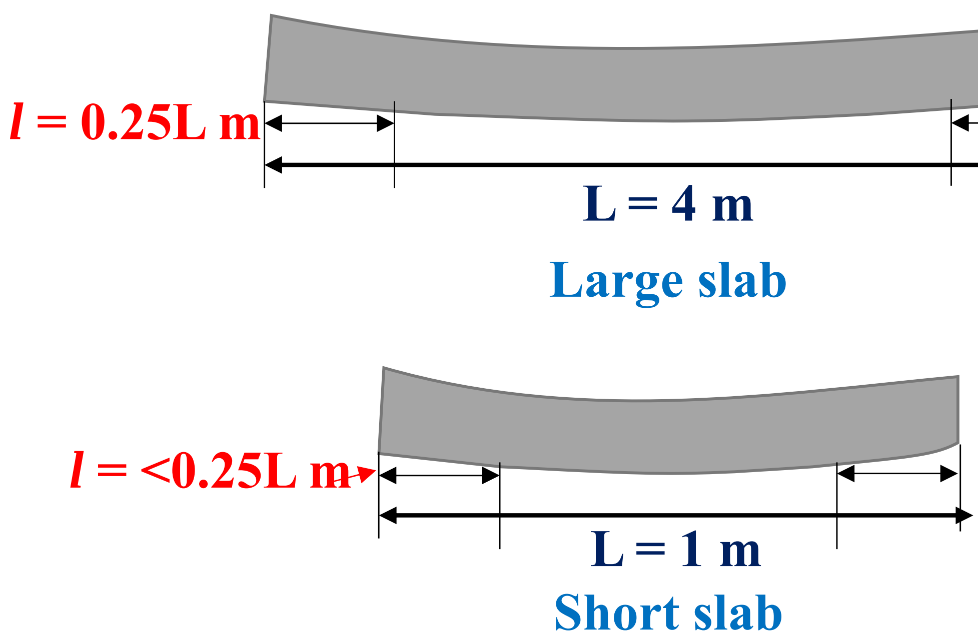
- Transverse joint spacing considered by IRC: 58-2015 and IRC: SP:62-2014 is 4.5 m and 2.5 to 4 m respectively.
- Pavement performance is more affected by panel size as compared to thickness.
- Pavement thickness could be significantly reduced compared with conventional concrete pavements, when shorter slabs are used.
- **Advantageous:** Less thickness for given design traffic, No dowel bars except construction joint; saving upto 20%

Global Experience on Short Concrete Pavements

- ✓ First ever construction report on experimental short slab pavements indicated that material consumption is less and Roughness Index depends on base layer. *i). GB ii). ATPM iii). BB* (Chiunti, 1976).
- ✓ Riding quality is better in short slabs compared to long slabs and joint faulting of 4.75 mm, and 3% in 5 yr. (Arnold, 1973).
- ✓ **Load Transfer Efficiency (LTE)** of short spacing joints (3.4, 2.4, 2.1, and 1.5 m) is higher than the conventional spacing joints (5.8, 5.5, 4.0, and 3.7 m) (Long & Shatanawi, 2000).

Literature Review

- ✓ Portion of cantilever is 0.25 times of the length of slab during the slab curl is assumed. Shorter slabs do have shorter cantilevers compared to longer slabs. (*TC Pavements*).
- ✓ **Chile:** Field performance of short slabs on granular base layer have experienced longitudinal cracking as primary followed by transverse cracking, corner cracking (Salsilli et. al., 2015).



Research Gap

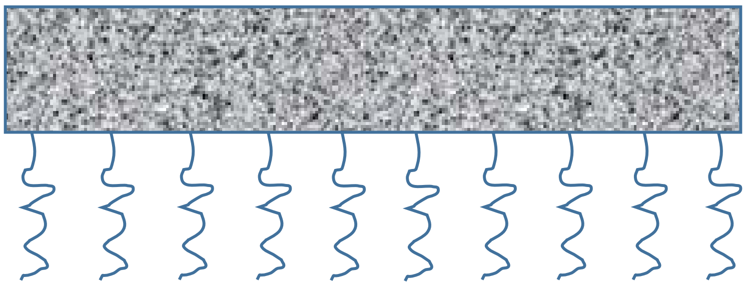
- No design methodology or design guidelines is available for Cast-in-situ short paneled concrete pavements (CiSPCP)

- No performance data is available for CiSPCP

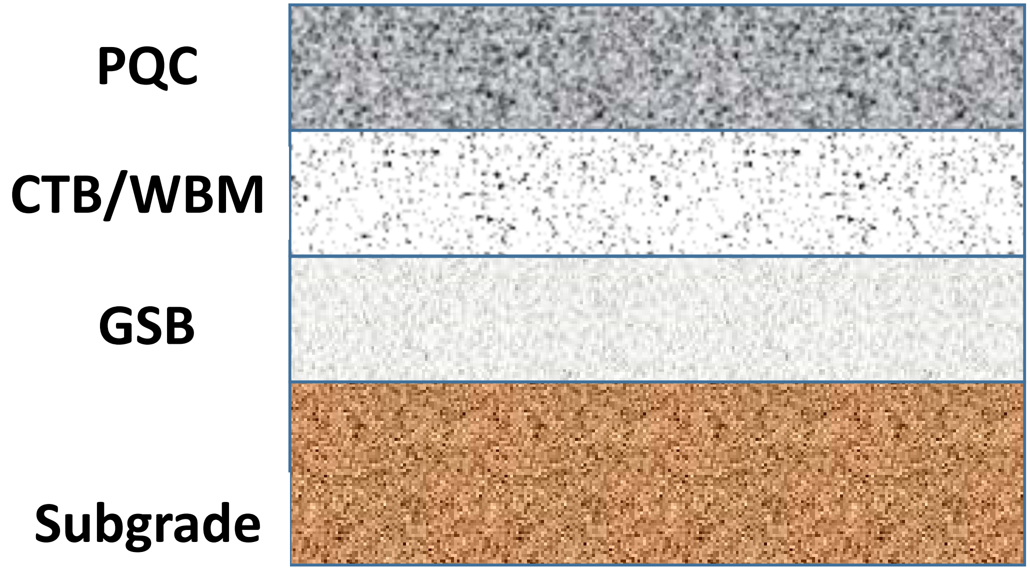
Design of Cast-in-situ short paneled concrete pavements (CiSPCP) for Low Volume Roads

Design of Ci-SPCP: Model Strategy

Decision on Foundation:



Winkler Foundation



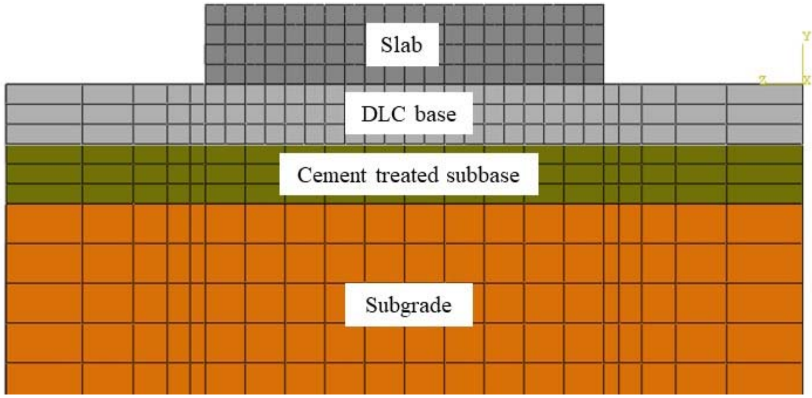
Elastic Foundation

Combinations for analysis (100 mm GSB)

