An Innovative Green Pervious Concrete Made with Modified Geopolymer Materials

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Green Pervious Concrete

Porous concrete is a typical type of concrete with interconnected pores that is made of cementitious paste and coarse aggregates with reduced or without sand/fine aggregates. Owing to this unique porous structure, pervious concrete is beneficial in several pavement applications, including storm water management, mitigation of urban heat island effect, tire-pavement noise reduction, and removal of pollutants through water infiltration

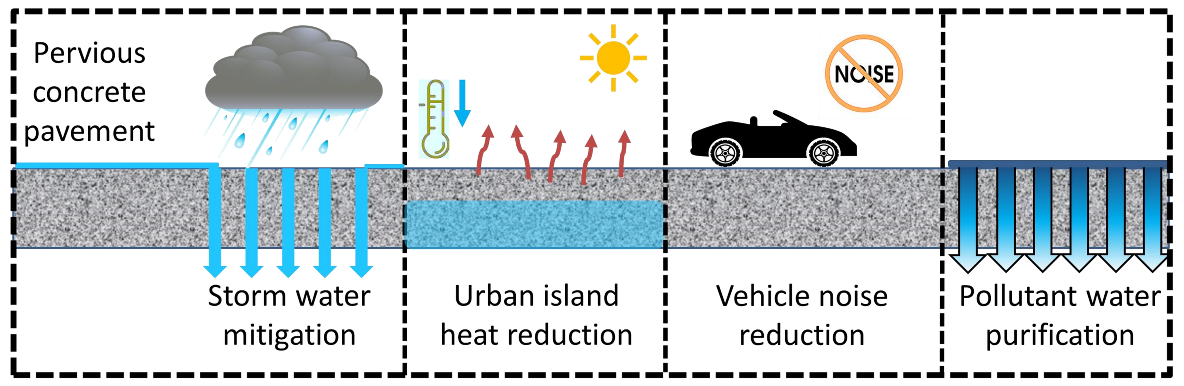

Fig. 1. Benefits of pervious concrete pavement

However, the relatively low mechanical strength of pervious concrete largely limits its application, and the use of cement is also proved to be the major source of carbon dioxide. Thus, it is desired to fabricate pervious concrete for superior performance while reducing the carbon footprint.

Recently, alkali-activated geopolymer has been developed due to its better durability and environmental benefits. It does not release carbon dioxide during production, and many waste materials or by-products can be used as raw materials, such as fly ash, slag, red mud, etc. The chemical components of these raw materials largely influence geopolymeric network formation and strength of hardened geopolymers.

It is desired to apply geopolymer in pervious concrete without interfering its original porous structure and enhance its mechanical performance. The geopolymer based pervious concrete has high potential to be applied as green pavement surface materials.

Objective

This study aims to develop and characterize two types of geopolymer based pervious concrete (metakaolin (MK) and fly ash (FA)) and improve their performance through chemical modification with granulated blast furnace steel slag (GBFS). The microscale characterization and mechanical strength of the modified pervious concrete are mainly investigated.

Laboratory Experiments

The metakaolin (MK) and fly ash (FA) based geopolymer paste were firstly synthesized at ambient temperature using GBFS as an additive. The optimized paste formula was further used to fabricate pervious concrete using limestone as aggregate. The optimum contents of GBFS were identified based on crystal phase analysis and surface morphology observation of geopolymer paste and mechanical properties of pervious concrete. The effects of geopolymer paste and aggregate gradation on compressive and tensile strength of pervious concrete were investigated.

