PERVIOUS CONCRETE PAVEMENT SYSTEMS FOR LOW-VOLUME ROAD APPLICATIONS

Presented by: KRISHNA PRAPOORNA

Associate Professor and Head, Civil and Environmental Engineering

INDIAN INSTITUTE OF TECHNOLOGY TIRUPATI, INDIA`

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भारतीय प्रौद्योगिकी संस्थान तिरुपति

IIT TIRUPATI

INTERNATIONAL CONFERENCE ON NEW TECHNOLOGIES AND INNOVATIONS IN RURAL ROADS, New Delhi, India

PRESENTATION OUTLINE

- Background / Introduction
- Pervious Concrete Pavement Parking Lots - Case Studies
  - *Indian Institute of Technology Kharagpur*
  - *Municipal Corporation of Tirupati*
  - *Indian Institute of Technology Tirupati*
- Field Performance Monitoring
- Pervious All-Road All-weather Multilayered paver (PARAMpave) blocks
- Way Forward: Field Implementation & Advanced Research

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INTRODUCTION TO PERVIOUS CONCRETE

Coarse Aggregates

+

Cement

+

Water

+

Admixtures

Pervious Concrete

Characteristic interconnected macroporous structure

Structural characteristics	Hydrological characteristics
Compressive strength: 3-28 MPa	Porosity: 15-35%
Flexural strength: 1-3 MPa	Permeability: 0.2-2.0 cm/s

Applications

- Sidewalks, pathways
- Parking lots, medians, shoulders
- Low-volume roads

BENEFITS & APPLICATIONS OF PERVIOUS CONCRETE

Road user:

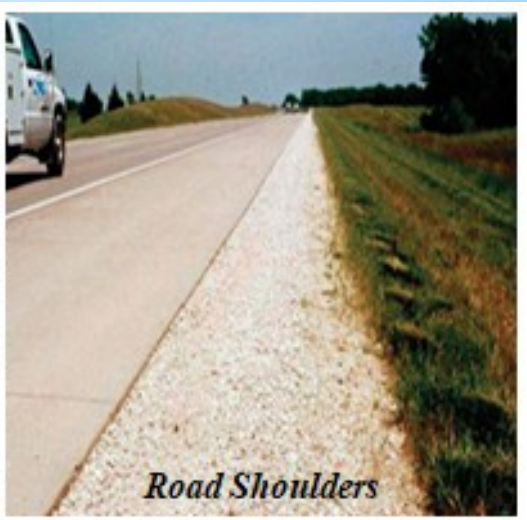
- *Skid resistant riding surface*
- *Reduced water spraying effect*
- *Less noisy*

Environmental:

- *Increased ground water recharge*
- *Reduced erosion*
- *Reduced flash flooding*
- *Reduced first flush*

Societal:

