Developing Multi-functional Pervious Concrete for Pavement

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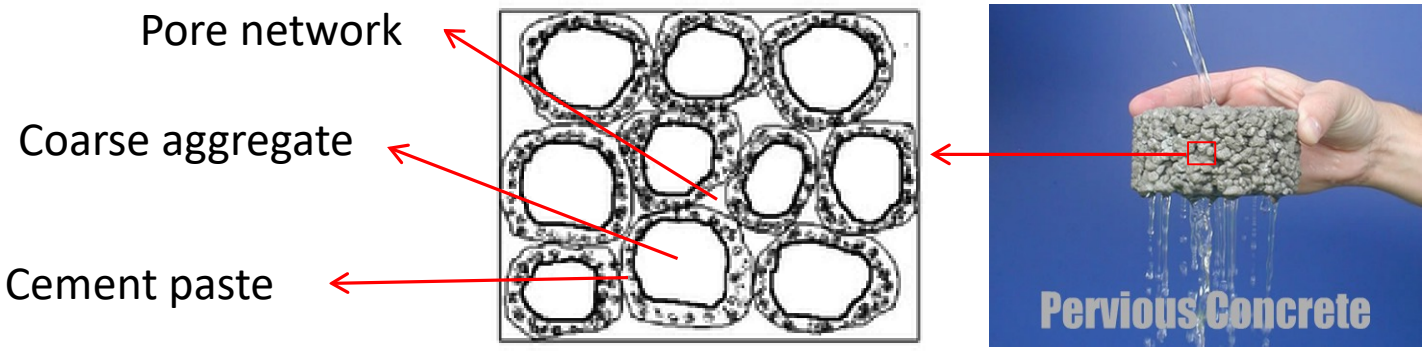
Outline

- Introduction of pervious concrete
- Multi-functions Of Pervious Concrete
- Summary and Future Studies

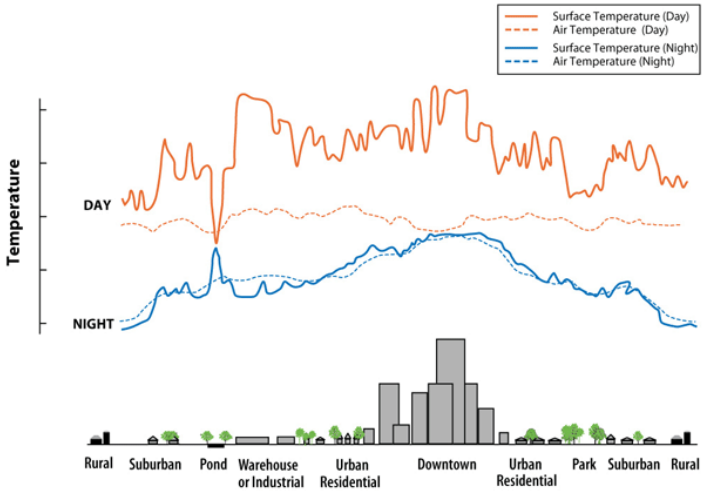
What is pervious concrete?

- Pervious concrete(PC) is consisted of the same raw materials with conventional concrete(CC), but PC has:
  - little or no fine aggregate
  - narrow graded coarse aggregate
  - 15%-35% porosity and 2-10 mm/s permeability

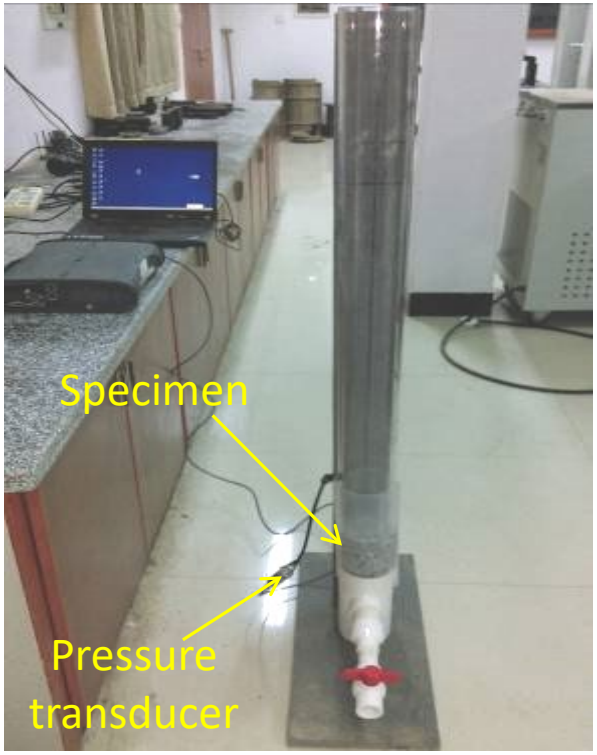


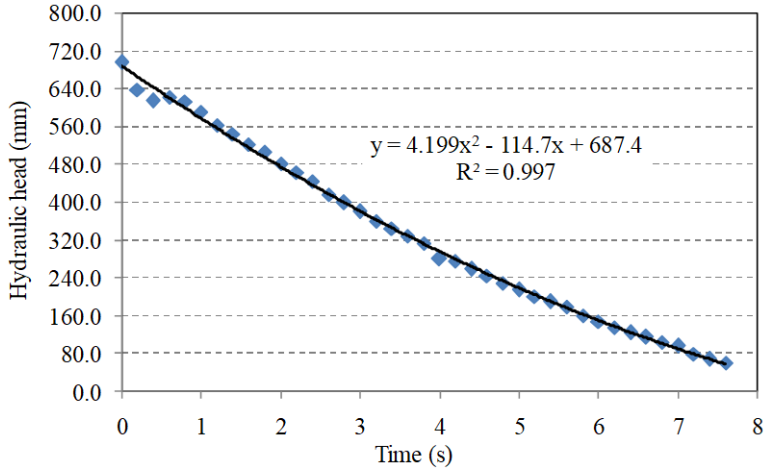
Benefits of pervious concrete

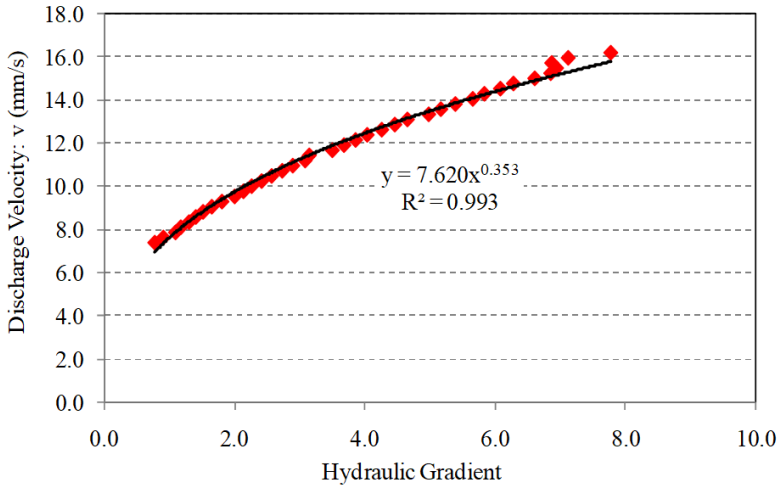
- Avoid waterlogging
- Reduce traffic noise
- Mitigate urban heat island effect
- Reduce storm water runoff
- Improve skid resistance