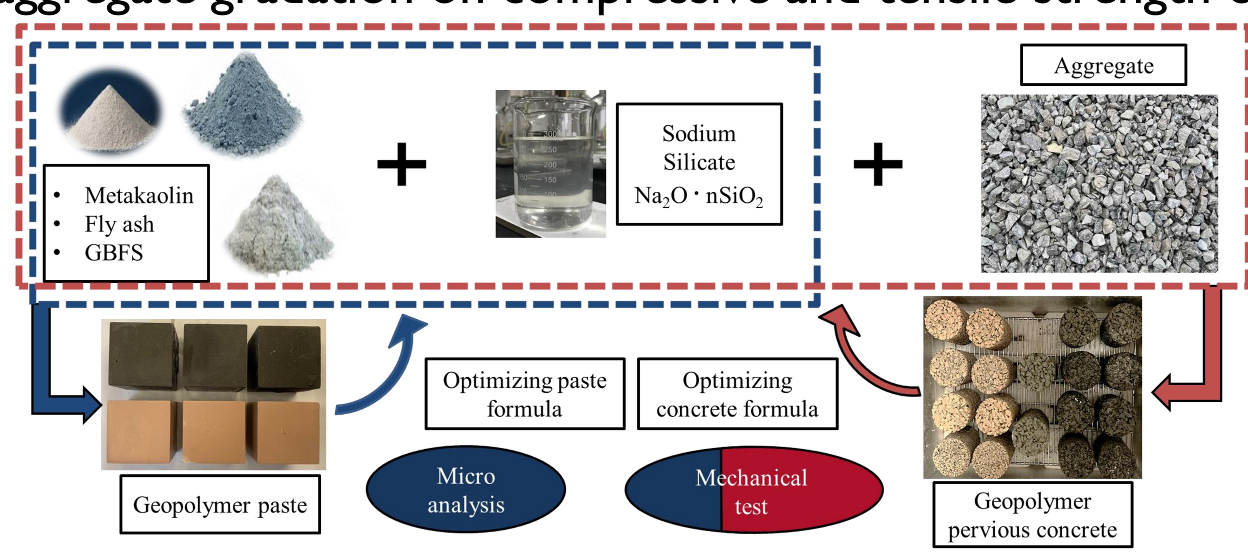

Fig. 2. Fabrication process of paste and pervious concrete

Table. 1. Gradations and mixing information of geopolymer paste and pervious concrete

Gradation code	A1	A2	A3	A4
Aggregate size range (mm)	0.15~4.75	0.15~12.5	0.3~12.5	A3+10% Sand

Binder type	GBFS content, replacement percent	Aggregate	b/a ratio	l/b ratio
Metakaolin (MK)	0%/10%/20%/30%	A3	0.11	1.21
	10%	A1/A2/A3/A4	0.11	1.21
Fly ash (FA)	0%/10%/20%/30%	A3	0.16	0.55
	30%	A1/A2/A3/A4	0.16	0.55