- *Reduced UHI effects*
- *Better urban land use*



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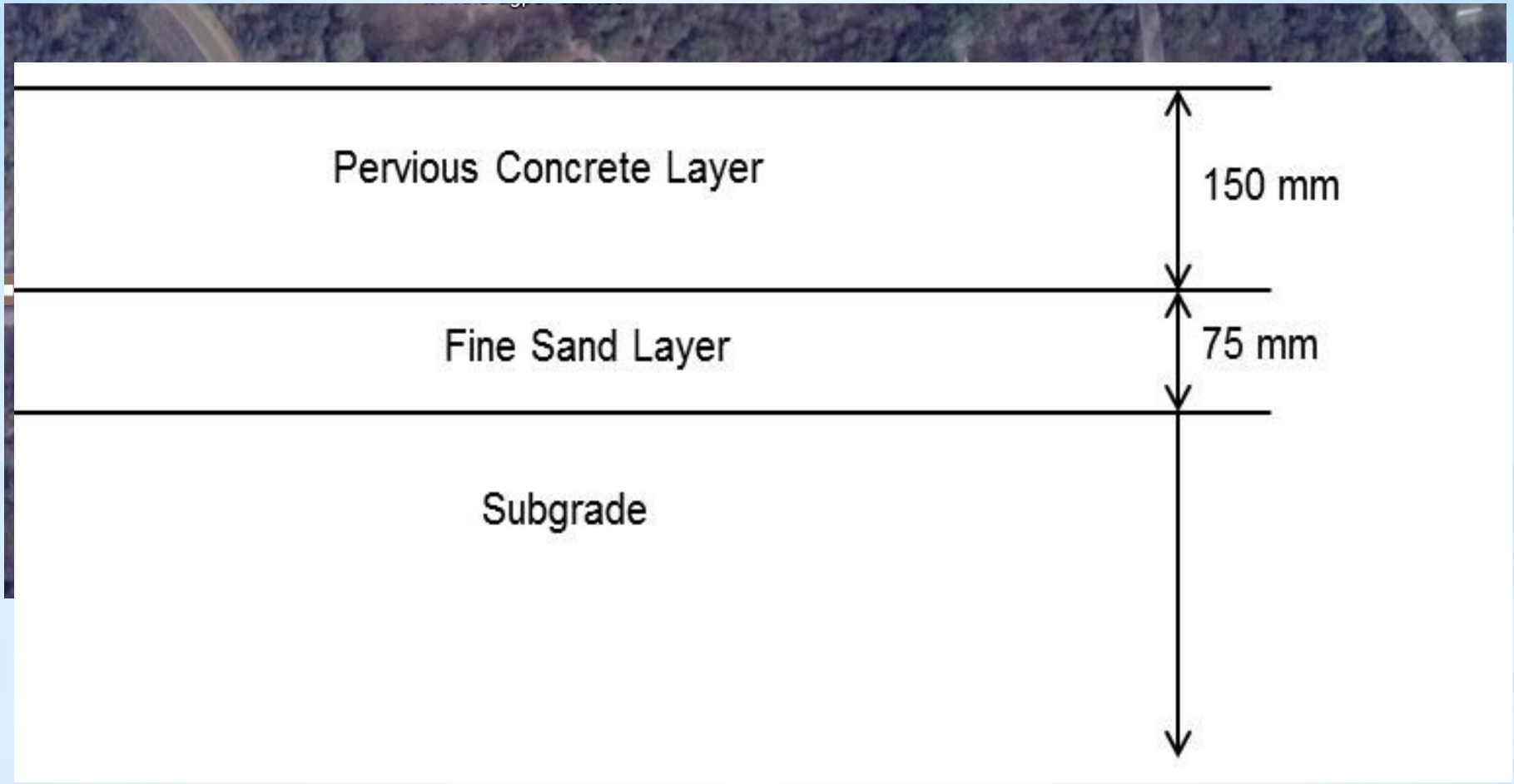
PERVIOUS CONCRETE PAVEMENTS - CASE STUDIES

- PCP test sections at Indian Institute of Technology Kharagpur



Chandrappa, A.K., Maurya, R., Biligiri, K.P., Rao, J.S., Nath, S., Laboratory investigations and field implementation of pervious concrete paving mixtures. ASTM International's Advances in Civil Engineering Materials, 2018, 7(1): 447-462. DOI: 10.1520/ACEM20180039

PERVIOUS CONCRETE PAVEMENTS - CASE STUDIES

Soil compaction in progress

Soil samples collected at different locations: properties

1-Ton manual roller

PERVIOUS CONCRETE PAVEMENTS - CASE STUDIES

Sand layer function:

- ***Provide uniform support for PC slabs***
- ***Temporary storage of stormwater***

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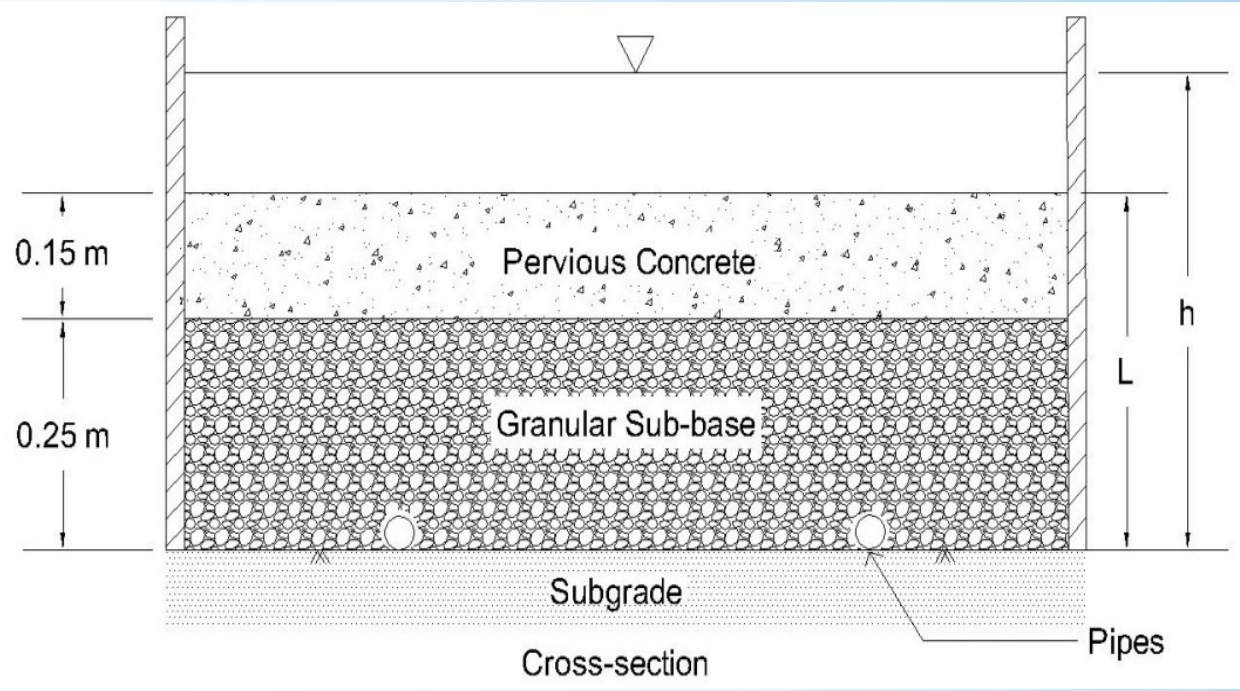
PCP test sections at Municipal Corporation of Tirupati *4 m wide and 125 m long*

