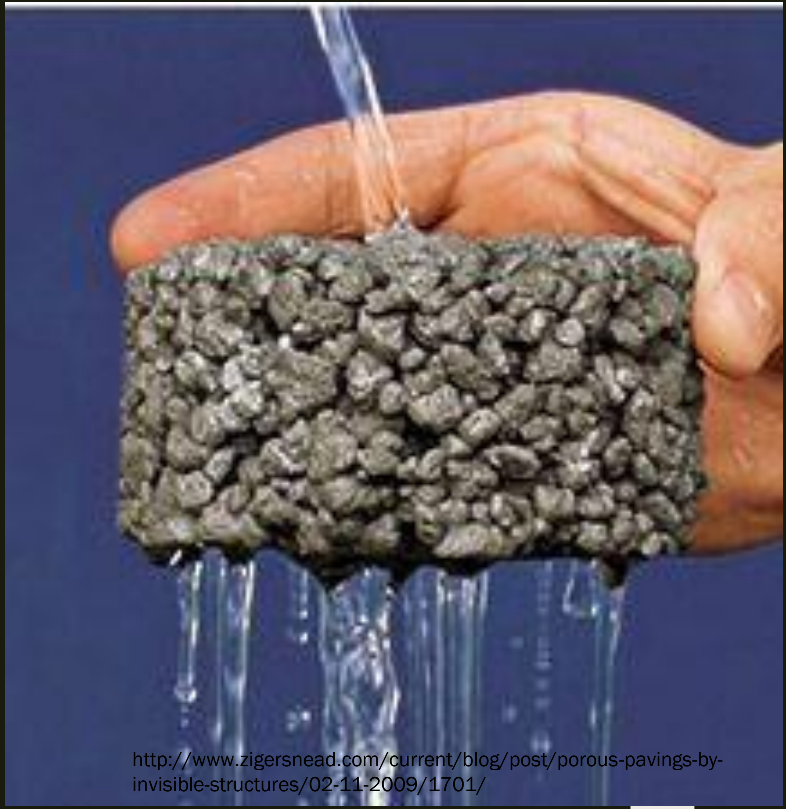
FULLY PERMEABLE PAVEMENTS AS A SUSTAINABLE APPROACH FOR MITIGATION OF STORMWATER RUNOFF


http://www.zigersnead.com/current/blog/post/porous-pavings-by-invisible-structures/02-11-2009/1701/

By

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Introduction

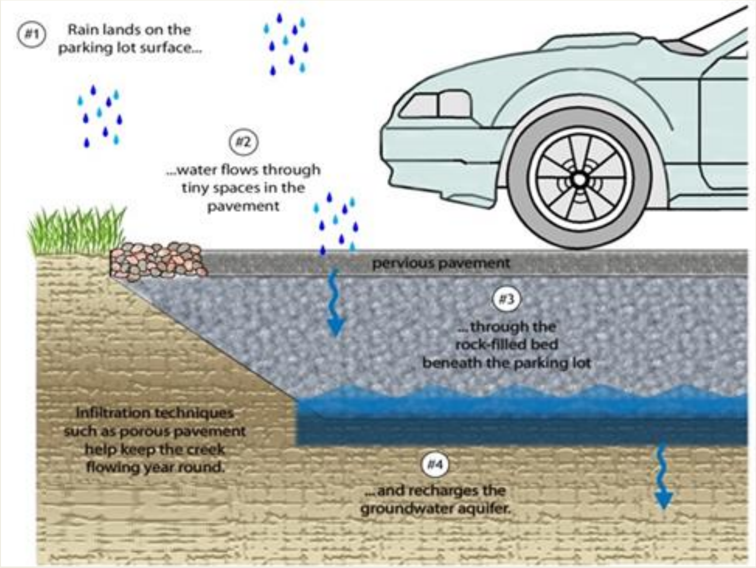
- Green lands and forest are being converted to concrete jungles.
- The water movement and ground water reserves are becoming dry.
- Permeable pavements are one of the solutions for the stormwater management.
- Permeable pavements can decrease the runoff volume on the pavements.
- The quality of permeable pavement hugely depends on design specifications, construction practice and maintenance.
- In pervious pavement, open graded mixes are used for percolation of water from the surface to subgrade.