Function 1: Permeability

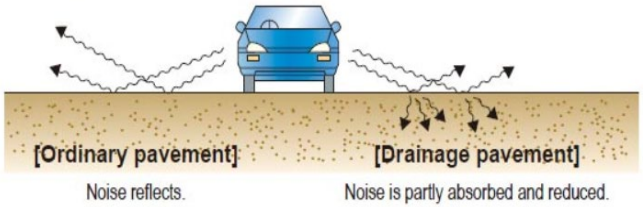




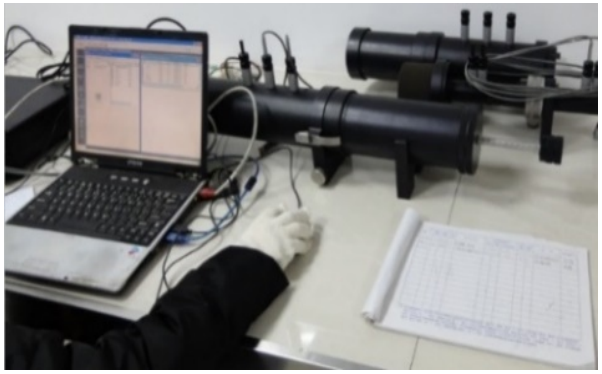


Permeability: $v = K' \cdot i^m$

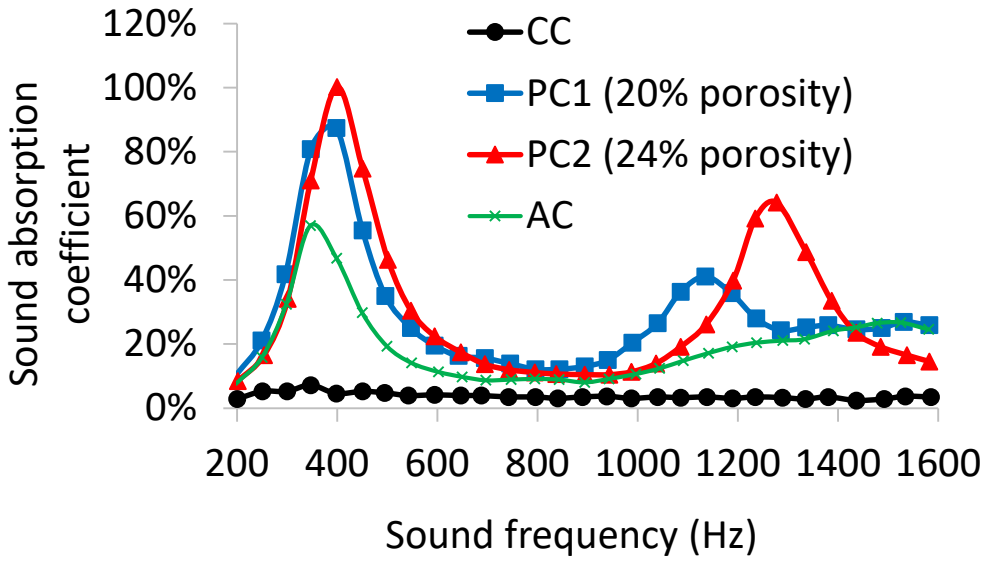
Function 2: Traffic noise reduction



Noise reduction mechanism

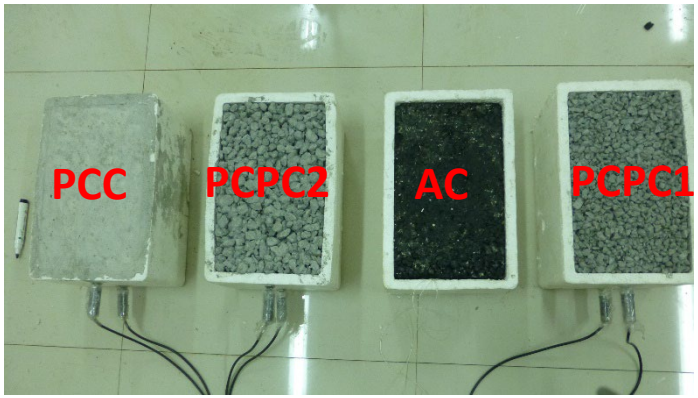


Sound absorption test



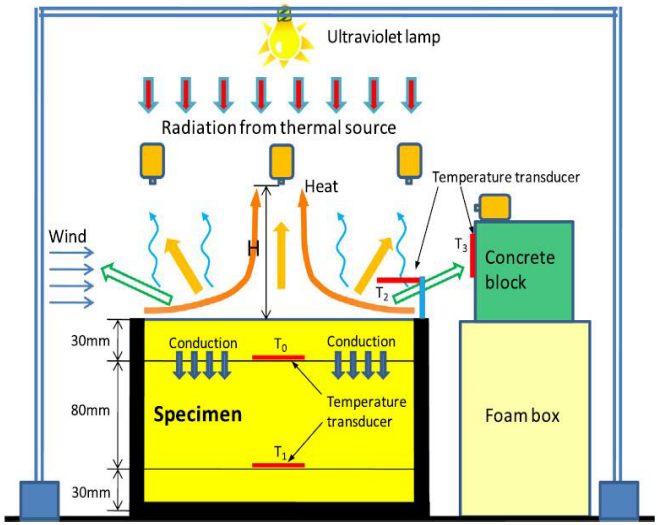
AC=asphalt concrete
CC= conventional concrete
PC= pervious concrete

Function 3: Friendly thermal properties

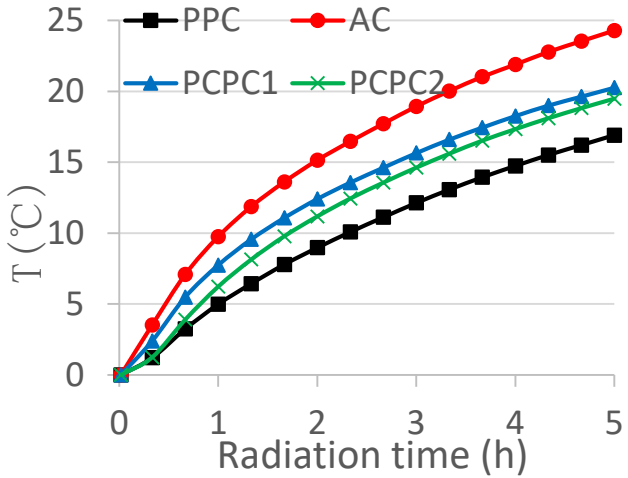


Specimens for testing

PCC=Portland Cement Concrete
PCPC=Portland Cement Pervious Concrete
AC= Asphalt Concrete