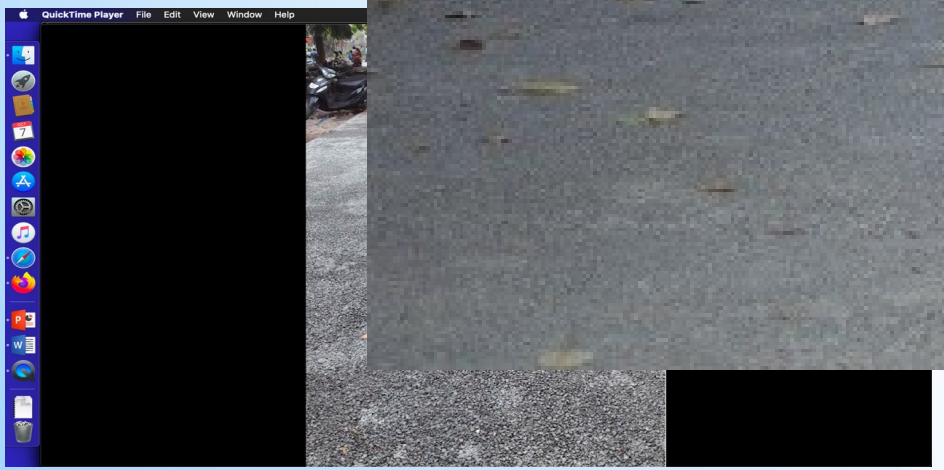
Materials and Mix Proportions

- *Aggregate - 12.5 mm and finer size; 6.3 mm and lower size*
- *Equal aggregate proportions: binary gradation*
- *Ordinary Portland Cement 53-Grade*
- *Cement-to-aggregate ratio: 1:3.75*
- *Water-to-cement ratio: 0.32*
- *Polycarboxylic ether-based superplasticizer (0.6% by mass of cement) conforming to ASTMC494 Type F*



Singh, A., Jagadeesh, G.S., Sampath, P.V., Biligiri, K.P. Rational approach for characterizing in situ infiltration parameters of two-layered pervious concrete pavement systems. J. Mater. Civ. Eng., 2019, 31(11): 04019258. DOI: 10.1061/(ASCE)MT.1943-5533.0002898

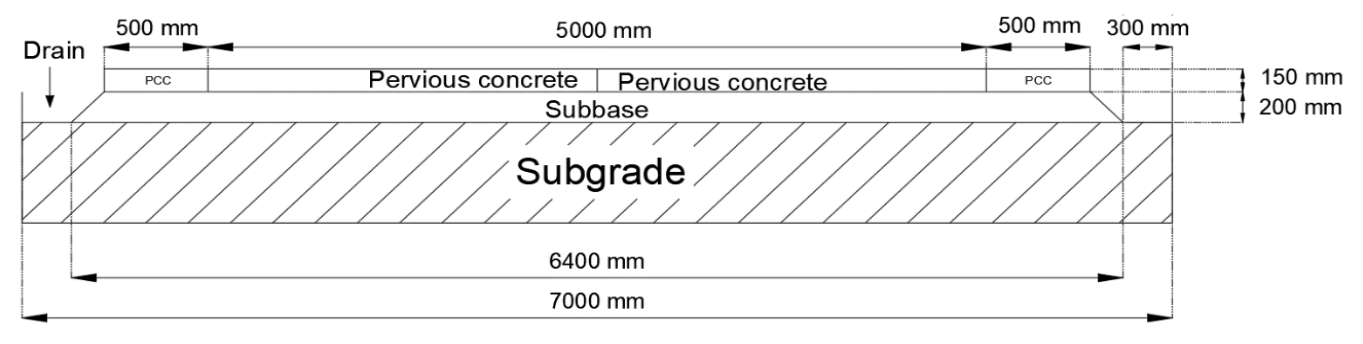
PERVIOUS CONCRETE PAVEMENTS - CASE STUDIES