https://wallpaperstock.net/beautiful-green-lands_wallpapers_45443_1600x1200_1.html

http://hires.patternpictures.com/PP16220906-New-York-Concrete-Jungle.jpg

Permeable Pavement Applications

- OGFC consists of aggregates with uniform grading and almost no filler or fine materials.
- Initially used to avoid the shortcomings of the chip seal construction.
- Later used for the setting of the aggregate during the rainstorm.
- The storm water percolates through the OGFC layer and then into the subgrade.



http://www.danville-stormwater.org/permeable-pavement.html

Standard Pavement vs Permeable Pavement

Permeable Pavement Benefits

- Storm water runoff is reduced.
- Contamination of runoff water is reduced.
- Ground water is recharged.
- The need for the drainage structure is reduced.
- Reduces the fatal accidents.
- Vision for driver is improved.
- The noise is reduced.

Background

- Fully permeable concrete and asphalt pavements were designed using the mechanistic-empirical design procedure proposed by the University of California Pavement Research Center (UCPRC).
- Site investigation was conducted and various tests were performed to assure the suitability of the subgrade in terms of permeability and strength at the test location.
- Test sections of concrete and asphalt pavement were constructed at California State University Long Beach (CSULB) for the implementation of the design method.
- Strain gages and pressure cells were installed before the construction of pavements.
- Data was collected to validate and calibrate the structural design procedure.

Objective

- A location is selected within CSULB for the construction of pavement.
- Installation of pressure cells and strain gages.
- Construction of concrete and asphalt pavement.
- Retrieving of data and analyzing.
- Validation and calibration of design method proposed.

Materials Characterization

- **Subgrade**
  - *Infiltration rate is 10^{-4} cm/s .*
  - *The percentage passing #200 was 54.7.*
- **Base Layer**
  - *Open-graded base.*
  - *ASTM#2 aggregate gradation*
- **Bedding layer**
  - *ASTM#8 aggregate gradation.*
- HMA-O: Aggregate size 12.5mm (NMAS). with PG 70-10.
- PCC-O: Aggregate size 9.5mm (MAS).

Design

- PCC-O test section of two lanes of local street and parking lane, with no subbase, in LA area:
- Compacted subgrade permeability: 0.45 in/hr.
- Storm design: 50 years
- Design Traffic Index: 5 (minimum required by HDM)
- Design truck speed: 7 km/h.
- Surface layer: Jointed, no dowels, PCC-O with 12 ft (3.6 m) slab length. Note that this is a test section where joints are either sawn or formed to link with existing joints in the adjacent lanes.

Design Steps

- Choose base thickness based on hydraulic performance.
  - *Using the hydraulic design chart select the thickness of base.*
  - *For permeability of 10^{-4} cm/s, 50-year design storm, and LA region.*
  - *The minimum base thickness should be 700mm.*
- Choose PCC-O slab thickness based on fatigue damage for given TI.

- For slab length of 3100mm and TI of 5.
- Using the PCC-O chart select the thickness of the slab i.e; 250mm.

Subgrade soil permeability (cm/s)[1]	Storm design (years) (Full storm duration)	Rainfall region											
		Sacramento (Sac)				Riverside (LA)				Eureka			
		Thickness of Granular Base + PCC-O Subbase (mm)				Thickness of Granular Base + PCC-O Subbase (mm)				Thickness of Granular Base + PCC-O Subbase (mm)			
		Number of highway lanes[2]				Number of highway lanes[2]				Number of highway lanes[2]			
		2	3	4	5	2	3	4	5	2	3	4	5
1.00E-05	2	270	450	600	700	270	400	480	680	600	900	1270	1570
1.00E-04		130	180	250	420	130	150	320	400	350	65		
1.00E-03		130	130	130	130	130	130	130	130	130	13		
1.00E-05	50	480	700	1050	1250	580	860	1180	1600	800	127		
1.00E-04		190	420	680	950	360	700	950	1350	500	85		
1.00E-03		130	130	130	130	130	130	130	230	130	13		
1.00E-05	100	600	800	1150	1430	680	1050	1300	1800	1150	172		
1.00E-04		210	500	750	1070	400	850	1200	1450	830	130		
1.00E-03		130	130	130	150	130	130	150	320	130	22		

