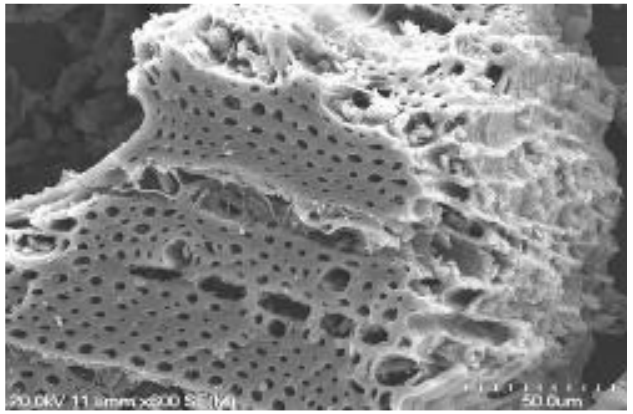
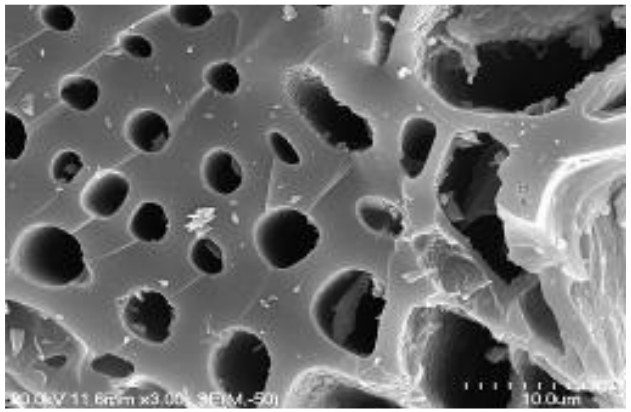
Black is the new green – carbon sequestration through green & sustainable pavement engineering





Ajit K Sarmah, PhD

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NEW ZEALAND

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Biochar Research Group

Designer biochar production, characterization and multidirectional application

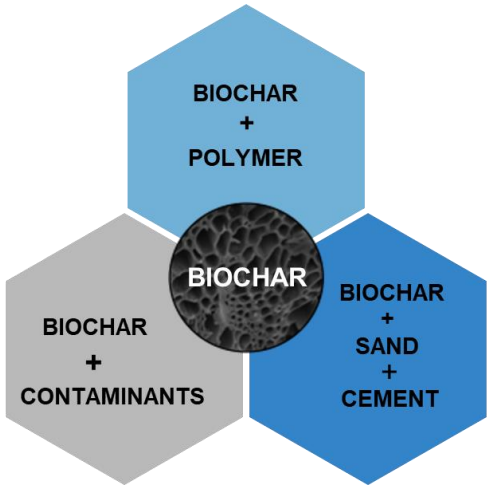
Collaboration within UoA:

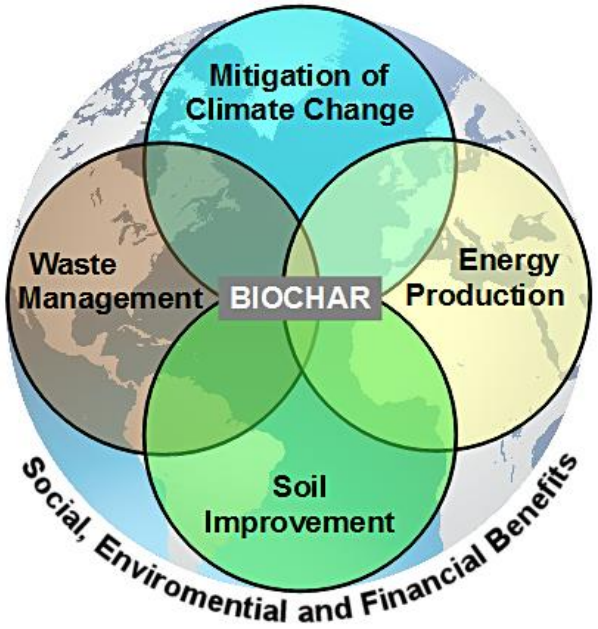
Civil & Environmental Engineering

- (Geotechnical engineering and structural hall)
- Mechanical Engineering
- Chemical & Materials Engineering

Collaboration overseas:

- Purdue University, West Lafayette, USA
- Tsinghua University, China
- Zhejiang University, China
- University of Trier, Germany
- University of Wuppertal, Germany
- National University of Singapore
- Indian Institute of Technology, Kharagpur
- ICRA, Catalan Water Research Institute, Spain