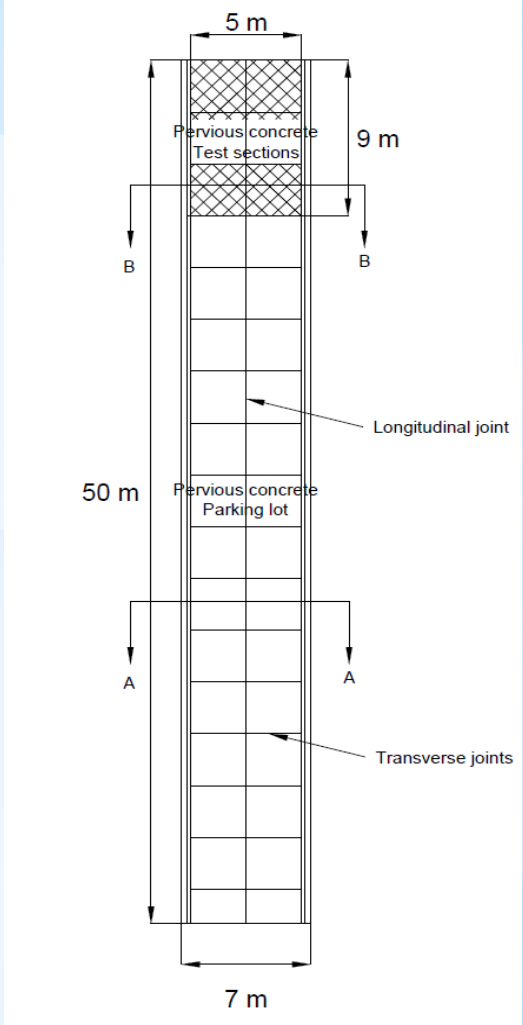


PERVIOUS CONCRETE PAVEMENTS - CASE STUDIES

PCP test sections at Indian Institute of Technology Tirupati, Transit Campus

(5 m wide and 50 m long)





Materials and Mix Proportions

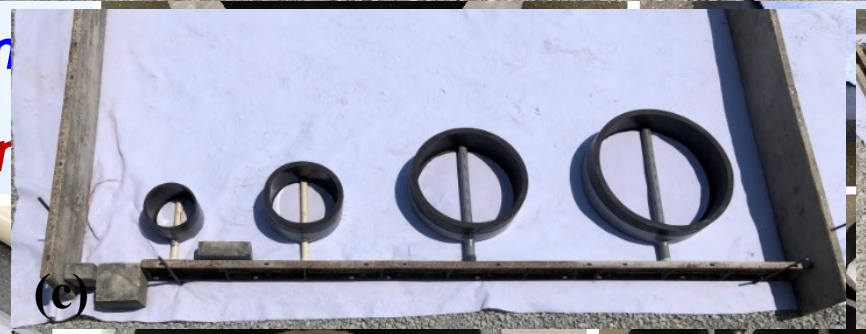
- *Aggregate - 12.5 mm and 4.75 mm*
- *Water-to-cement ratio: 0.30*
- *Ordinary Portland cement 53 - Grade*
- *Aggregate-to-cement ratio: 3.75*
- *Polycarboxylic ether-based superplasticizer (0.5% by mass of cement) conforming to ASTMC494 Type F*

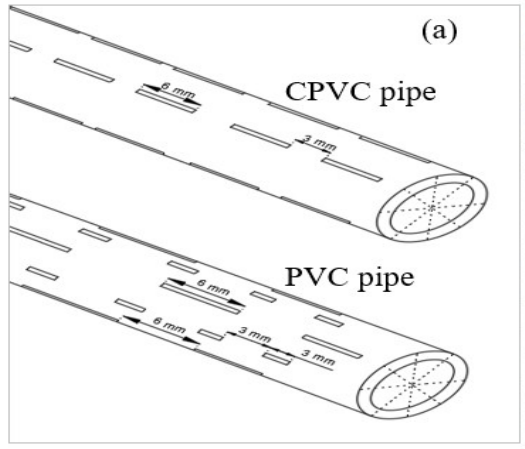
Vaddy, P., Singh, A., Sampath, P.V., Biligiri, K.P. Multi-scale in-situ investigations for characterization of infiltration parameter in pervious concrete. Journal of Testing and Evaluation. Published ahead of print, September 01, 2021, https://doi.org/10.1520/JTE20200052