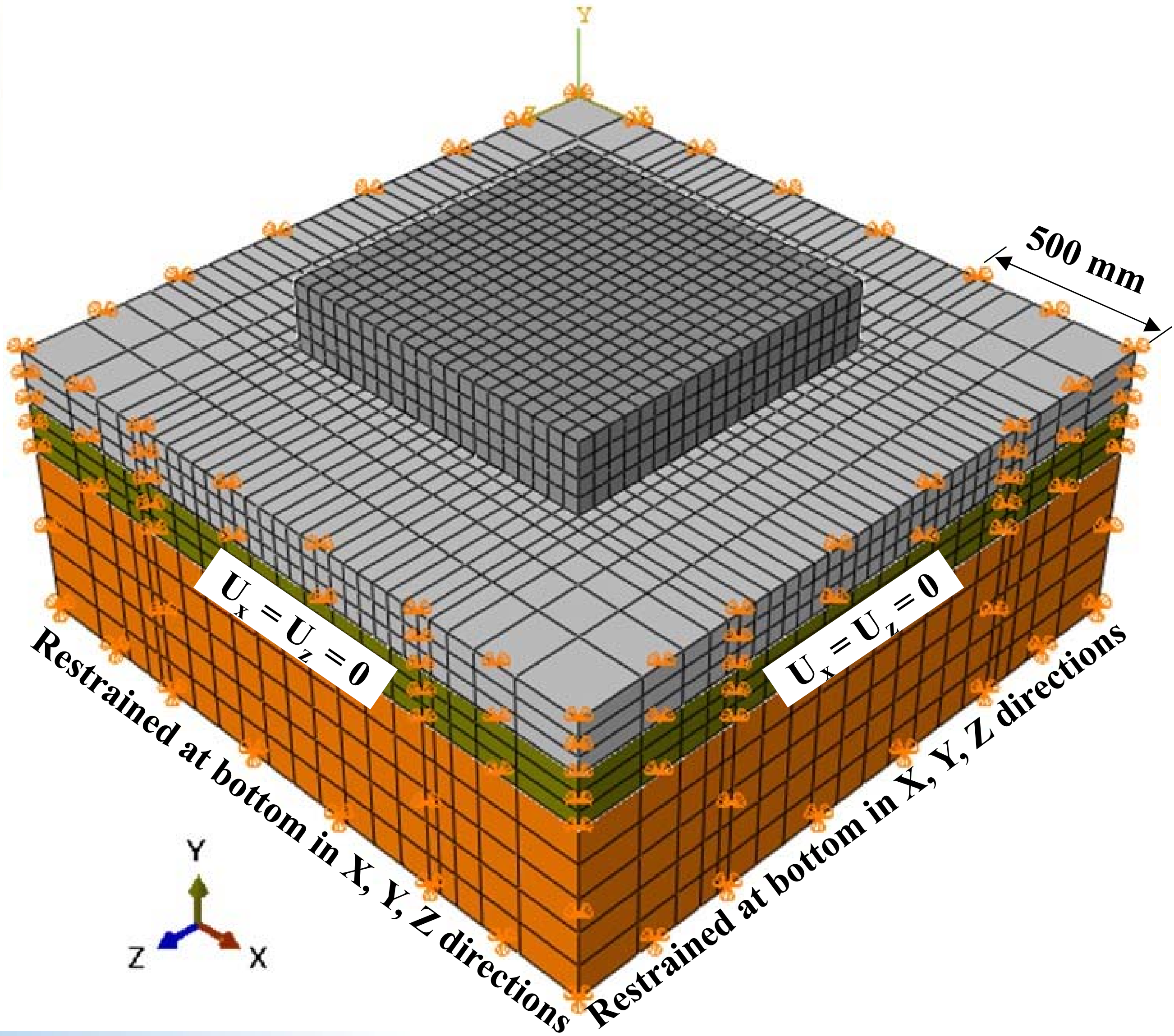
Parameters	Values
Foundation	Elastic layer
Panel Size (m)	1.0 X 1.0 ; 1.5 X 1.5; 2.0 X 2.0
Thickness of PQC (mm)	100, 150, 180
Load Levels (kN)	40, 80, 120 & 160
Positive ΔT (^{0}C)	12.5 , 15 & 17.3
Base course	100 mm CTB/ 75,150 – WBM/WMM
Subgrade level	4,6,8, 10 and 12%- CBR