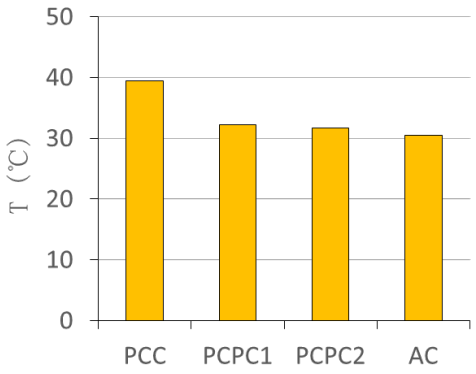


Temperature response under radiation

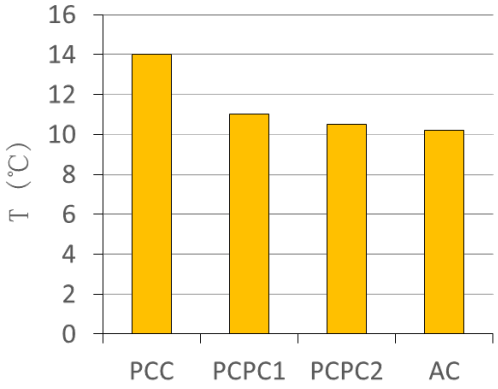


a) Specimen surface temperature

PCC=Portland Cement Concrete
PCPC=Portland Cement Pervious Concrete
AC= Asphalt Concrete

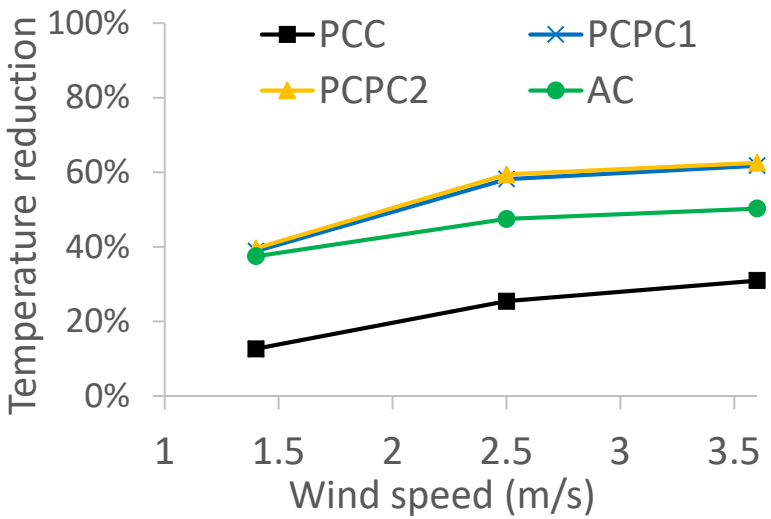


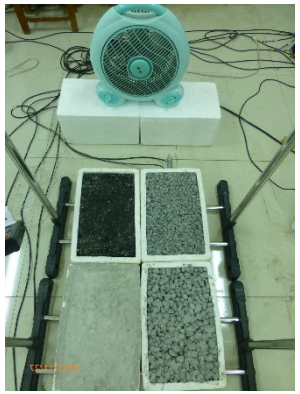
b) Ambient air temperature



c) Ambient concrete block temperature

Temperature response under windy conditions

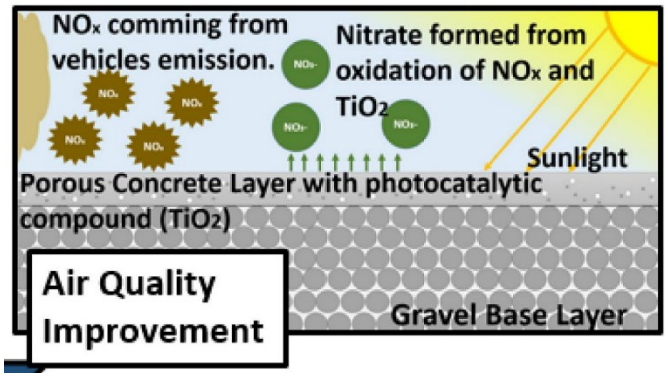




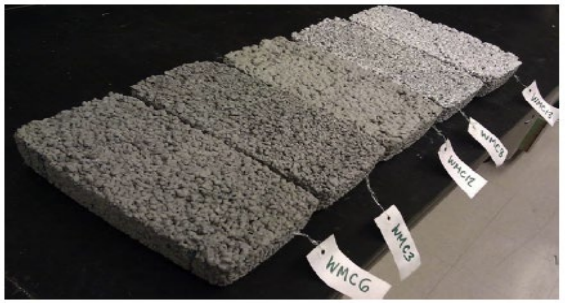
temperature reduction

- **In summary,** compared with PCC, AC pavement, PCPC has
  - ➢lower surface temperature,
  - ➢less thermal impact to ambient environment,
  - ➢better cooling effect under windy conditions.

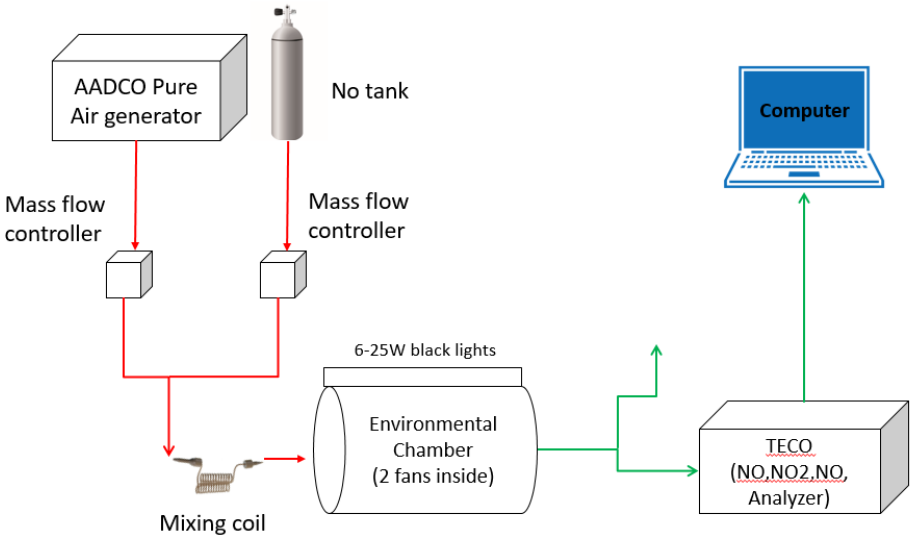
Function 4: Air scrubbing with Photocatalytic TiO2