Research areas

- Biochar as filler in concrete, roading pavement material
- Remediation of contaminants in soil and aqueous system
- Reversing climate change by carbon sequestration
- Biochar composites
- Biochar in geotechnical engineering

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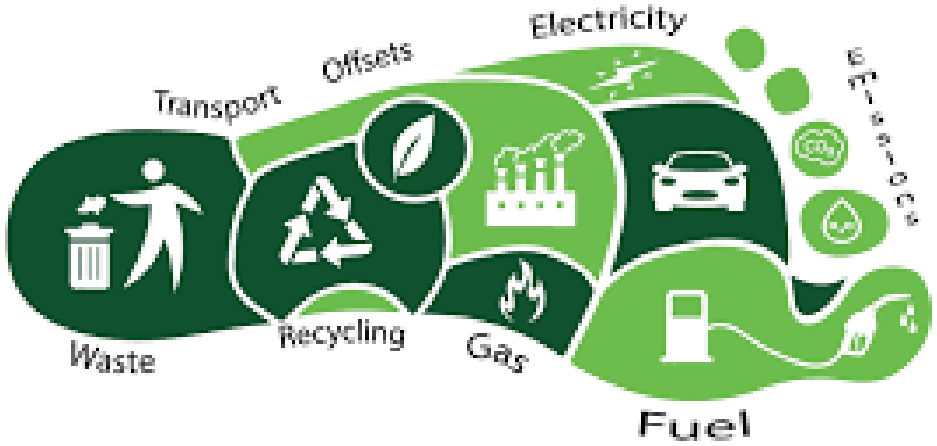
Outline

- Drivers
- Research in our group
- Available literature
- Food for thoughts
- Questions/Comments/Discussion

Drivers



Current Global atmospheric CO_2 is 409.8 ± 0.1 ppm

- Road transport – 12% of the total greenhouse emissions worldwide
- Total length of road networks: 32 Million Kms (International Road Federation)
  - World Road Statistics (WRS) in 2017
- Transport sector accounts - **21% of NZ's annual greenhouse gas emissions**
- The sector is the fastest growing source of emissions (Ministry of Transport, NZ)

Drivers- Cont'd

Hot Mix-Asphalt

Material in Hot Mix Asphalt (HMA)	Energy consumption (MJ/t)	Emissions CO_2 eq. (kg/t)
Asphalt binder	5810	480
Sand or gravel	21	0.0728
Crushed stone	32	1.42
Polymer additive	76,742	3715

Chen et al., 2021

- Global demand for asphalt is projected to expand 2.8 %/year to 122.5 million metric tons

- Australian example:
  - Construction of a 100-m road section using virgin materials
  - 180 tonnes of CO_2-e
  - 10.7 terajoules (TJ)

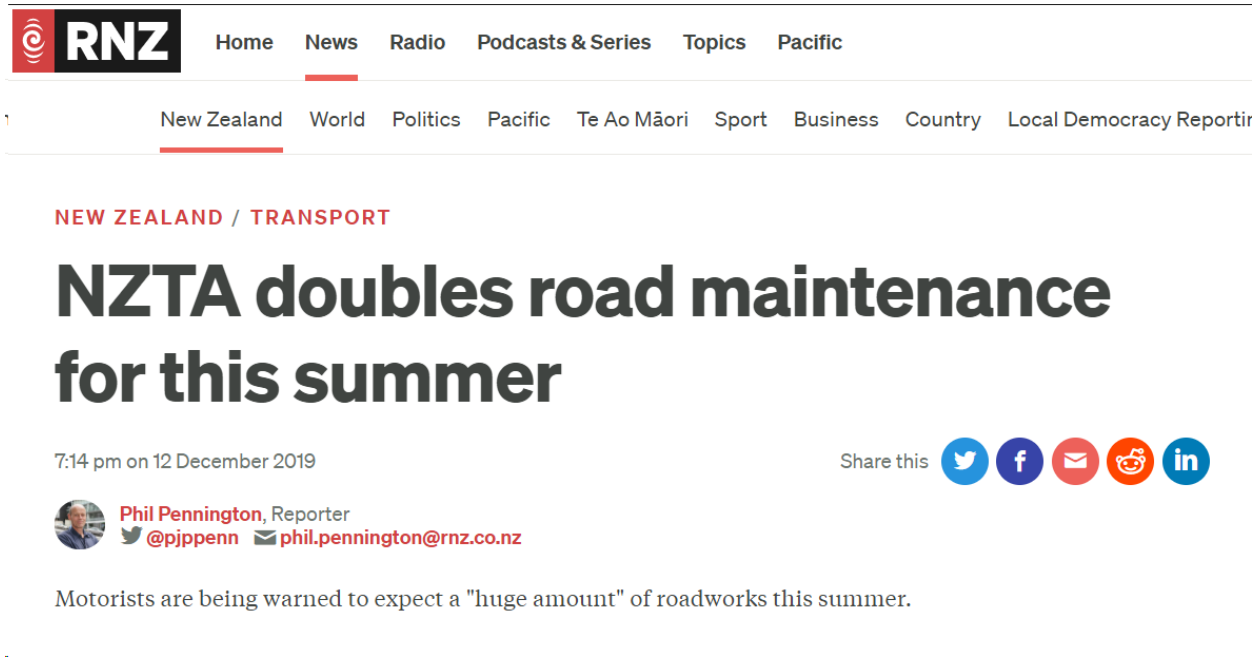
(Biswas, 2013)