ABAQUS FE Package

Design of Ci-SPCP: Single Slab Model Cont'd…



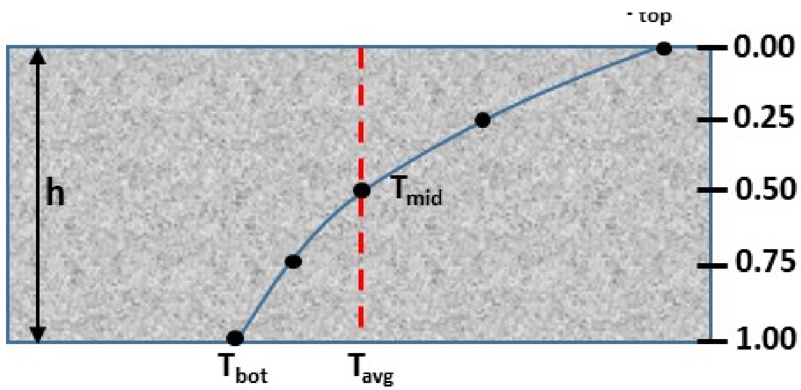
ABAQUS Single slab model



Design of Ci-SPCP: Thermal Gradient

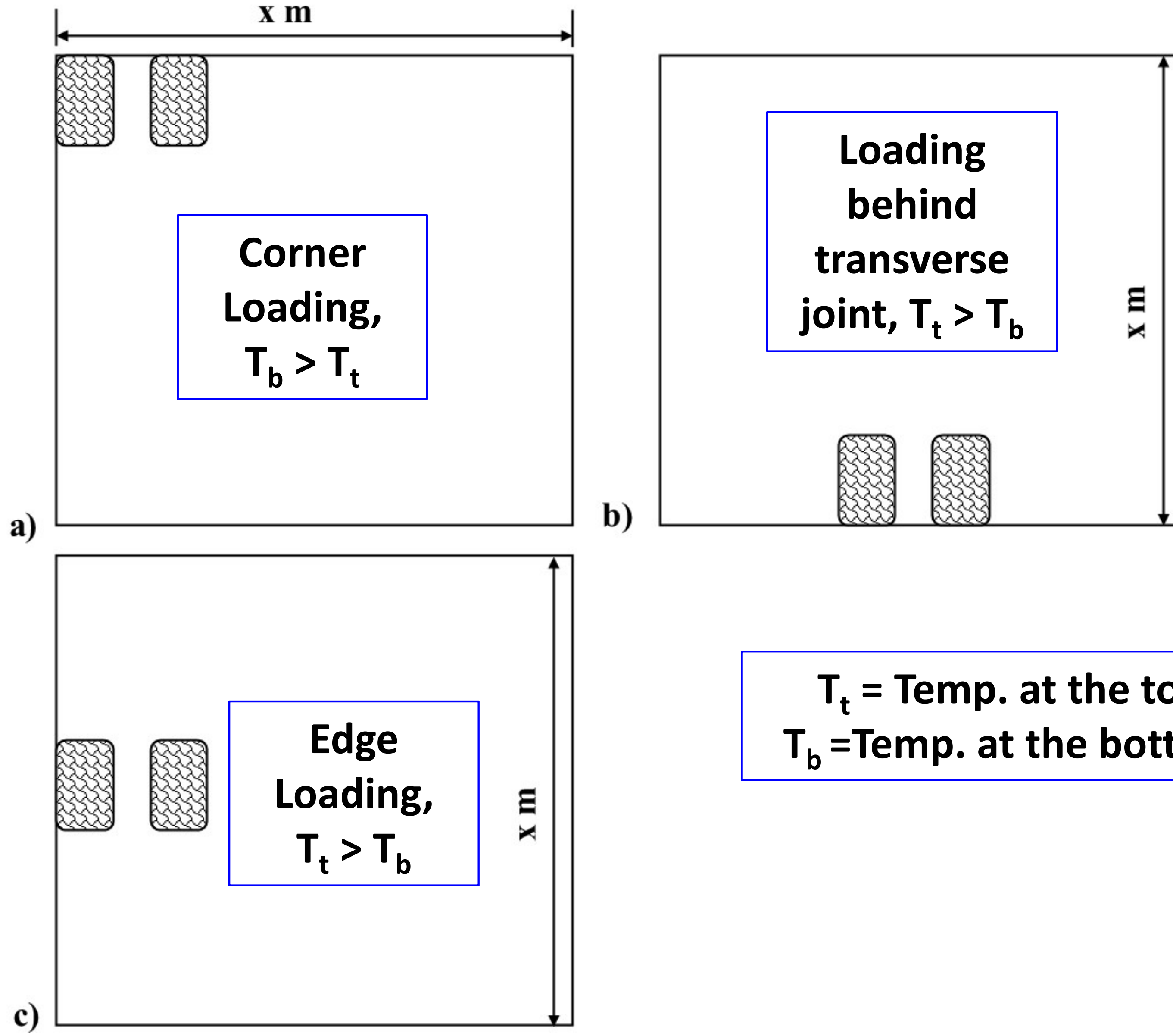
Temperature

- **Zone – I of Table 1, IRC 58, 2015**
- **Zone – IV of Table 1, IRC 58, 2015**



Initial Temperature of the model: lowest temperature of specific thermal gradient

Design of Ci-SPCP: Critical Loading Conditions

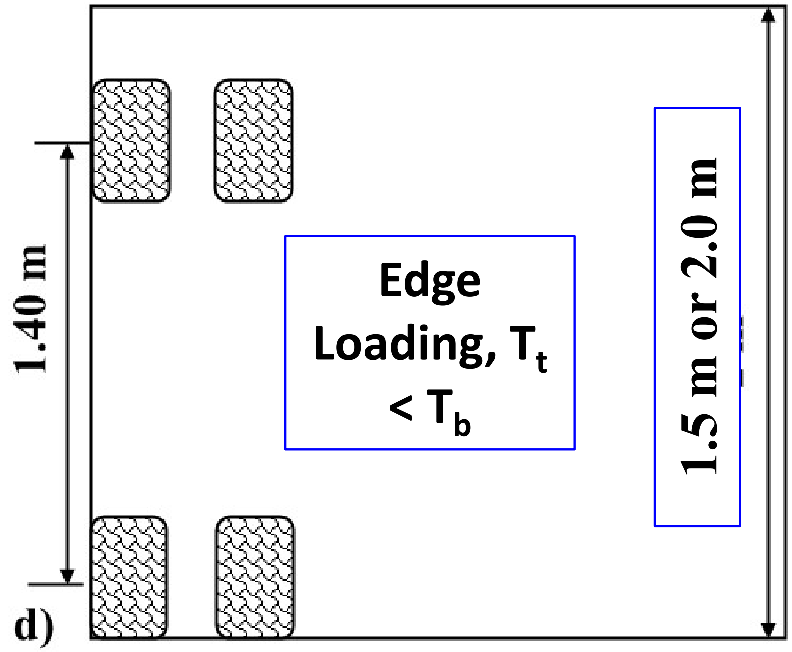


Common Critical Loads

T_t = Temp. at the top
T_b =Temp. at the bottom

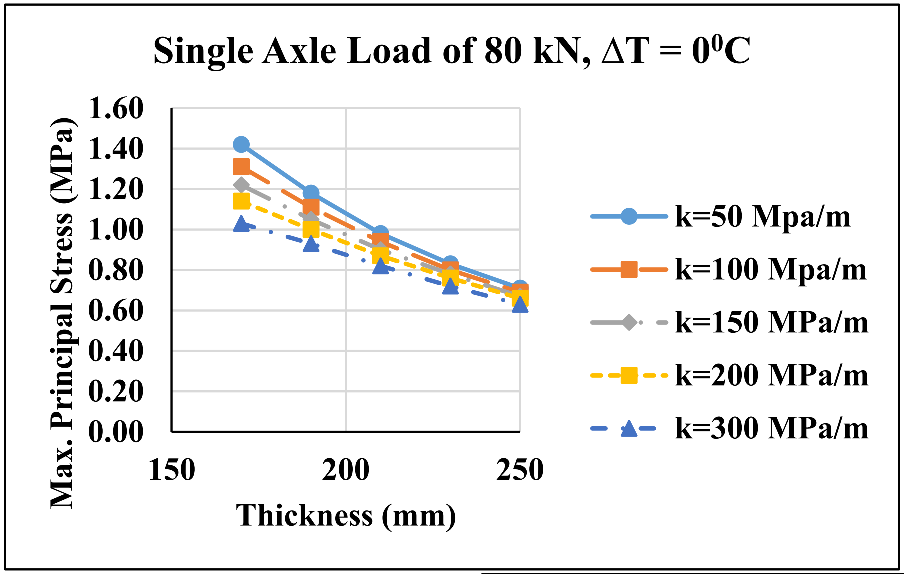
Design of Ci-SPCP: Critical Loading Conditions…contd