Mechanism

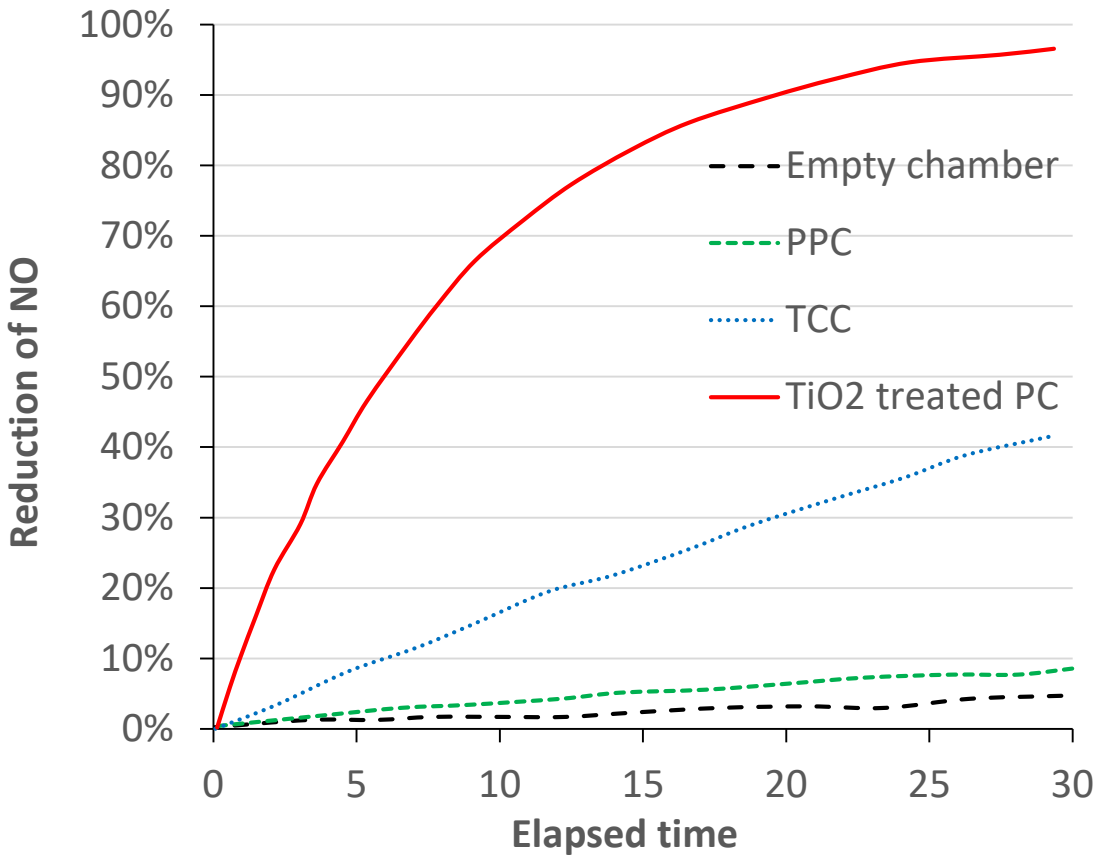


Specimens for testing



Environmental chamber set-up

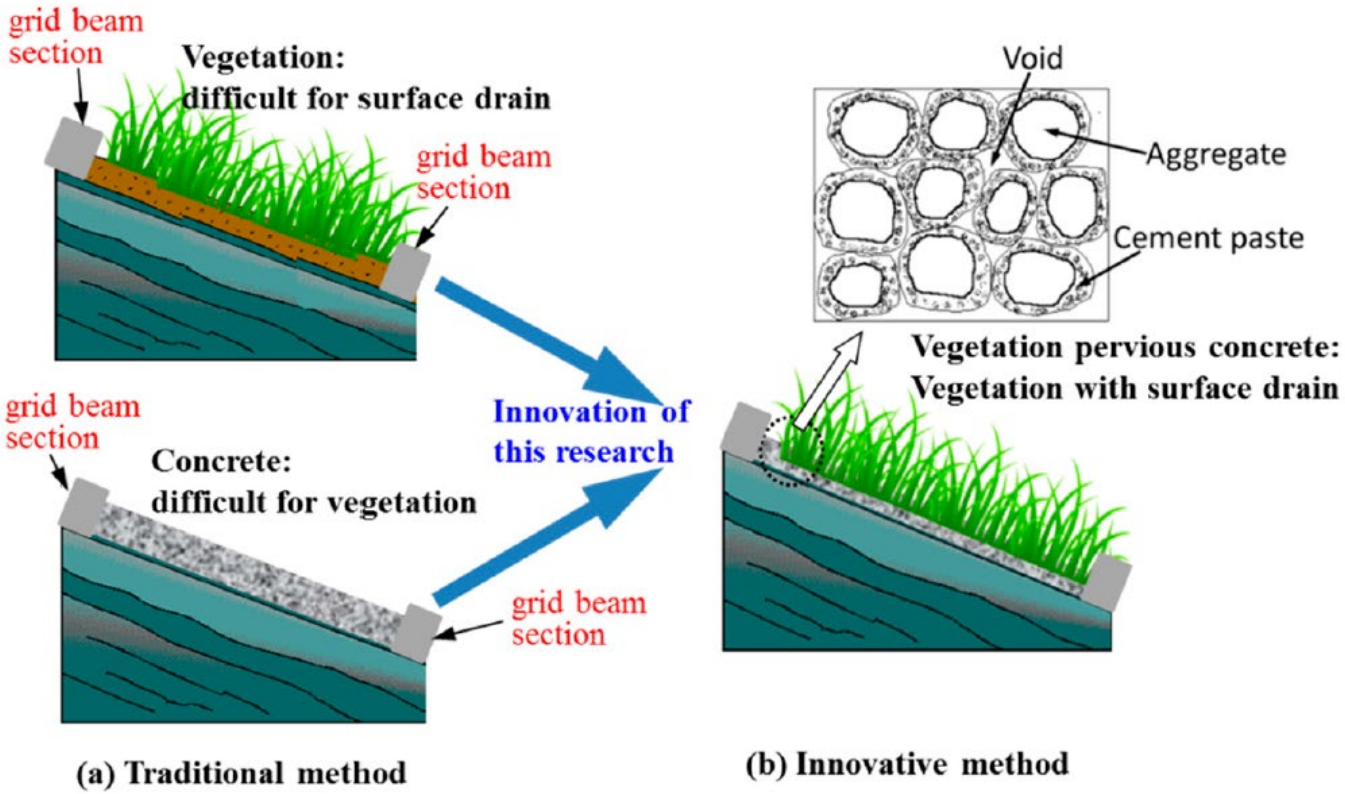
Reduction of NO



PPC =plain pervious concrete with no TiO_2

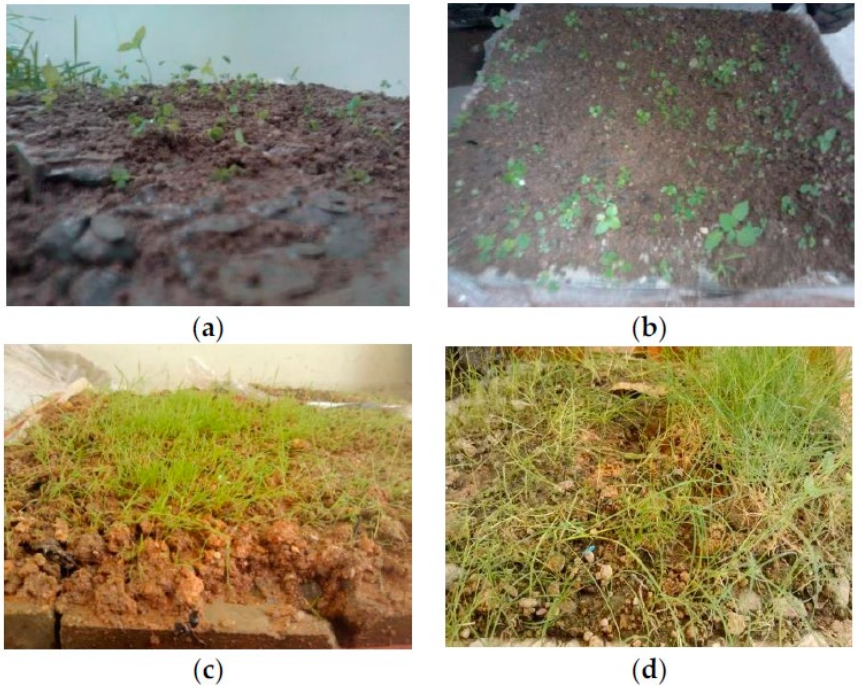
TCC = TiO_2 treated traditional concrete

Function 5: Vegetation-growing



Vegetation-growing pervious concrete

3.6 % admixture for reducing cement alkaline is added



Vegetation growth after seeding a) 1 week, b) 2 weeks, c) 3 weeks, d) 4 weeks

Summary and future studies

- Compared with the traditional pavement, pervious concrete pavement has
  - ➢ good permeability
  - ➢ considerable sound absorption property