Fig. 3. Mechanical test setup and failure specimens

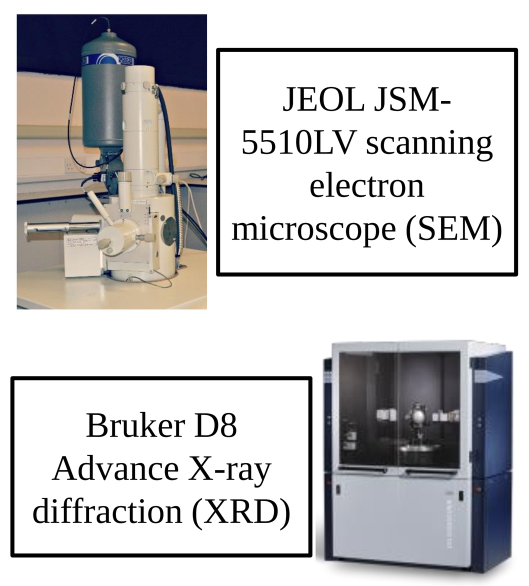

Fig. 4. Micro analysis instruments

Mechanical Properties and Microanalysis

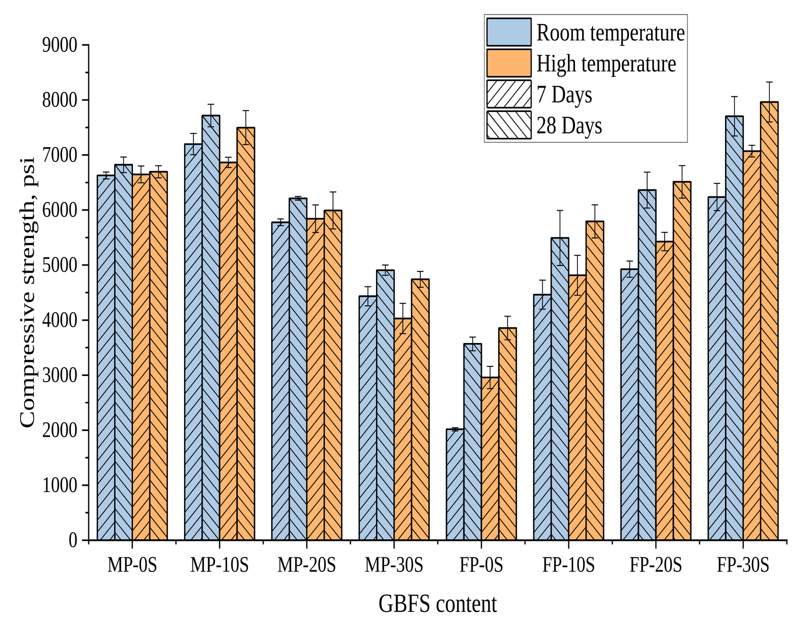

Fig. 5. Compressive strength of geopolymer paste

- All geopolymer paste specimens could achieve considerable high strength by ambient curing method.
- 10% and 30% of GBFS content were found being the optimized dosages to achieve the highest strength for MK and FA based geopolymer paste, respectively.
- Micro analysis presented that the variation of compressive strength was mainly caused by new crystal phases and different integrity of geopolymer paste, which was induced by GBFS.
- Image analysis also showed that 10% and 30% of GBFS were the optimized content for MK and FA based geopolymer paste, respectively.