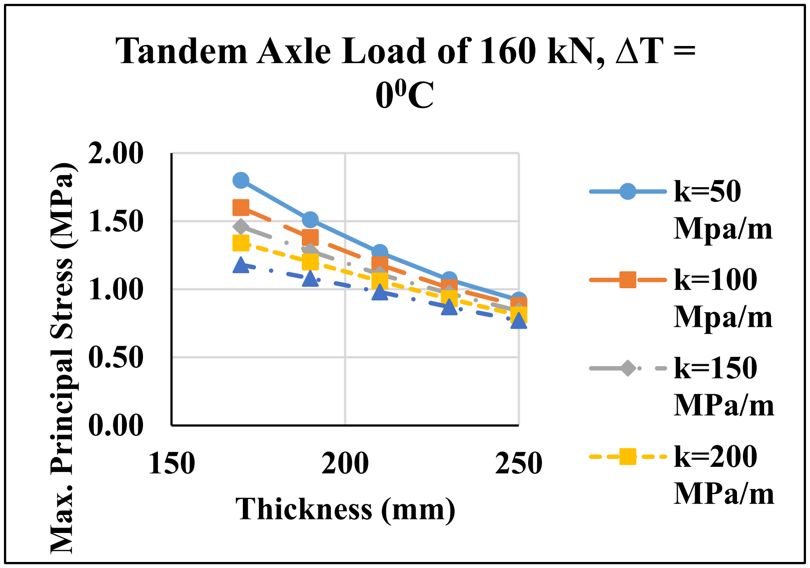
Additional Critical Loads

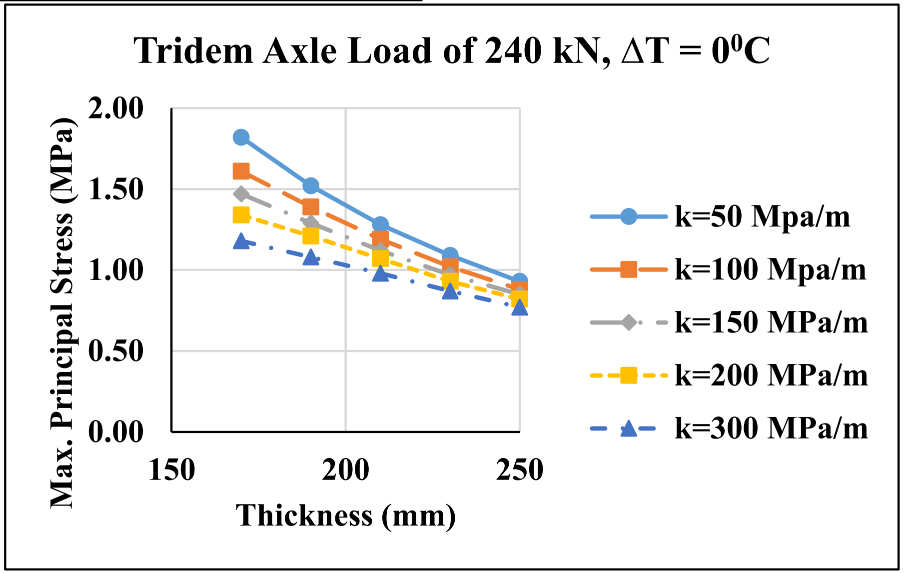


Design of Ci-SPCP

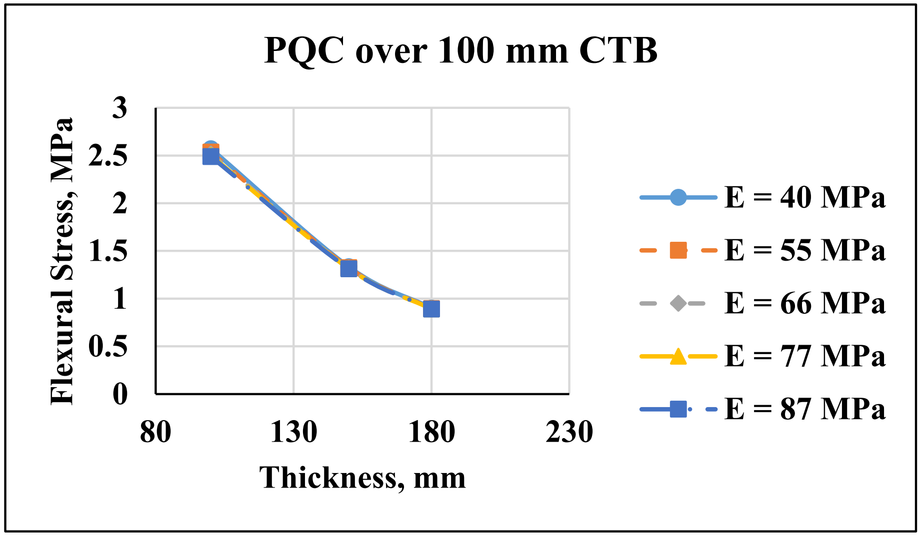
Stress Charts (1.75 m x 1.75 m slab)

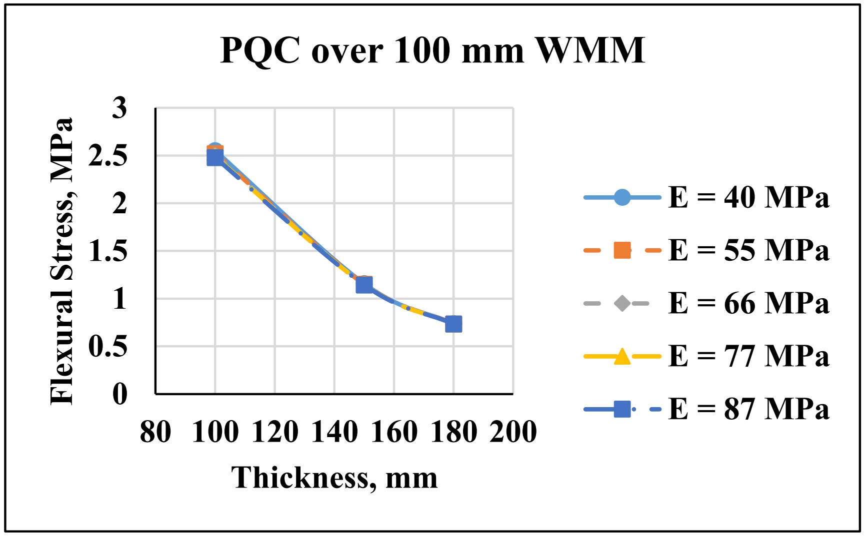






Stress Charts (1.0 m x 1.0 m slab)

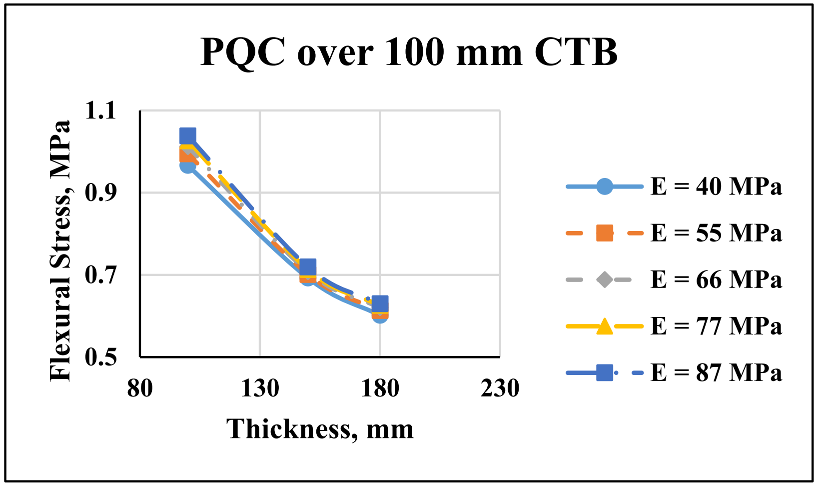




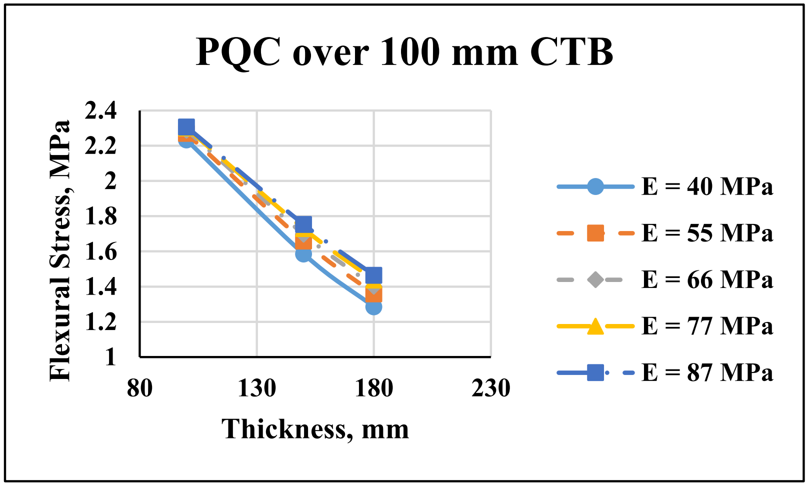
Stress due to 80kN at the edge with PTG

Design of Ci-SPCP

Stress charts (1.5 m x 1.5 m slab)