1 Note that draw down times will vary significantly and are dependent primarily on subgrade soil permeabilities, but also on other factors such as numbe recurrence interval, etc as well. Draw down times could vary between one hour for subgrades with a permeability of 1.00E-03 to several months for su permeability of 1.00E-05 and higher. Refer to Reference 4 for discussion on the calculation of drain down times.

2 The number of highway lanes must include the shoulder. Shoulder width is 10 ft. (3.0 m).

Hydraulic Table

Structural Design Chart

PCC Layer Thickness (mm)	Slab Length (mm)															
	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500
250	12.0	12.0	11.5	11.5	11.0	11.0	11.0	10.5	10.5	10.0	10.0	10.0	9.5	9.5	9.0	9.0
260	16.0	16.0	15.5	15.0	15.0	14.5	14.5	14.0	14.0	13.5	13.0	13.0	12.5	12.5	12.0	11.5
270					18.5	18.5	18.0	17.5	17.0	16.5	16.5	16.0	15.5	15.0	15.0	14.5
280													18.5	18.0	17.5	17.0
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Note: Slab Width = 3.5 m

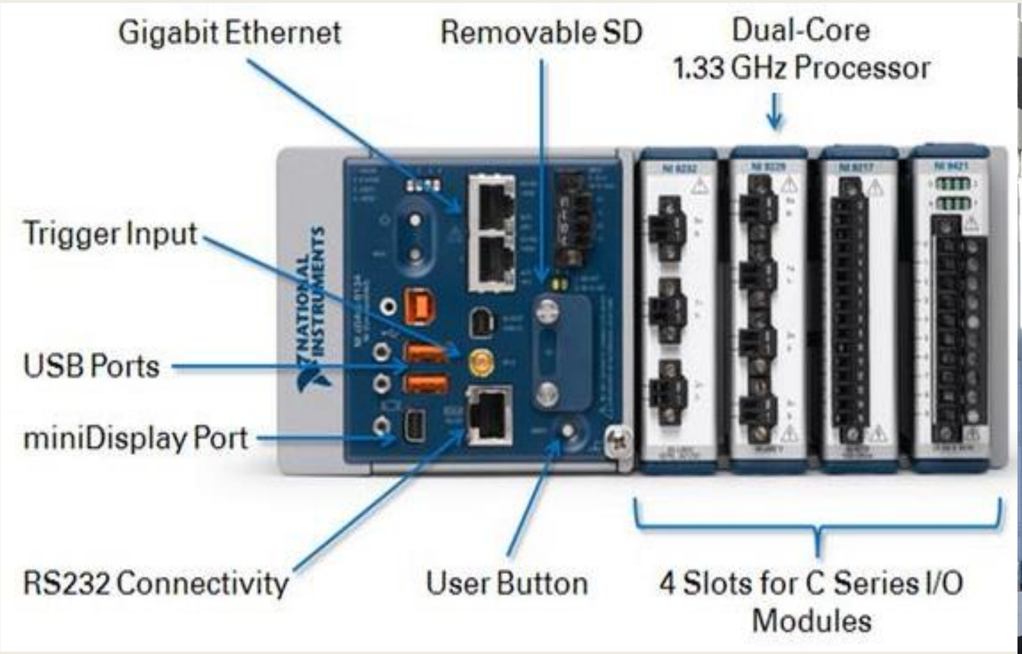
Concrete Test Section Design

Installation of Strain gages and Pressure cell

- Installation of pressure cell.

- Installation of strain gages.