  - ➢ more friendly thermal behavior to environment
  - ➢ air scrubbing capability if treated with Photocatalytic TiO2
  - ➢ potential in growing vegetation
- Future studies will focus on:
  - ➢ how to improve strength and durability of pervious concrete?
  - ➢ How to deal with the clogging problem of pervious concrete?
  - ➢ how evaporation influence the cooling effect of PC pavement?

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Thanks!

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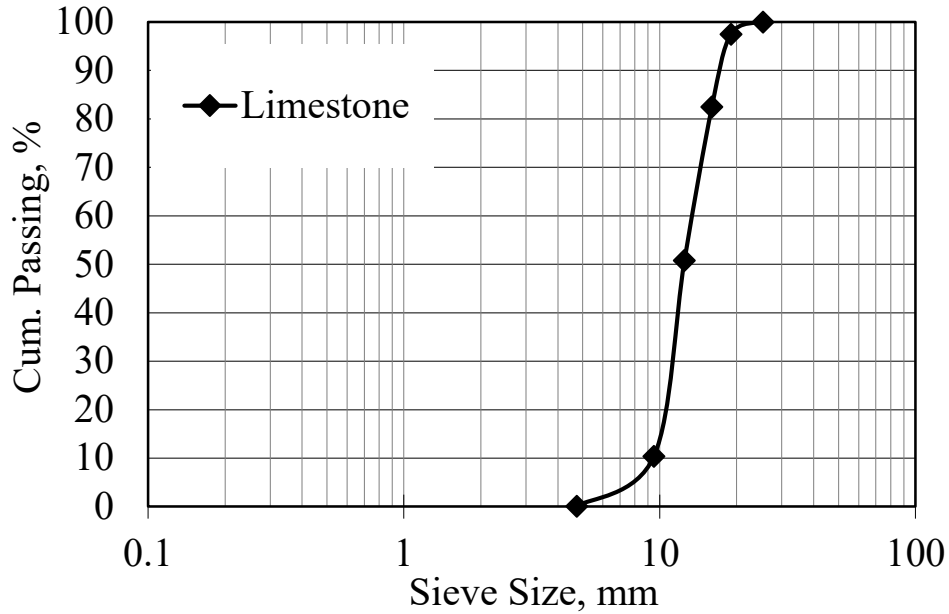
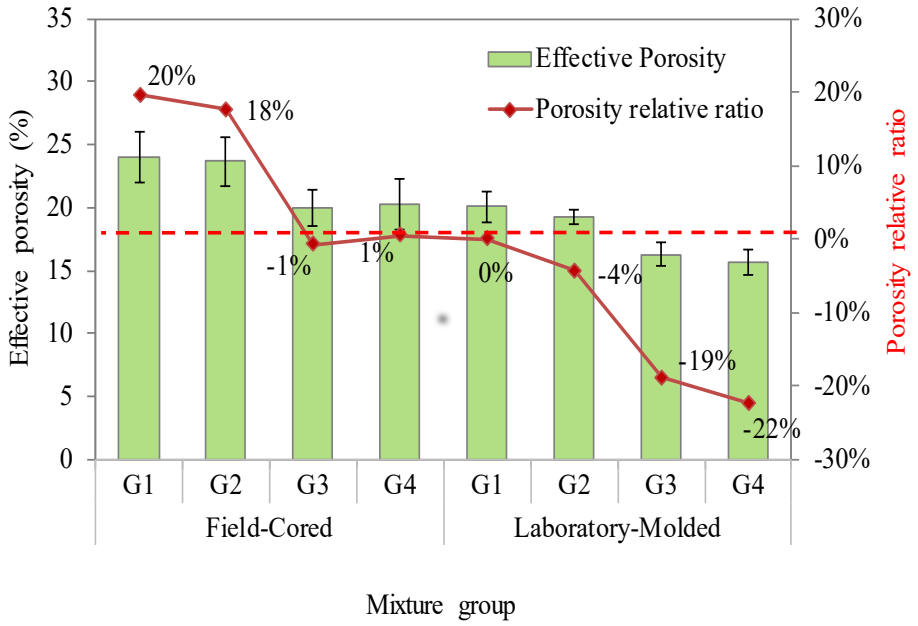
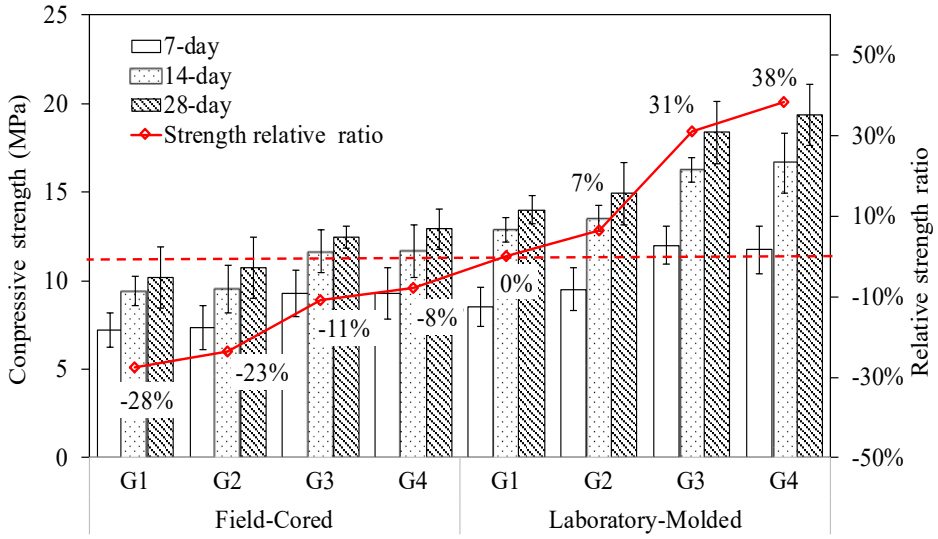
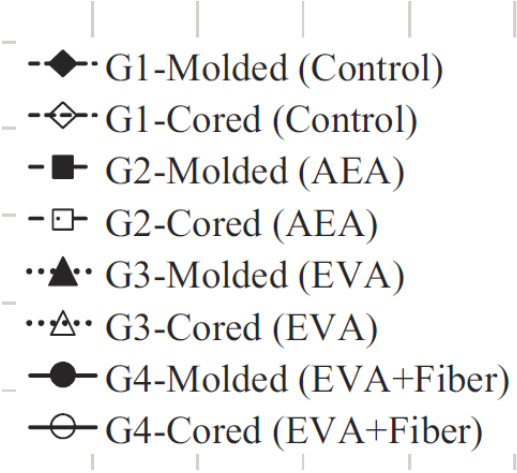