PERVIOUS CONCRETE PAVEMENTS - CASE STUDIES

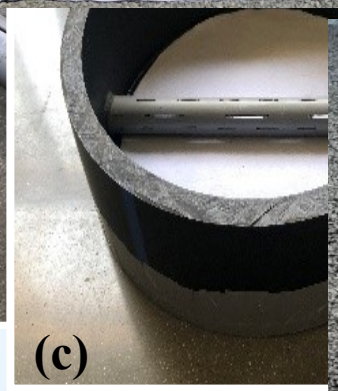
b) Preparation of Embedded Infiltration Rings in Field Test Sections

- CPVC pipes,
(infiltration ri
diameter)
- PVC pipes, 40 mm
rings 500 & 630 mm

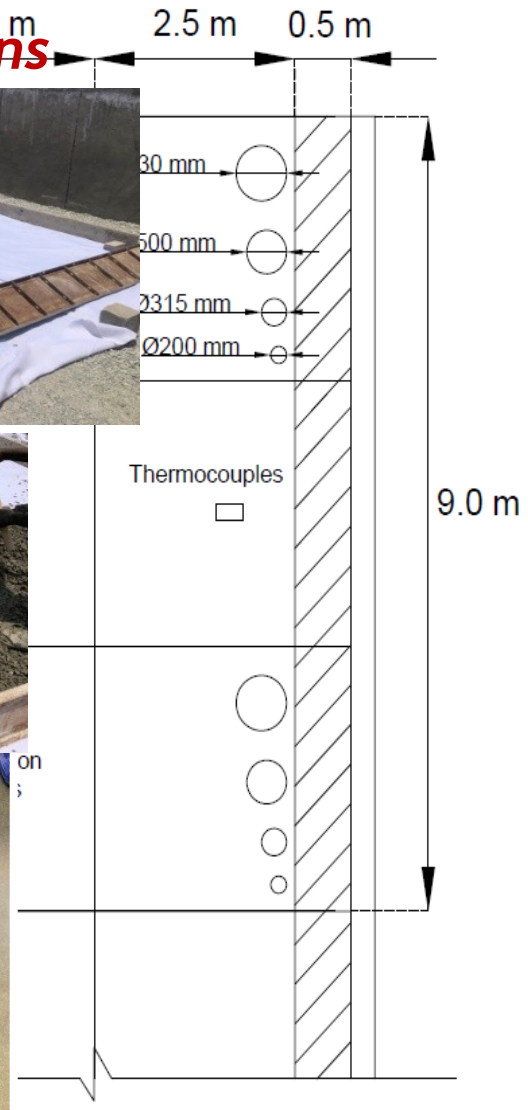




Schematic of Slots in Pipes



Preparation of Infiltration Rings for Field Placement of Embedded Infiltration Rings