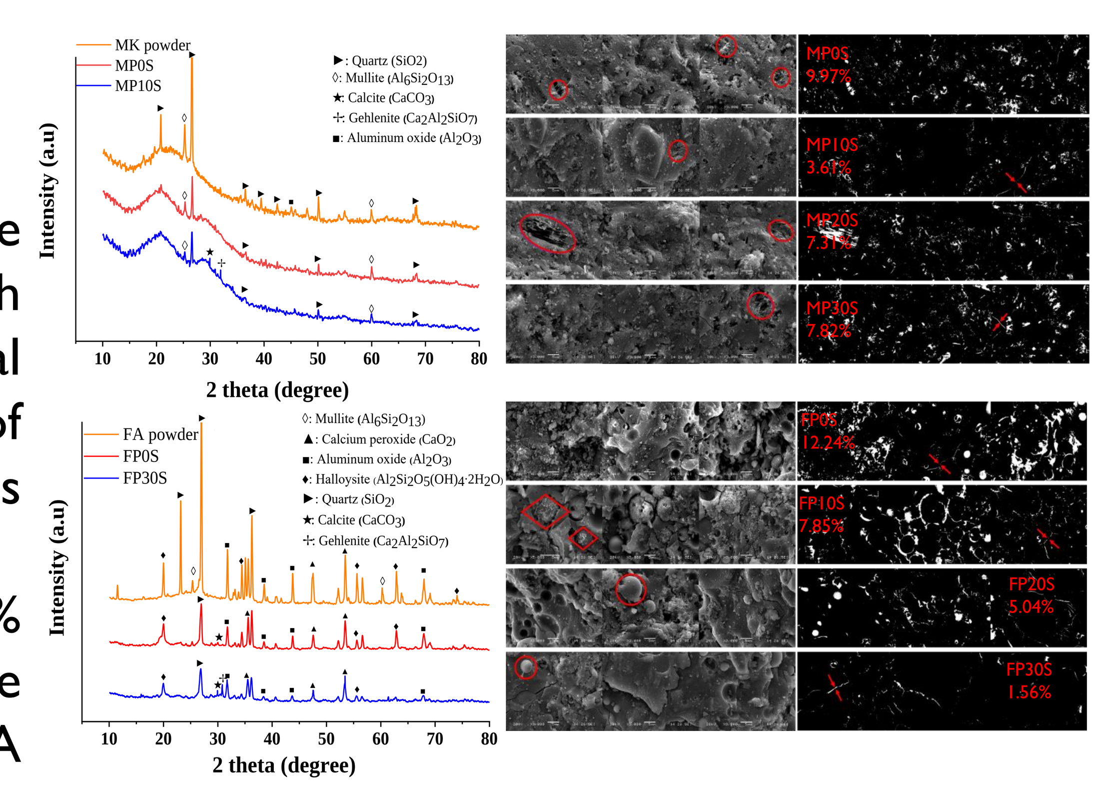

Fig. 6. XRD and SEM tests results of geopolymer paste

Table. 2. Porosity and permeability of pervious concrete

Binders	Porosity				Permeability (cm/second)			
	A1	A2	A3	A4	A1	A2	A3	A4
MK	20.98%	20.32%	19.84%	17.11%	1.47	1.38	1.29	1.03
FA	25.72%	21.32%	19.52%	16.53%	1.66	1.51	1.35	1.14

- Gradation of geopolymer pervious concrete largely influenced the porosity, which was proportional to the permeability.