Corner loading

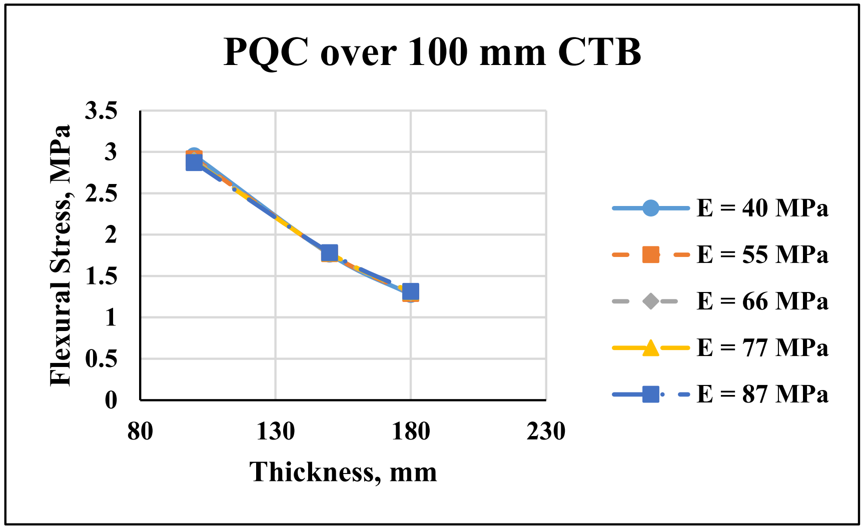


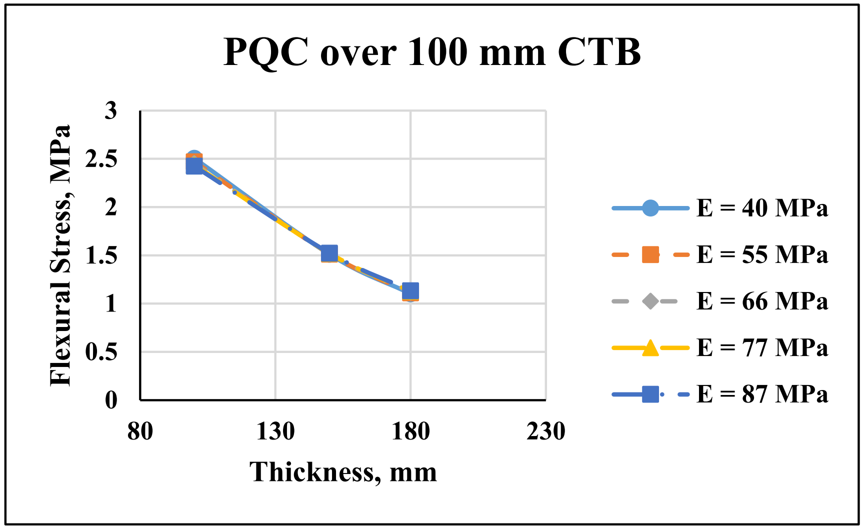
Edge Loading

Comparison of stresses for 80 kN load with NTG

'E' is the Elastic Modulus of the Subgrade

Stress charts (1.5 m x 1.5 m slab)





Edge Loading

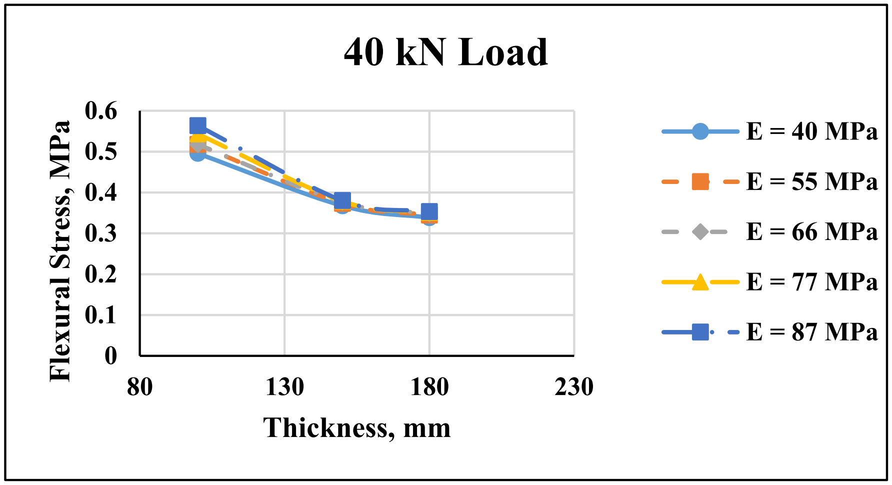
Transverse Edge Loading

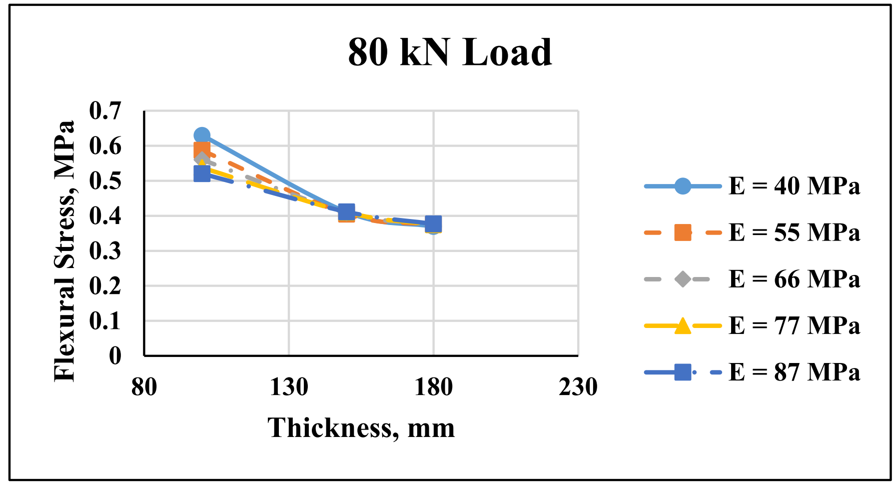
Comparison of stresses for 80 kN load with PTG

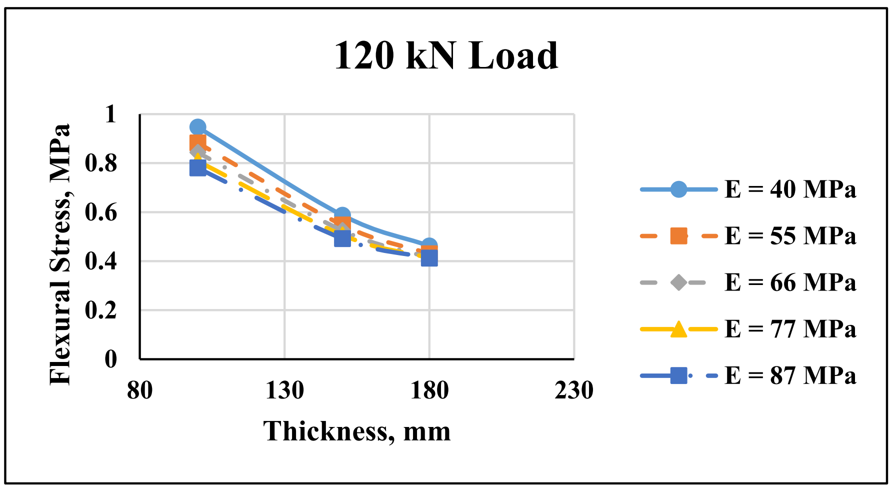
'E' is the Elastic Modulus of the Subgrade