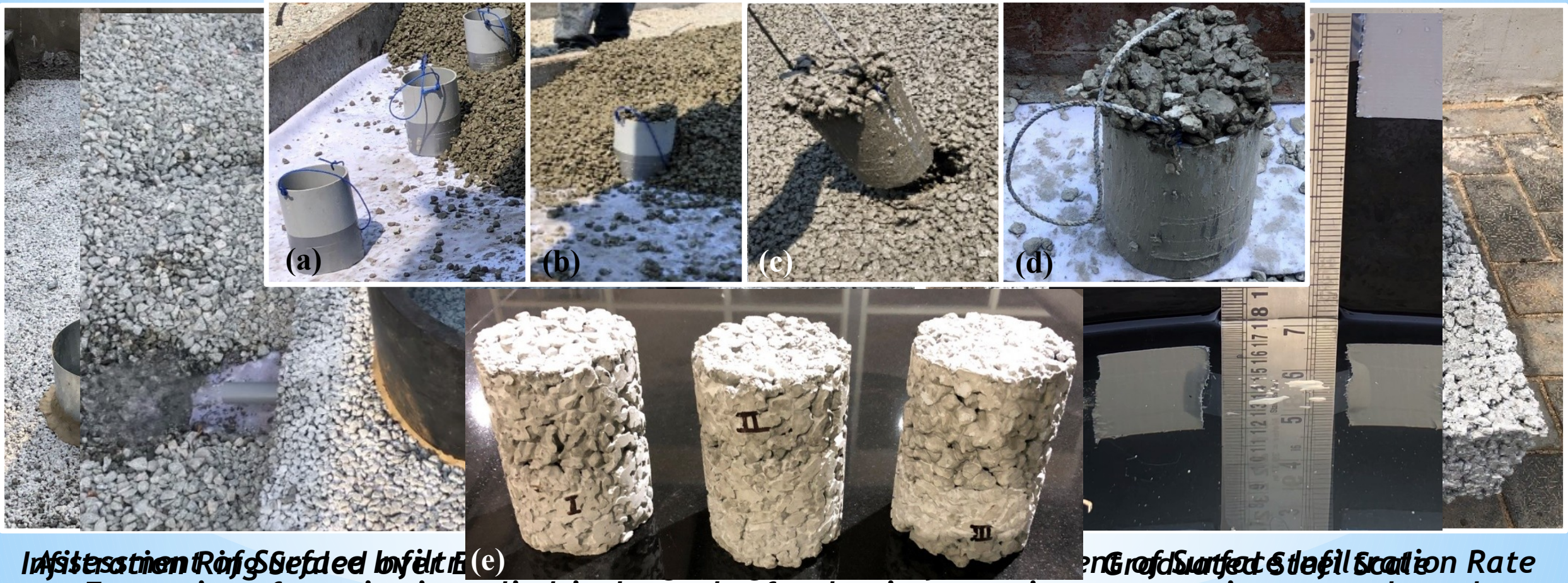
Placement of PC Test Section

PERVIOUS CONCRETE PAVEMENTS - CASE STUDIES

Testing & Evaluation

b) Surface Infiltration Rate Test ASTM C1701

c) Field Preparation of Cylindrical Specimen



Infiltration Rig Used for Field Testing

Measurement of Surface Infiltration Rate

Graduated Steel Scale

Extraction of cast-in-situ cylindrical samples for density, porosity, compressive strength and permeability testing

Concrete Test Slabs

For Laboratory Pervious Concrete Slabs

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LEARNINGS: IN-SITU AND READY-MIX CONCRETE CONSTRUCTION

Parameter \ Process	In-situ mixing	Ready-mix pervious concrete
Quality		
Time of e		
Suitabilit	Small	
Material	R	
Production, transportation, and placement	Slow Labor-intensive	Rapid Saves labor requirement
Supervision	Continuous	Batching
Consistency	Uniform	*Non-uniform (Kevern, 2009)*

In-situ mixing

Ready-mix concrete

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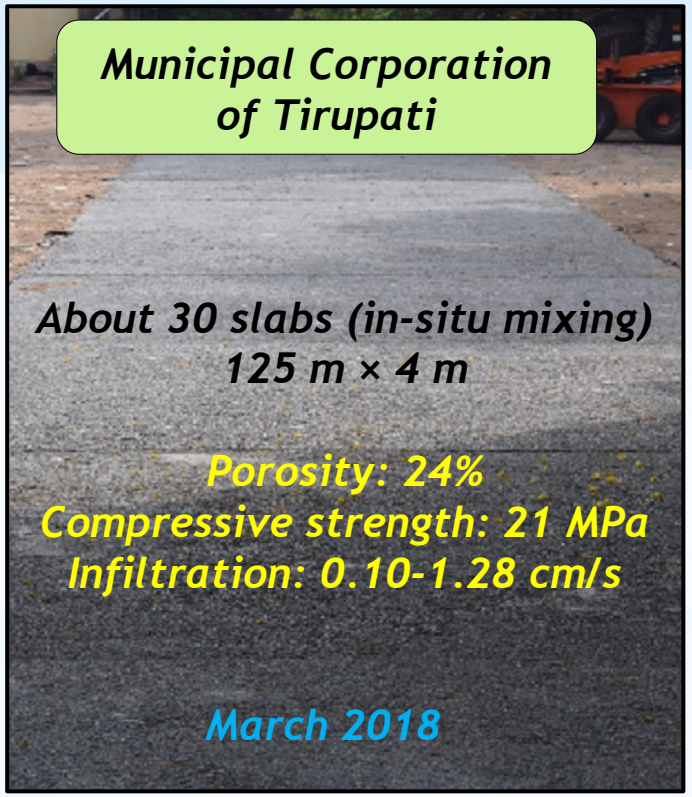
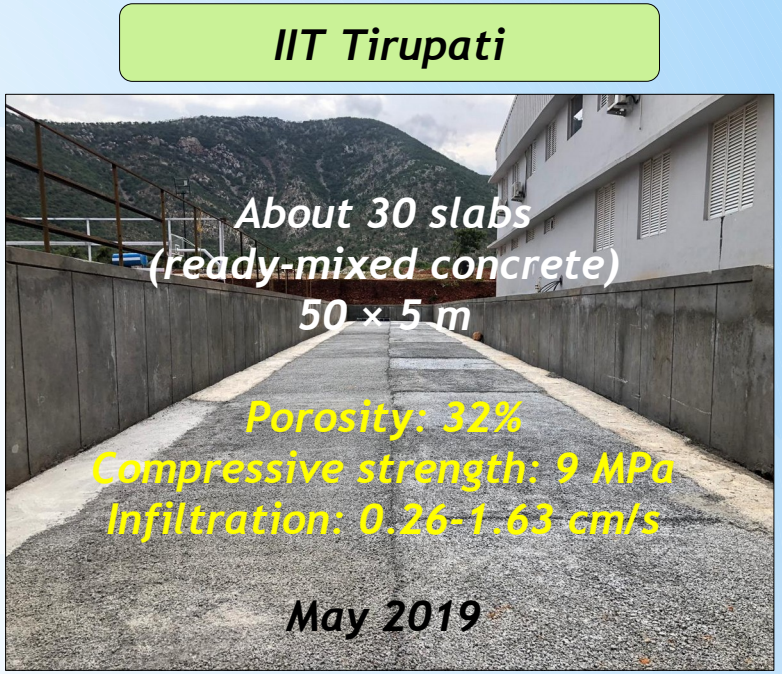
FIELD PERFORMANCE MONITORING