100
90
80
70
60
50
40
30
20
10
0
Cum. Passing, %
Limestone
0.1
1
10
100
Sieve Size, mm


Effective Porosity
Porosity relative ratio
Effective porosity (%)
Porosity relative ratio
20%
18%
-1%
1%
0%
-4%
-19%
-22%
G1
G2
G3
G4
Field-Cored
Laboratory-Molded
Mixture group


7-day
14-day
28-day
Strength relative ratio
Compressive strength (MPa)
Relative strength ratio
-28%
-23%
-11%
-8%
0%
7%
31%
38%
G1
G2
G3
G4
Field-Cored
Laboratory-Molded


G1-Molded (Control)
G1-Cored (Control)
G2-Molded (AEA)
G2-Cored (AEA)
G3-Molded (EVA)
G3-Cored (EVA)
G4-Molded (EVA+Fiber)
G4-Cored (EVA+Fiber)

Porosity test: Vacuum-submersion method

a) Vacuum device

b) Sealed specimen

c) Tested in water

SG1= Bulk Specific Gravity ;
SG2= Apparent Specific Gravity ;
A= mass of dry specimen in air ;
B= mass of dry and sealed specimen;
C= mass of unsealed specimen underwater;
E=mass of sealed specimen underwater;
F= apparent specific gravity of plastic sealing material when sealed;
F'=apparent specific gravity of plastic sealing material when opened under water.

$$SG2 = \frac{A}{B - C - \frac{B - A}{F'}}$$

$$SG1 = \frac{A}{B - E - \frac{B - A}{F}}$$

air voids for Interconnected pores

$$\textit{Effective Porosity (\%)} = \frac{SG2 - SG1}{SG2} \times 100\%$$

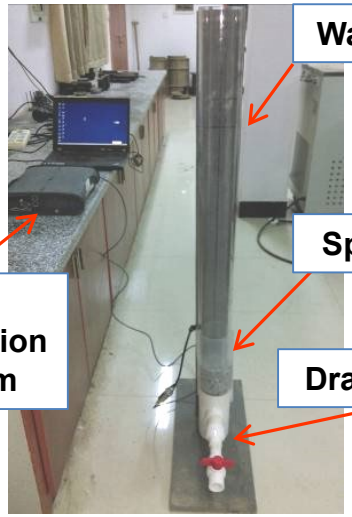
(ASTM D7063/D7063M – 11)

$$\textit{Porosity (\%)} = \left(1 - \frac{A - C}{B - E}\right) \times 100\%$$

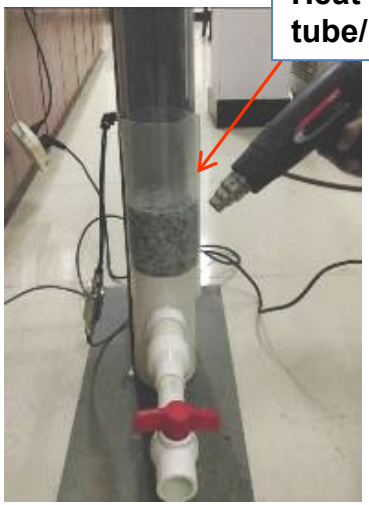
air voids for open pores

Open-pore porosity ≈ (1.1-1.2) * Effective porosity

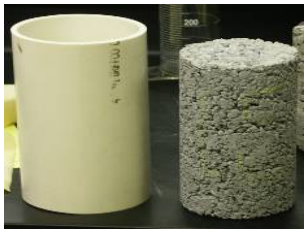
Permeability test: Falling head method

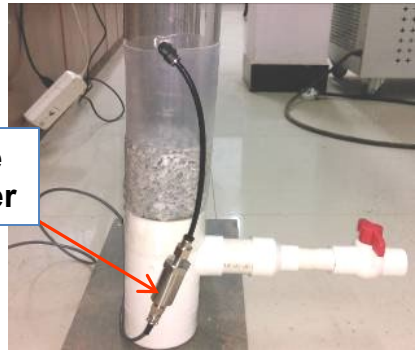


a) test setup



b) Specimen installation





c) side view

$$h = a_0 + a_1 t + a_2 t^2$$

$$\frac{dh}{dt} = \alpha_1 + \alpha_2 t$$

$$i = \frac{\Delta h}{l}$$

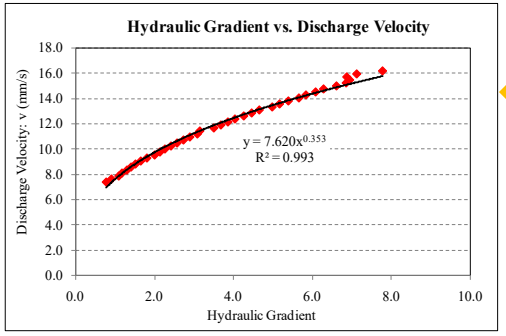
$$v = \frac{dQ}{A_2 dt} = \frac{A_1}{A_2}\frac{dh}{dt} = \frac{r_1^2}{r_2^2}\frac{dh}{dt}$$