Drivers- Cont’d

- Approx. 95% of all highways in the world are surfaced with asphalt mixtures.
- Asphalt binder is the key component in these mixtures
  - binds the aggregates together to provide a smooth and comfortable riding surface.
- Derived from petroleum crude—a non-renewable fossil fuel
- Consistent supply is an issue for future road infrastructure development.

Drivers- Cont'd

- Climate Change Response (Zero Carbon) Amendment Act 2019
- To reduce net emissions of all greenhouse gases (except biogenic methane) to zero by 2050
- Need to have alternative materials in pavement sector with lesser carbon foot print without comprising on properties of conventional pavements
- Effectively use and recycle the New Zealand available waste
- To reduce the annual maintenance in the roads with sustainable approach



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New Zealand World Politics Pacific Te Ao Māori Sport Business Country Local Democracy Reportir

NEW ZEALAND / TRANSPORT

NZTA doubles road maintenance for this summer

7:14 pm on 12 December 2019

Share this

Phil Pennington, Reporter
@pjppenn phil.pennington@rnz.co.nz

Motorists are being warned to expect a "huge amount" of roadworks this summer.

Three interim rutting repairs on the Te Rapa section have cost the New Zealand Transport Agency **$755,000**

Need for alternative materials for partial replacement of asphalt binder

Can the carbonaceous biochar be that SMART material?

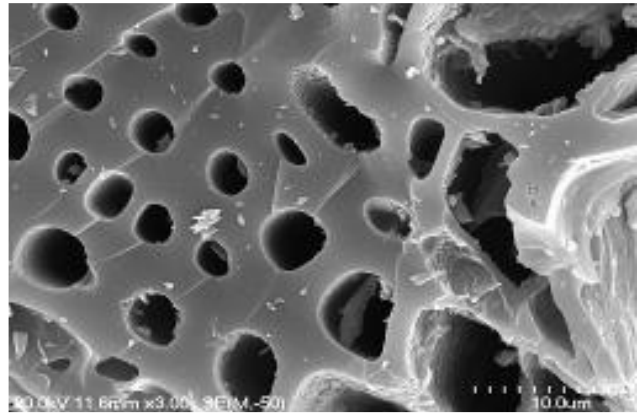
Biochar

Pyrolysis of biomass under inert conditions/ little oxygen

Biochar

- **High porosity**
- **Diverse functional groups**
- **High surface area**
- **High carbon content**