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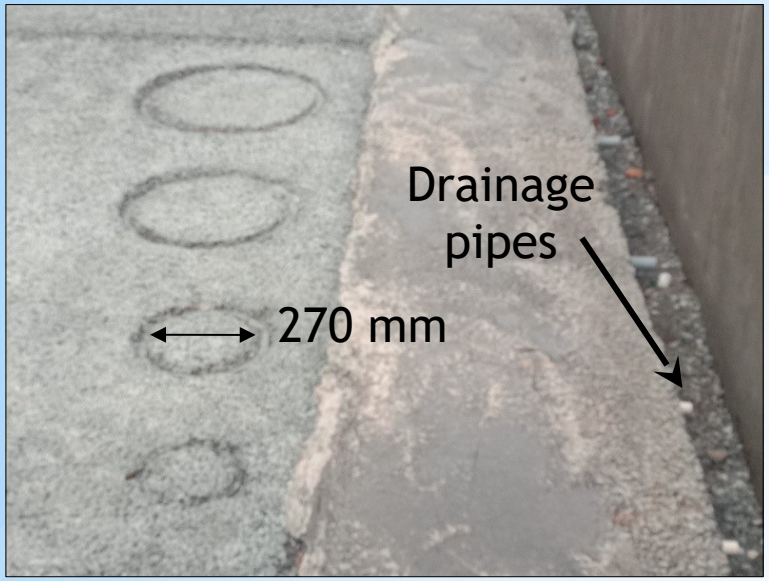

Reduction in infiltration rate over two years at the IITT: 5.7%

Need to develop high-strength pervious concrete material; Design and construction practices vary: agency to agency; On-site quality control: major problem; On-site manual / ready-mix concrete: consistency; Clogging: lack of maintenance strategies

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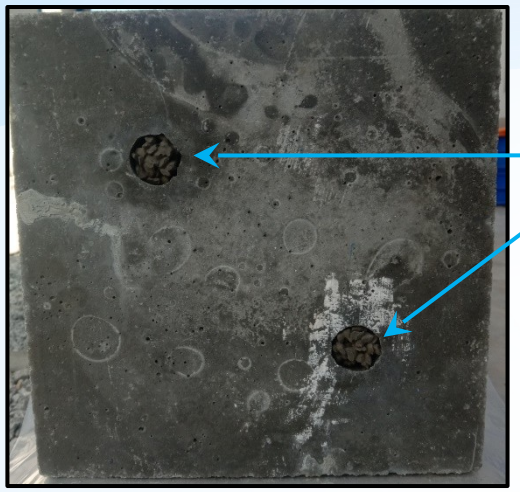
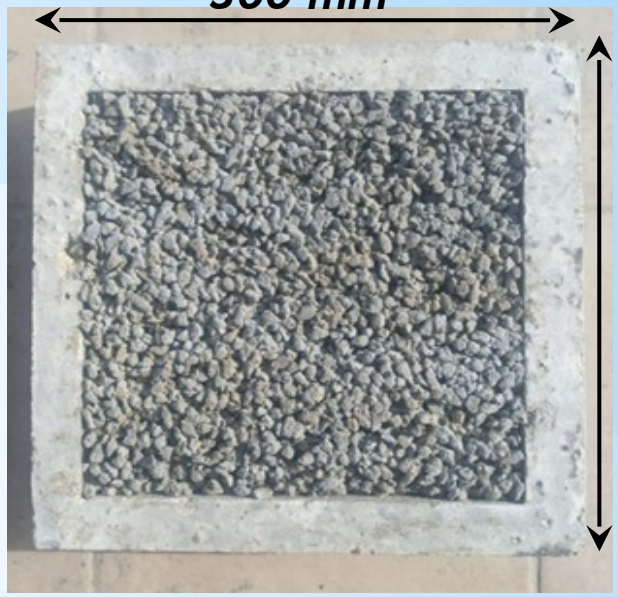
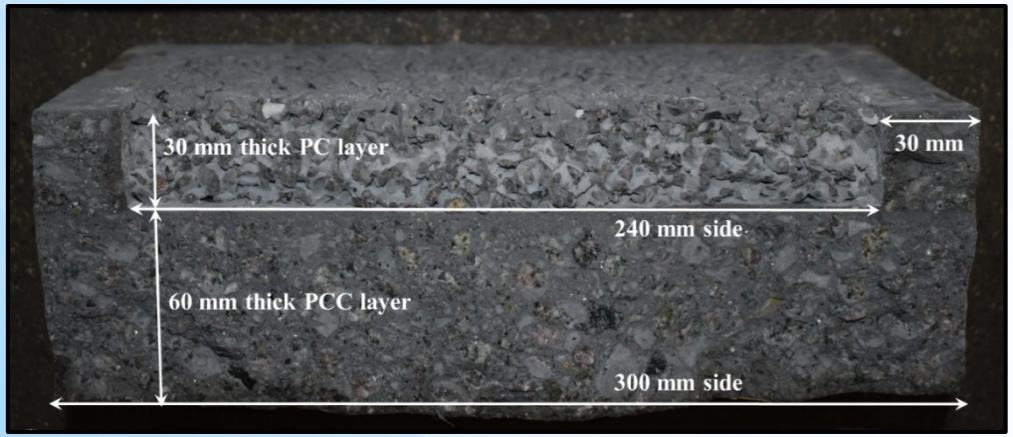
Pervious All-Road All-weather Multilayered paver (PARAMpave) blocks