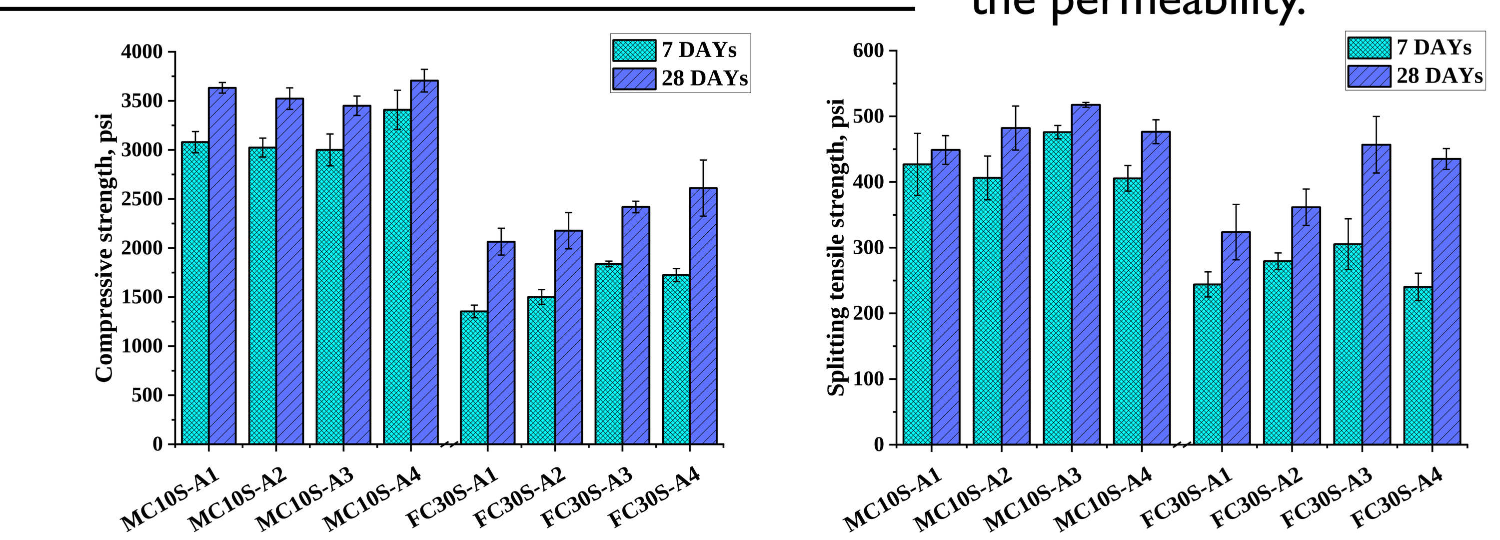

Fig. 8. Compressive and splitting tensile strength of pervious concrete by different gradations

- The porosity is the major influencing factor.
- The aggregate size affects splitting tensile strength of geopolymer based pervious concrete.
- Sand has positive effect on compressive strength but negative effect on splitting tensile strength.

Findings and Conclusions

- Ambient temperature curing was sufficient to develop high strength of geopolymer paste and pervious concrete.
- New crystal phases were observed after introducing GBFS into geopolymer. Optimized GBFS content could provide better integrity and less cracking, voids, and unreacted components in geopolymer paste.
- Lower porosity induced higher compressive and splitting tensile strength, however, smaller aggregate size induced higher compressive but lower splitting tensile strength at the similar porosity.