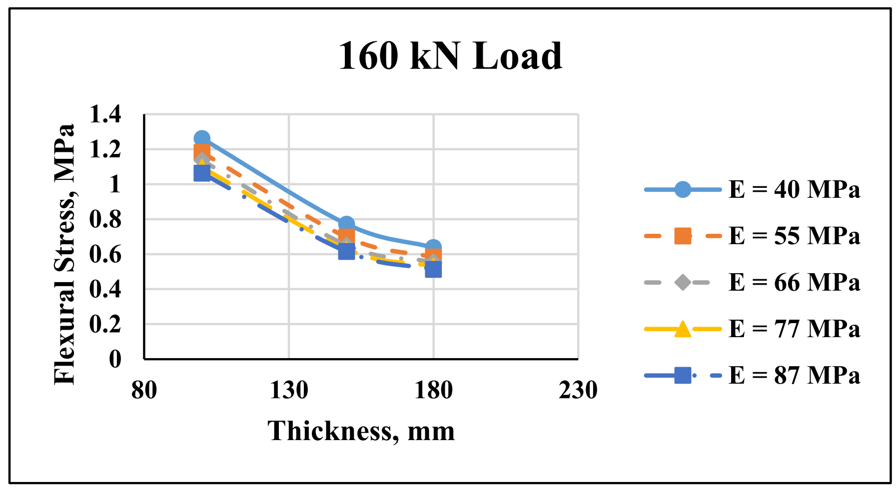
Design of Ci-SPCP

Stress Charts (1.0 m X 1.0 m slab)









'E' : Elastic Modulus of Subgrade

Comparison of stresses

Stress comparison between 1.75 m slab and 4.5 m slab for k = 150 MPa/mm and 250 mm thickness

Load (kN)	Maximum Principal Stress (MPa) in									
	3.50 m slab	1.75 m slab	3.50 m slab	1.75 m slab	3.50 m slab	1.75 m slab	3.50 m slab	1.75 m slab	3.50 m slab	1.75 m slab
	ΔT = 0^0C		ΔT = 8^0C		ΔT = 13^0C		ΔT = 17^0C		ΔT = 21^0C	
80	1.214	0.95	1.579	1.04	1.807	1.11	1.99	1.16	2.172	1.21
120	1.91	1.42	2.275	1.52	2.503	1.58	2.685	1.63	2.868	1.68
160	2.606	1.89	2.971	1.99	3.199	2.05	3.381	2.1	3.563	2.15
200	3.301	2.36	3.666	2.46	3.894	2.52	4.077	2.57	4.259	2.62
240	3.997	2.84	4.362	2.94	4.59	3	4.772	3.05	4.955	3.1

Design of Ci-SPCP

Comparison of stresses

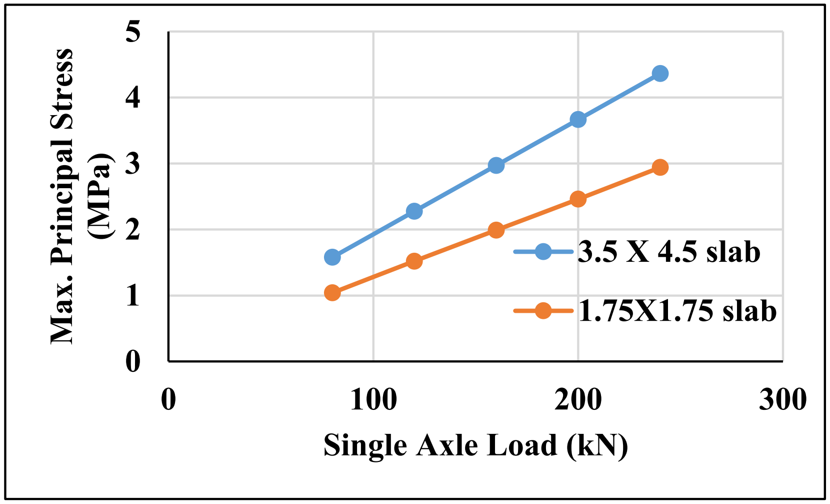
Comparison of stresses in slabs : 1.0 m x 1.0 m, 1.5 m x 1.5 m and 2.0 m x 2.0 m

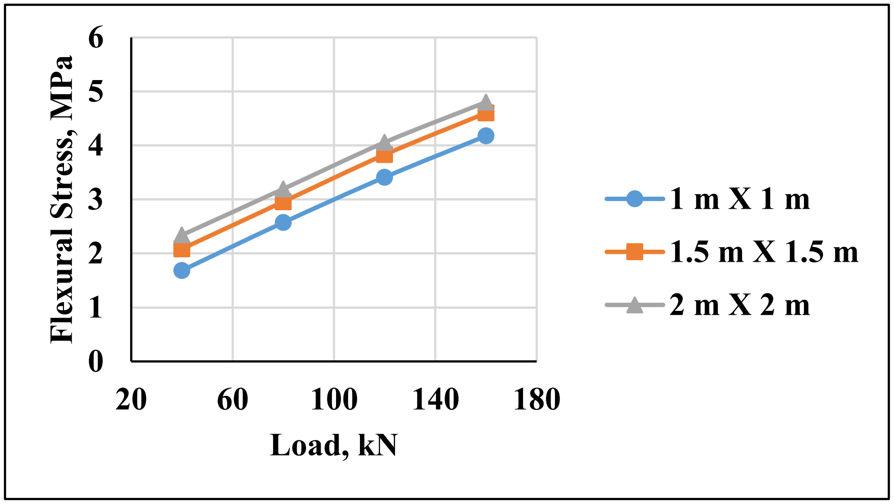
Load (kN)	Max. flexural stress in slab (MPa)		
	1.0 m X 1.0 m	1.5 m X 1.5 m	2.0 m X 2.0 m
40	1.685	2.085	2.341
80	2.573	2.956	3.193
120	3.410	3.829	4.056
160	4.177	4.600	4.801

Slab thickness: 100 mm

Design of Ci-SPCP

Comparison of stresses





Comparison of stresses in different slab sizes

Construction of Cast-in-situ Short Paneled Concrete Pavement (CiSPCP)

Construction of Cast-in-situ Short Paneled Concrete Pavement (CiSPCP)

STEPS

- Preparation of subgrade
- Construction of Sub-base (100 mm-GSB)
- Construction of Base (100- CTB: preferred/ WMM 75/100/150 mm Thicknesses as per IRC:SP-62-2014)
- Construction of PQC (M30)- Cutting of grooves at selected panel size (1.0 m x 1.0 m, 1.5 m x 1.5 m or 2.0 m x 2.0 m)- Depth of groove -1/3 rd thickness of slab
- Thickness of SPCP- From Design