Holes filled with pervious concrete





Property	PARAMpave	Conventional PC
Porosity (%)	*16.60-23.56*	15-35
Permeability (cm/s)	*0.77-1.33*	0.2-5
Texture depth (mm)	*2.64-2.78*	> 1.8
Flexural strength (MPa)	*4.83-6.13*	1-3

Avishreshth Singh, 2021. Development of Pervious All-Road class All-weather Multilayered paver blocks, Ph.D. Thesis, Civil & Environmental Engineering, Indian Institute of Technology Tirupati, December 2021

Pervious All-Road All-weather Multilayered paver (PARAMpave) blocks

Mix ID	Mass / paver (kg)		Material cost / paver (INR)		Total cost / paver (INR)		Total cost per sq.ft. (INR)		Cost savings (%)
	PARAMpave	Concr					Mpave	Concrete	
M7	17.12						21		10.71
M18	17.56						61		9.87
M1-S	17.12	19.4					30	48.39	10.52
M16-S	17.12						30		10.52
M13-S	17.12		40.15		41.57		43.30		10.52

Cost/km single-lane road, 3.5 m width

Mix ID	Total cost (INR)	
	PARAMpave	Concrete
M7	16,27,699	18,22,927
M18	16,43,021	
M1-S	16,31,181	
M16-S	16,31,181	
M13-S	16,31,181	

*Other costs include - labor, electricity, fuel, mold, wastages, and overhead
Maintenance, interest, and depreciation costs were not included

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CONCLUSIONS & RECOMMENDATIONS

- PC conserves natural resources: *reduction in sand quantity*
- PC: *high infiltration capacity*; *potential to reduce flash flooding* and problems associated with *surface runoff*
- PARAMpave superior to in-situ construction and RMC construction
- Embodied energy and GHG emissions: *lower* for PARAMpave than RMC and in-situ construction
- Cost of PARAMpave: *10% lower* *compared to conventional cement concrete paver blocks*

FUTURE IMPLEMENTATION PLAN

- *Performance of field pavement systems:*
  - *Test sections: all road classes*
  - *Parking lots*
  - *Footpaths*
  - *Village roads*
  - *Others?*
- *Establish laboratory & field correlations*
- *Develop field design specifications for construction*
- *Sustainable roadway infrastructure: LID*
- *Financial implications: LCA; LCCA; B/C ratio*

Foster collaboration(s) between academia & industry to create SUSTAINABLE roads

RESEARCH TEAM

Dr. Anush K. C.

Assistant Professor

IIT Bhubaneswar

akc@iitbbs.ac.in

Dr. Avishreshth Singh

Scientist

IIT Tirupati

avi.theriac@gmail.com

Dr. Prasanna V. S.

Assistant Professor

IIT Tirupati

prasvenk@iittp.ac.in

Krishna Prapoorna

Associate Professor

& Head, IIT Tirupati

bkp@iittp.ac.in

THANK YOU
Questions & Comments

Email: bkp@iitp.ac.in

Mobile: +91-9036955552

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