Acknowledgement

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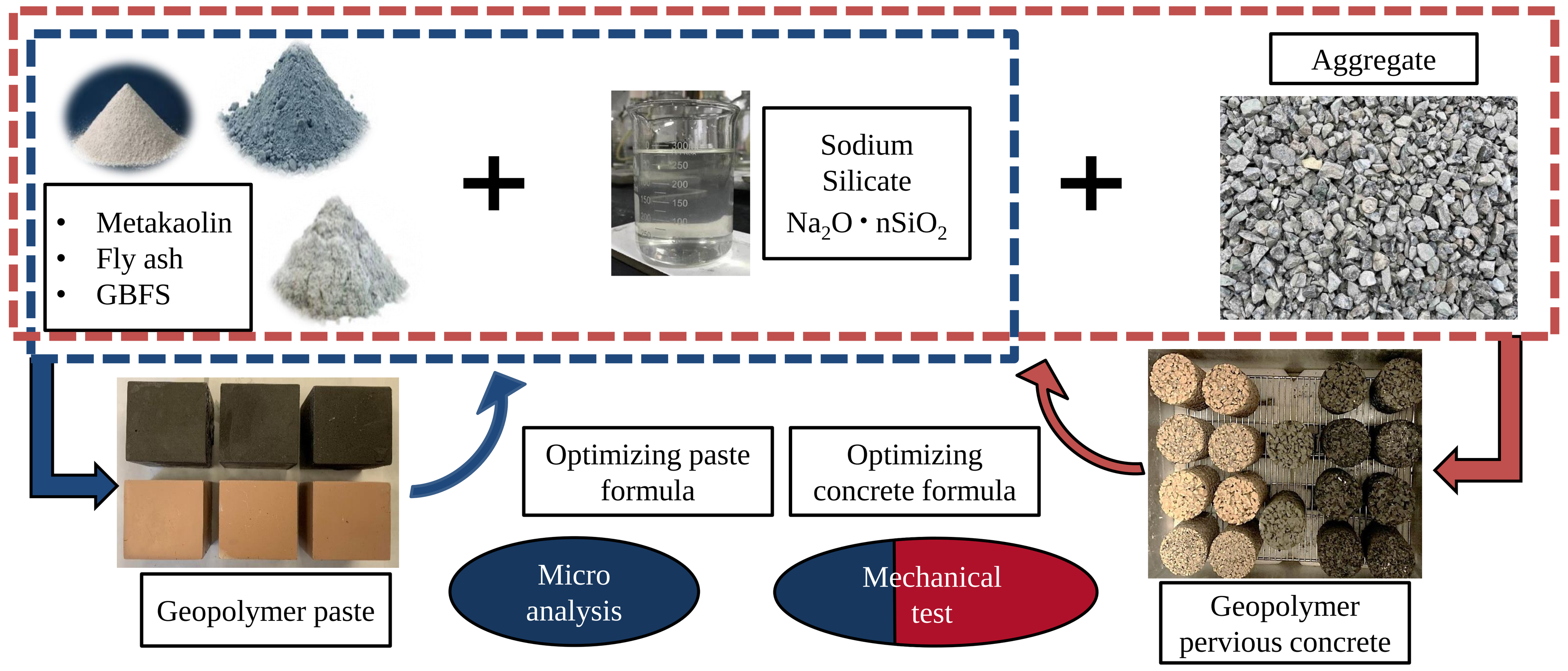
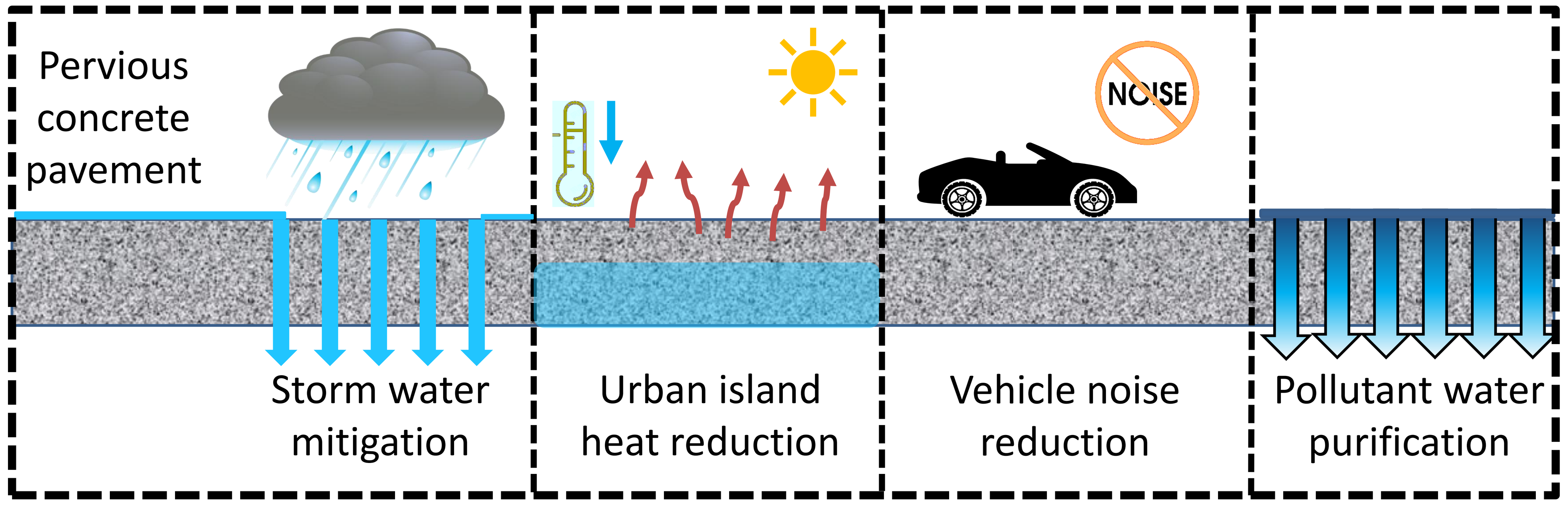

Metakaolin
Fly ash
GBFS
Sodium Silicate
$Na_2O \cdot nSiO_2$
Aggregate
Optimizing paste formula
Optimizing concrete formula
Micro analysis
Mechanical test
Geopolymer paste
Geopolymer pervious concrete


Pervious concrete pavement
NOISE
Storm water mitigation
Urban island heat reduction
Vehicle noise reduction
Pollutant water purification