CDaq

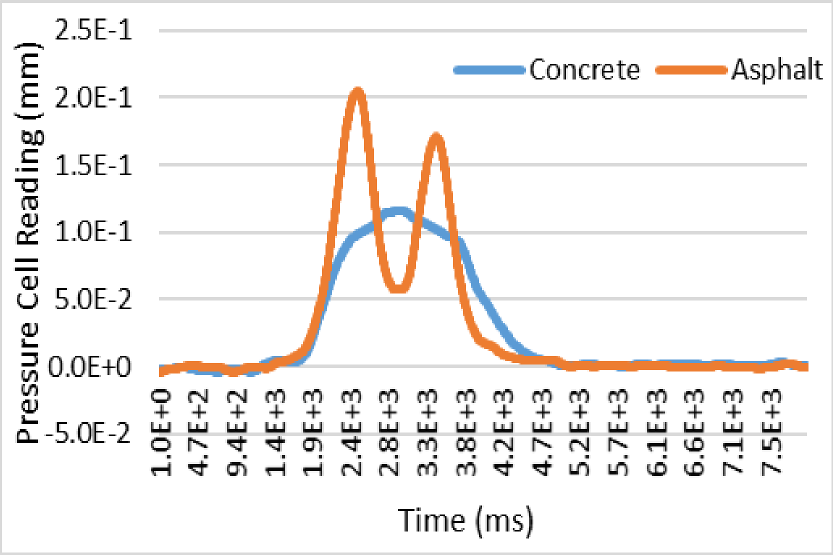

Gigabit Ethernet
Removable SD
Dual-Core
1.33 GHz Processor
Trigger Input
USB Ports
miniDisplay Port
RS232 Connectivity
User Button
4 Slots for C Series I/O
Modules

Pavement Construction

- Subgrade should be protected from heavy equipment.
- The top of subgrade is covered with geotextile.
- ASTM#2 aggregate is placed.
- Then ASTM #8.
- Then permeable concrete is placed.
- Then HMA-O is placed and compacted.
- Traffic is allowed after 24hrs for asphalt pavement.

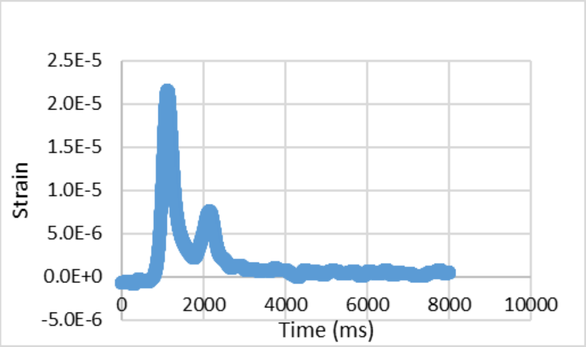
Data Analysis

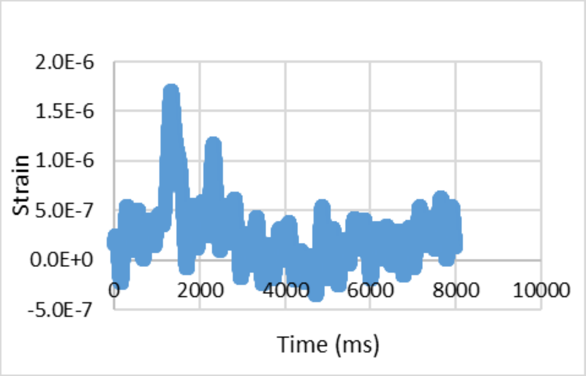
- Pressure cell was installed on the surface of the subgrade on both the sections.
- The data was recorded for the general traffic in the parking lot.
- The vertical pressure on the top of porous asphalt section was high comparatively.
- High stiffness of concrete lead to low stress.



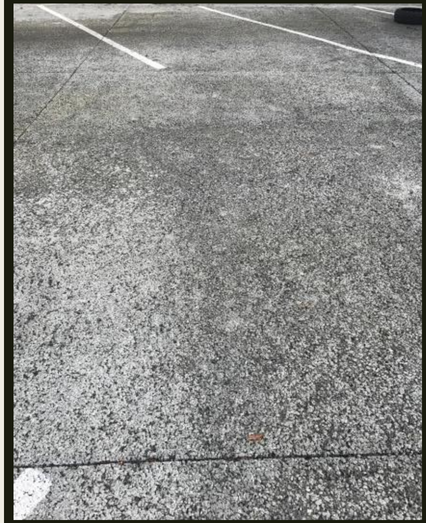
Data Analysis

- The strain gages were installed on the top of the base layer in longitudinal and transverse direction.
- Due to heat longitudinal strain gage in the asphalt section failed.
- The collected data showed high strain in the porous asphalt section, as expected.
- The strain was too small in the concrete section.