Construction of Ci-SPCP on LVR

Prior to short slabs

Existing Block pavement
2011

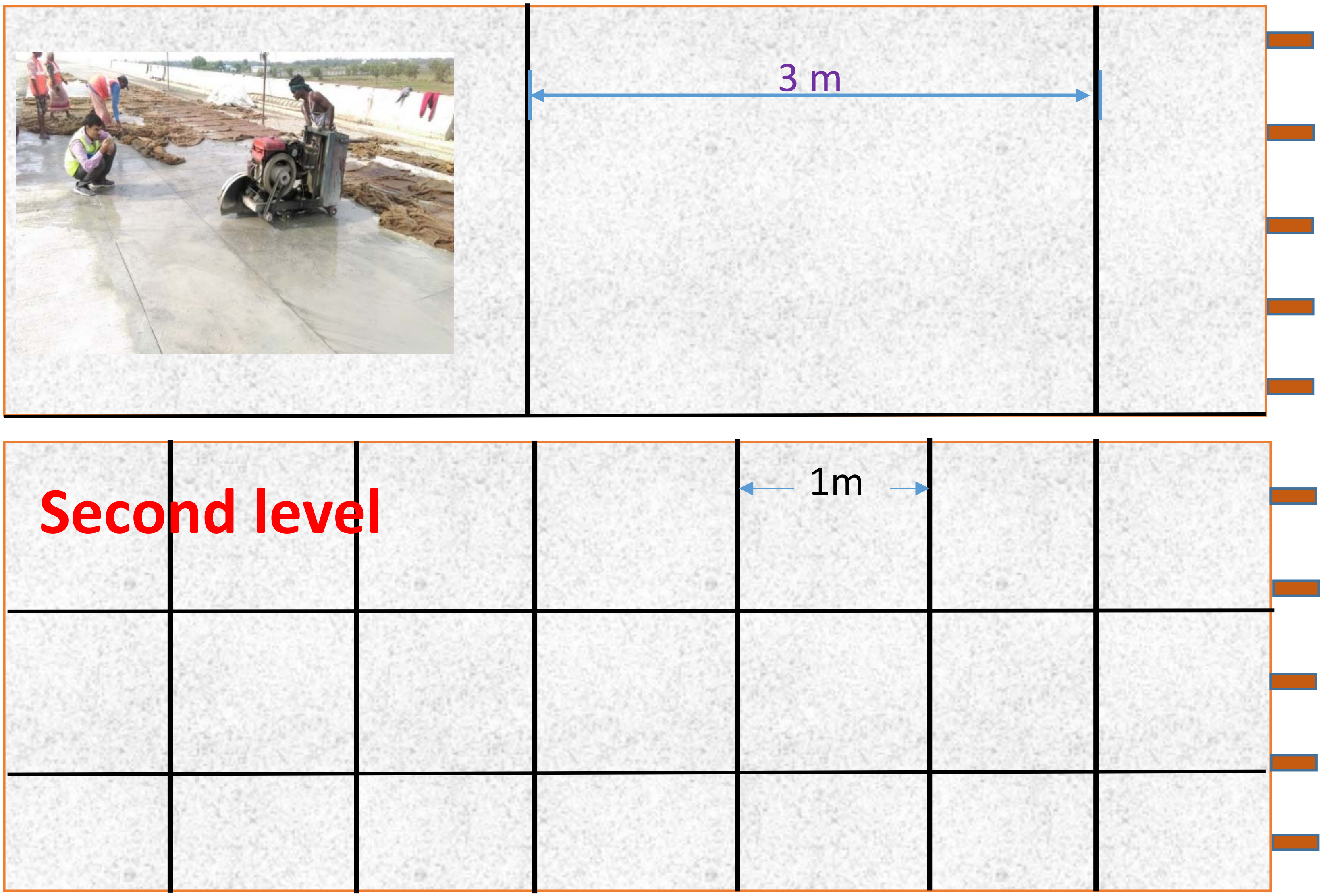
PMGSY Road, Mankar Village, West Bengal, India

Construction of Ci-SPCP on LVR

PMGSY Road, Mankar Village, West Bengal, India

Ci-SPCP: Joint saw cutting

First level



Cast-in-situ Short Paneled Concrete Pavement (CiSPCP)

Ci-SPCP on Low Volume Roads

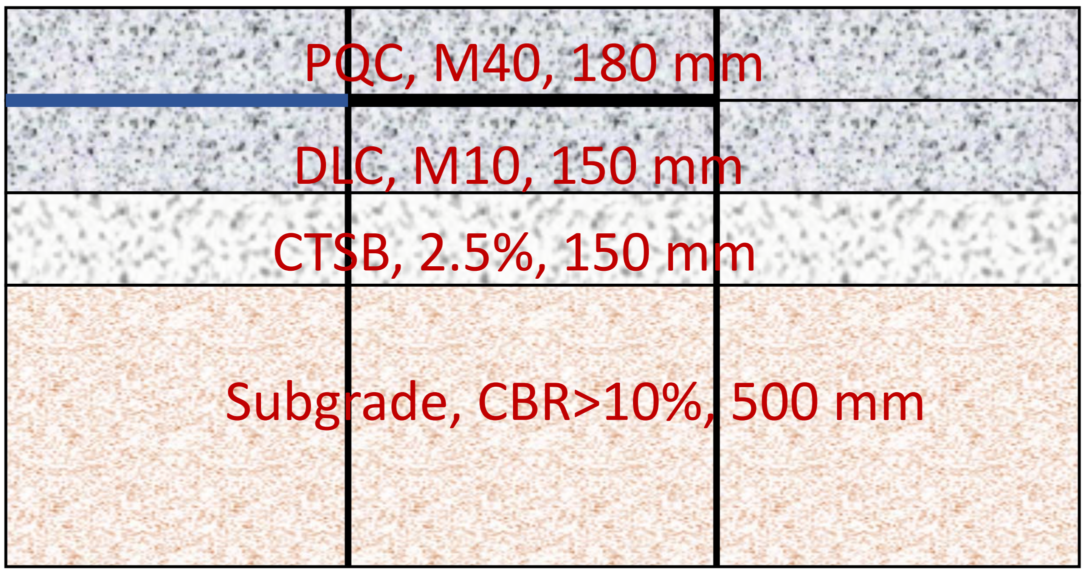
Slab thickness of 100 mm and joint saw-cut depth of 25-30 mm

PMGSY Road, Janardhanpur, Near IIT Kharagpur, West Bengal, India

Test section- Ci-SPCP on NH-19 (High volume roads)

384 m long, NH-19, Panagarh Bypass, West Bengal (Sep, 2016)