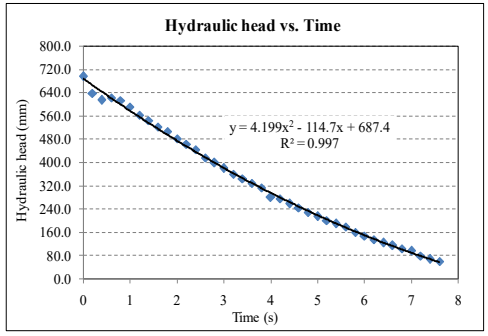
General permeability for laboratory tests

$$v = K' \cdot i^m$$

$$k = \frac{r_1^2}{r_2^2} \cdot \frac{l}{t} \ln(h_1/h_2)$$

permeability for field tests

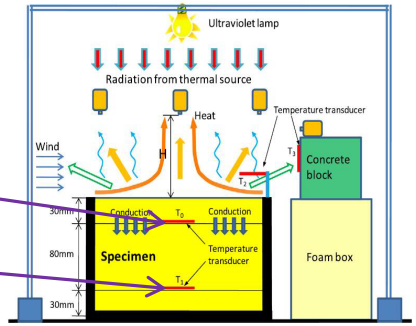


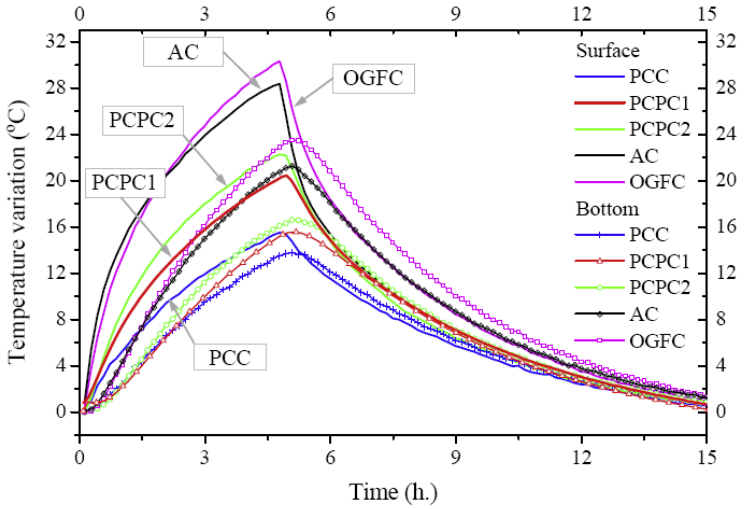


Thermal behaviors of specimens

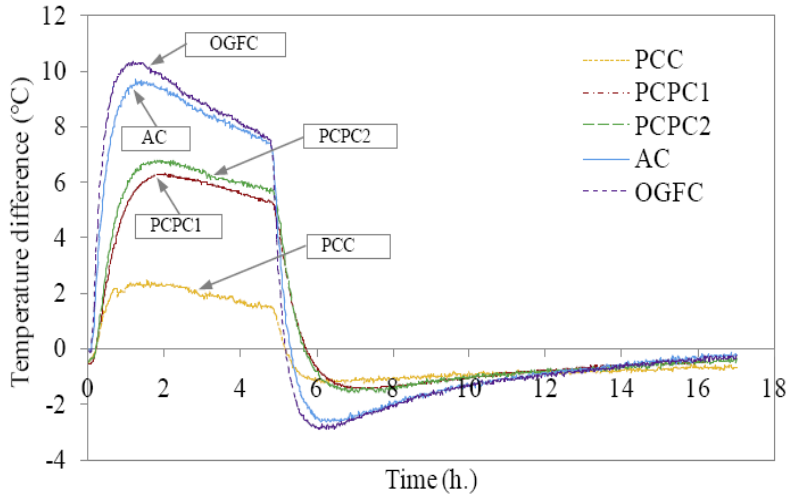
Surface temperature

Bottom temperature





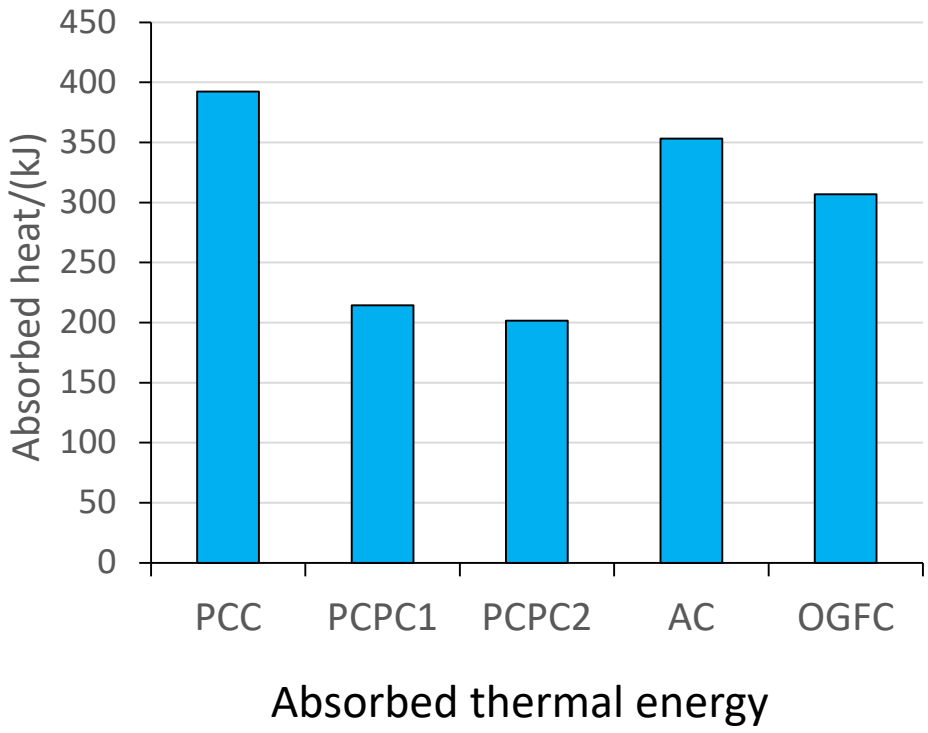
Surface and bottom temperature variations