Performance of Pavement Sections



Pavement Distress

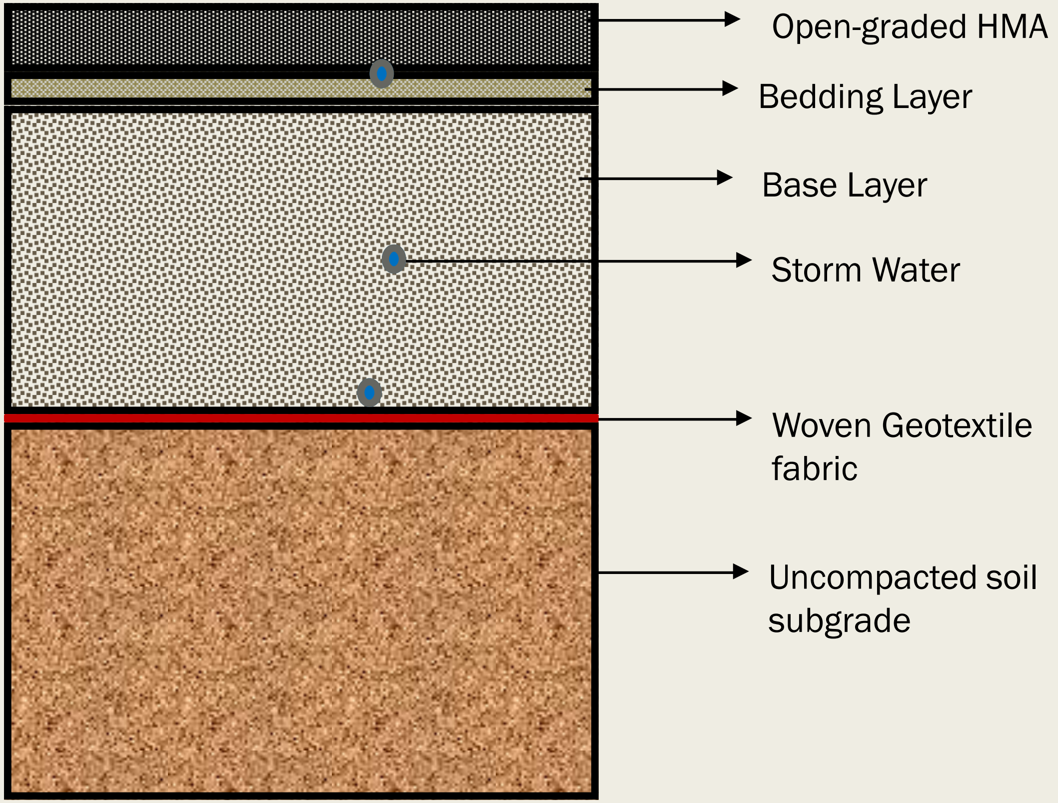
- Longitudinal cracking was exhibited on the concrete pavement.
- Raveling was exposed on the concrete pavement.

Conclusion

- The collected data reveals that high stress and strain was recorded on the asphalt section when compared with concrete section, as expected.
- High stiffness of the concrete is the reason for less stress and strain.
- Both the pavements have shown good performance in terms of distresses and stormwater infiltration.
- The collected data will be used to validate and calibrate the structural design proposed by UCPRC.
- The proposed design of fully permeable pavement will be used in truck traffic roadways for storm water mitigation and as best management practice.

THANK YOU……☺

Fully Permeable Pavement Composition



Traffic Volume Count

- Traffic volume count was determined using ARIMA method.
- Among all the models, model with least RMSE value is selected as best model.
- The analysis show that (7,2,3) is the best model for the morning peak hour traffic forecasting.
- The ARIMA (8,2,3) is best model for the evening peak hours.