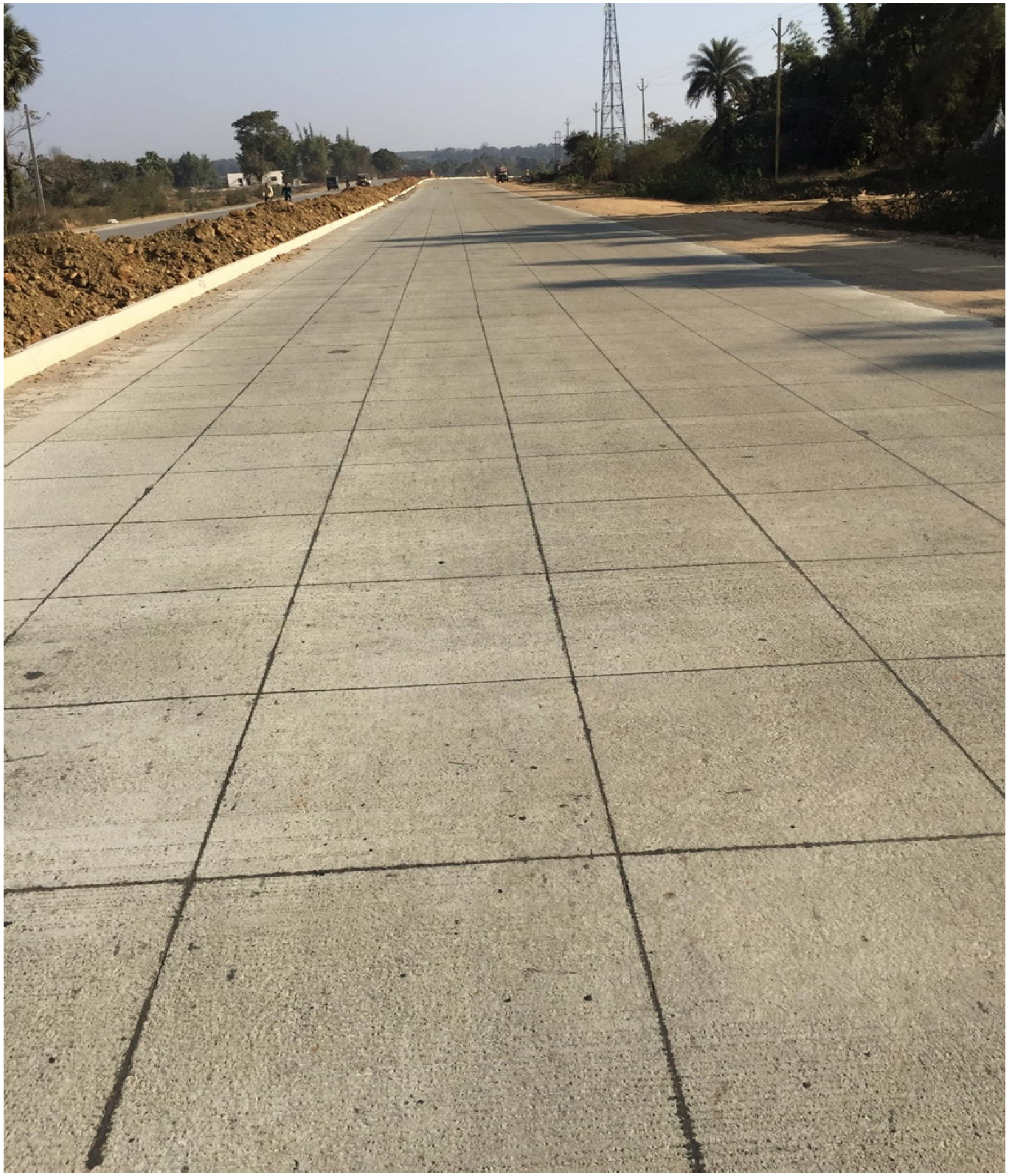
Panel Size, Sq.m	Thickness, mm	Interface b/w Panel and DLC	Chainage, km	Length, m
1 x 1	180	Nonwoven Geotextile	519+316 to 519+450	134
		Emulsion of RS-I	519+450 to 519+550	100
		Bonded	519+550 to 519+700	150



Research Project – sponsored by NHAI, Govt. of India (2016-22)

Test section of Ci-SPCP on NH 18 (old NH-33)
(High volume Roads)

Test section of Ci-SPCP on NH 18 (old NH-33)
(High volume Roads)



Test section of Ci-SPCP on NH 18 (old NH-33)
High volume Roads

Test Section 1: NH-19 (old NH-02), Durgapur, West Bengal

Test Section 2: NH-18 (old NH-33), Ghatsila, Jharkhand

Performance Evaluation- Ci-SPCP

- November 2017 - Winter
- June 2018 - Summer
- December 2018 - Winter
- March 2019 - Interim
- May 2019 – Summer
- January 2020 – Winter

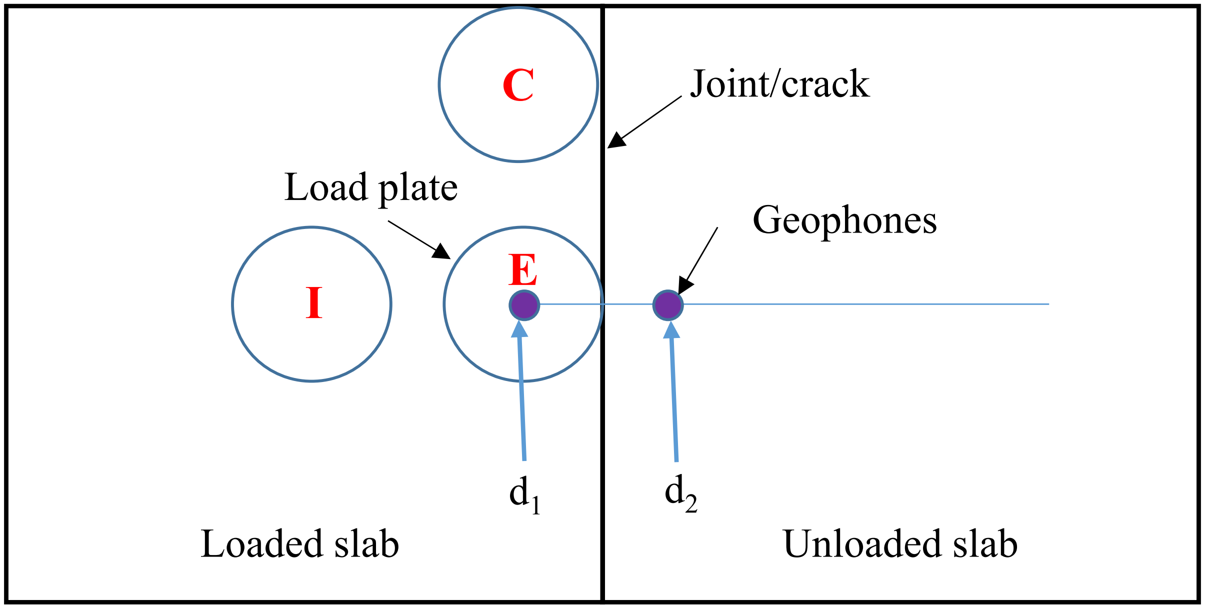
Testing Positions:

Interior, Edge, Corner

Load Transfer Efficiency (LTE):

LTE, % = d_2/d_1

Roughness - NSV



Conclusions

Cast-in-situ Short Paneled Concrete Pavement (CiSPCP)

- Maximum flexural stress decreases with decrease in panel size of the slab (only one wheel set over the slab at a time).
- Critical tensile stresses are lesser in thicker slabs as compared to thin PQC slabs.
- Stresses are found to be increasing with increase in the load values applied over the slab.
- Generally, stresses in PQC are lesser when placed over CTB as compared to WMM. (some exceptions do exist).

Conclusions cont'd…

- Critical stresses due to load with PTG are found to be higher as compared to stresses due to loads with NTG.
- Stresses in PQC are higher for lower "E" values at lower temperatures. With increase in ΔT, trend reverses.
- Edge loading with NTG is more critical as compared to corner loading with NTG.
- Corner loading with NTG is causing the least flexural stress.
- CiSPCP promising pavements for Low Volume Roads.

Thank you…