Temperature difference

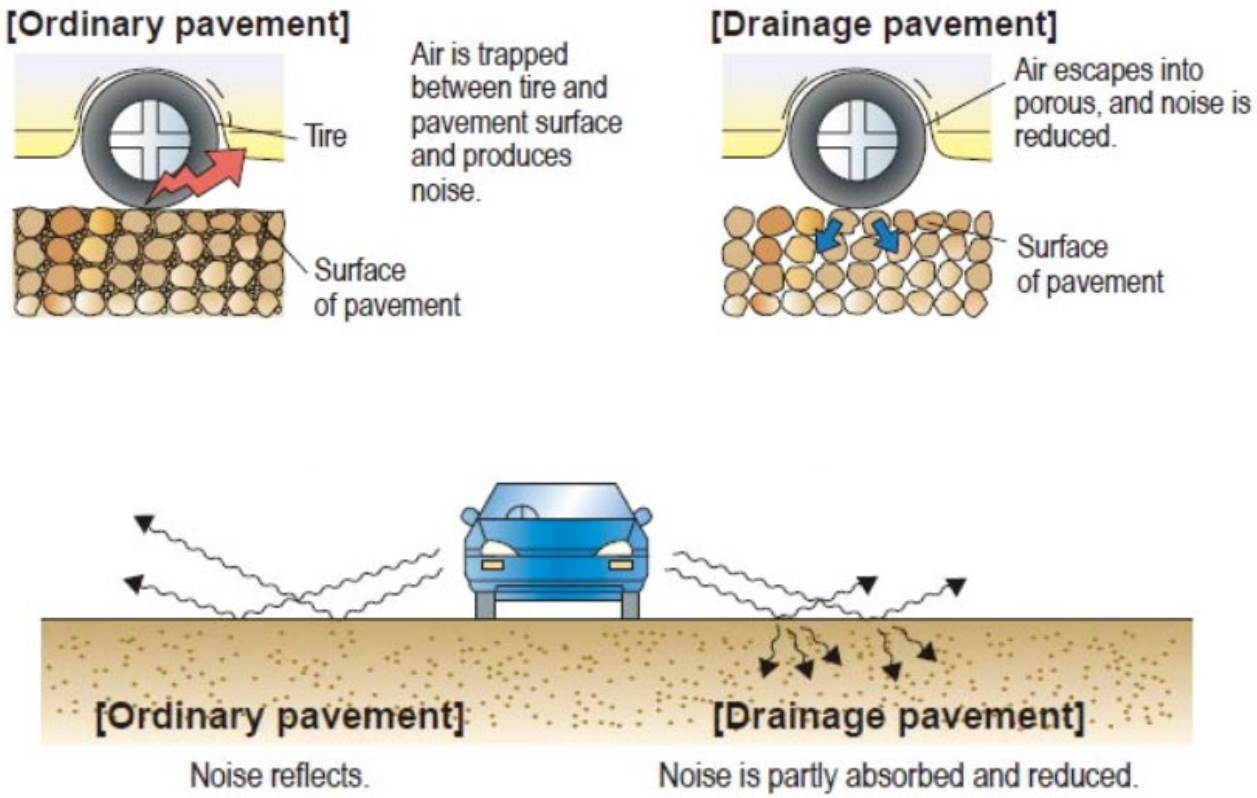
Specific heat capacity of pavement materials at 30 °C, unit: J/(kg·°C)

Materials	Water	Cement	Coarse Aggregate	River Sand	PCC	PCPC1	PCPC2	AC	OGFC
Specific heat capacity	4175	838	745	757	1025	916	904	793	790

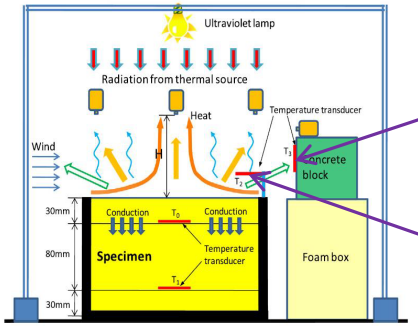


Absorbed thermal energy

Traffic noise reduction: mechanisms

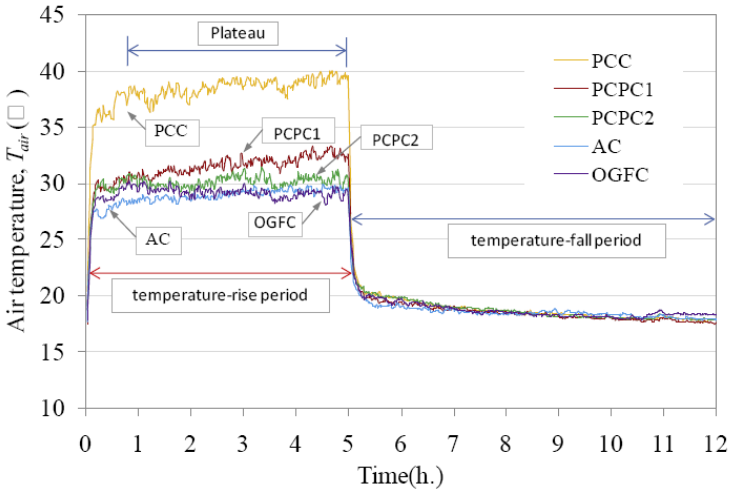


Thermal impacts on ambient environment

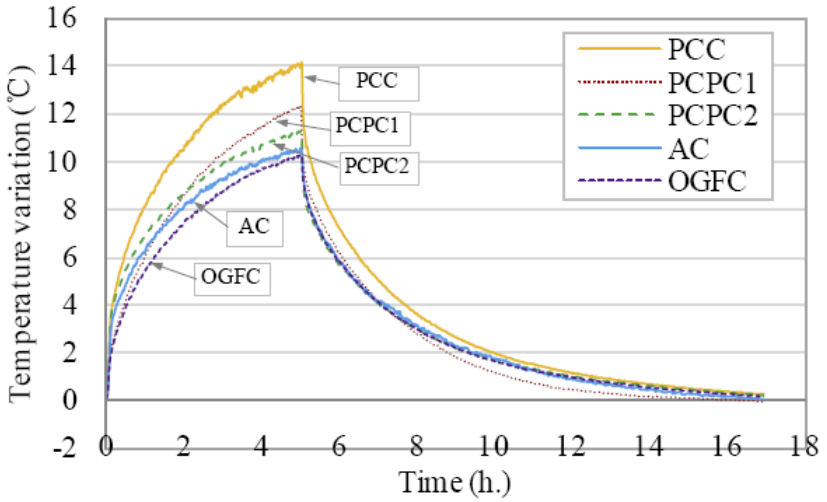


Ambient concrete block temperature

Ambient air temperature



Air temperature above specimens



Temperature variation on sideward concrete