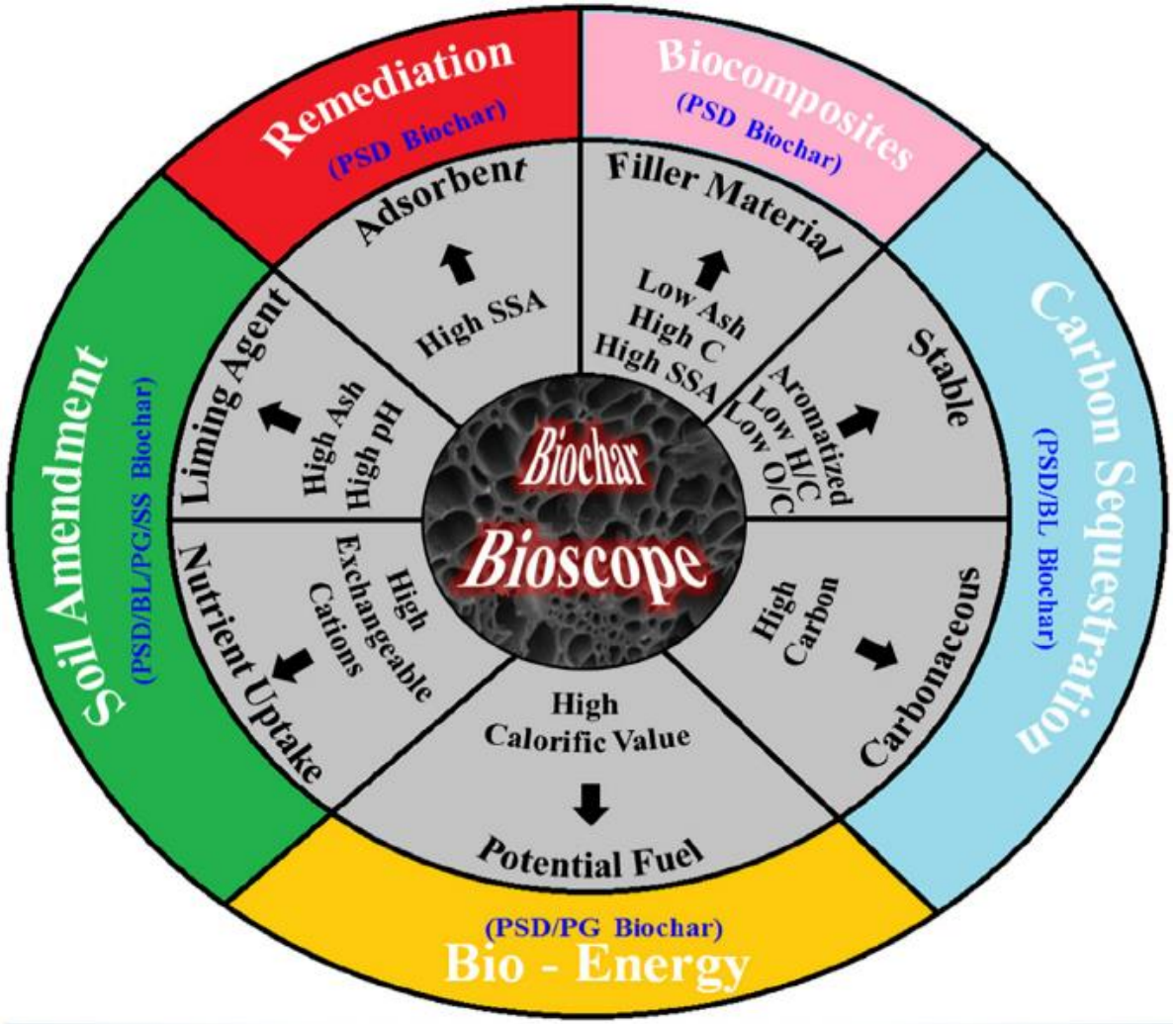
Pyrolysis

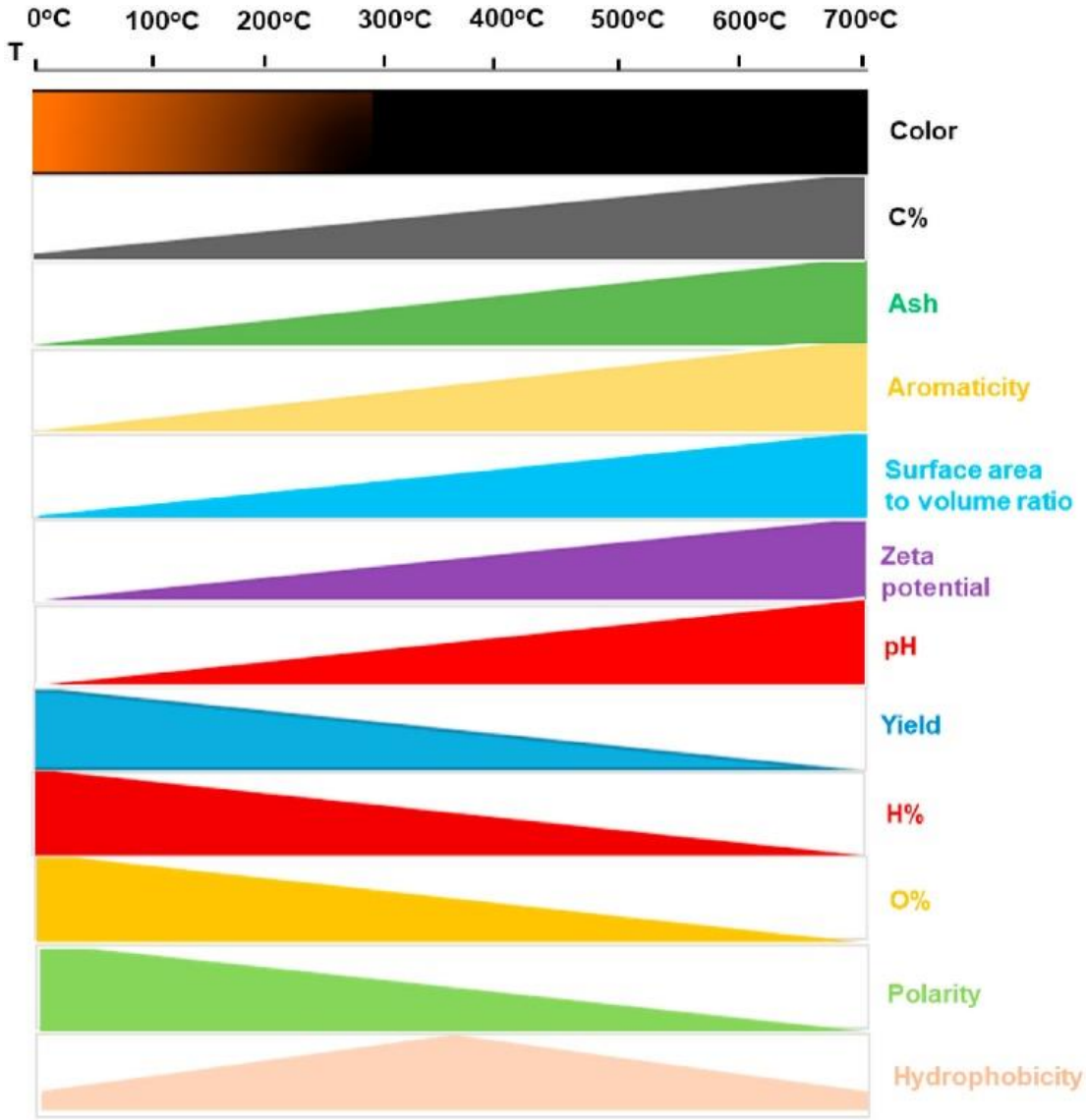


Corn stover biochar - **-0.86 Kg CO_2** equivalents/ Kg of dry feed stock

Yard waster biochar- **- 0.88 Kg CO_2** equivalents/ Kg of dry feed stock

Biochar


Remediation
(PSD Biochar)
Biocomposites
(PSD Biochar)
Carbon Sequestration
(PSD/BL Biochar)
Bio - Energy
(PSD/PG Biochar)
Soil Amendment
(PSD/BL/PG/SS Biochar)
Adsorbent
High SSA
Filler Material
Low Ash
High C
High SSA
Stable
Aromatized
Low H/C
Low O/C
High Carbon
Carbonaceous
High
Calorific Value
Potential Fuel
Nutrient Uptake
High
Exchangeable
Cations
Liming Agent
High Ash
High pH
Biochar
Bioscope


0°C
100°C
200°C
300°C
400°C
500°C
600°C
700°C
T
Color
C%
Ash
Aromaticity
Surface area
to volume ratio
Zeta
potential
pH
Yield
H%
O%
Polarity
Hydrophobicity

Biochar as building material: Reversing climate change with carbon sequestration

Present CO_2 emissions from the cement industry is around 7-8 % of global anthropogenic emissions

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Novel biochar-concrete composites: Manufacturing, characterization and evaluation of the mechanical properties

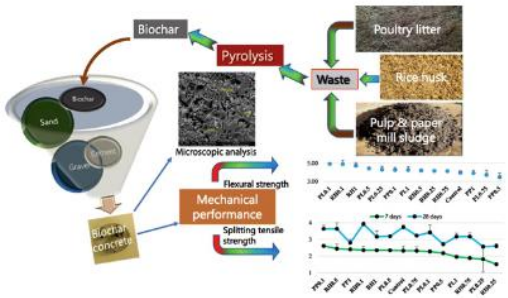
Ali Akhtar, Ajit K. Sarmah *

Department of Civil and Environmental Engineering, Faculty of Engineering, The University of Auckland, Private bag 92019, Auckland 1142, New Zealand

HIGHLIGHTS

- Waste derived biochar has potential to be used as cement replacement.
- Flexural strength improved approximately 20% with the addition of biochar.
- Water absorption of biochar concrete is comparable to the control at 0.1% of total volume.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 18 August 2017
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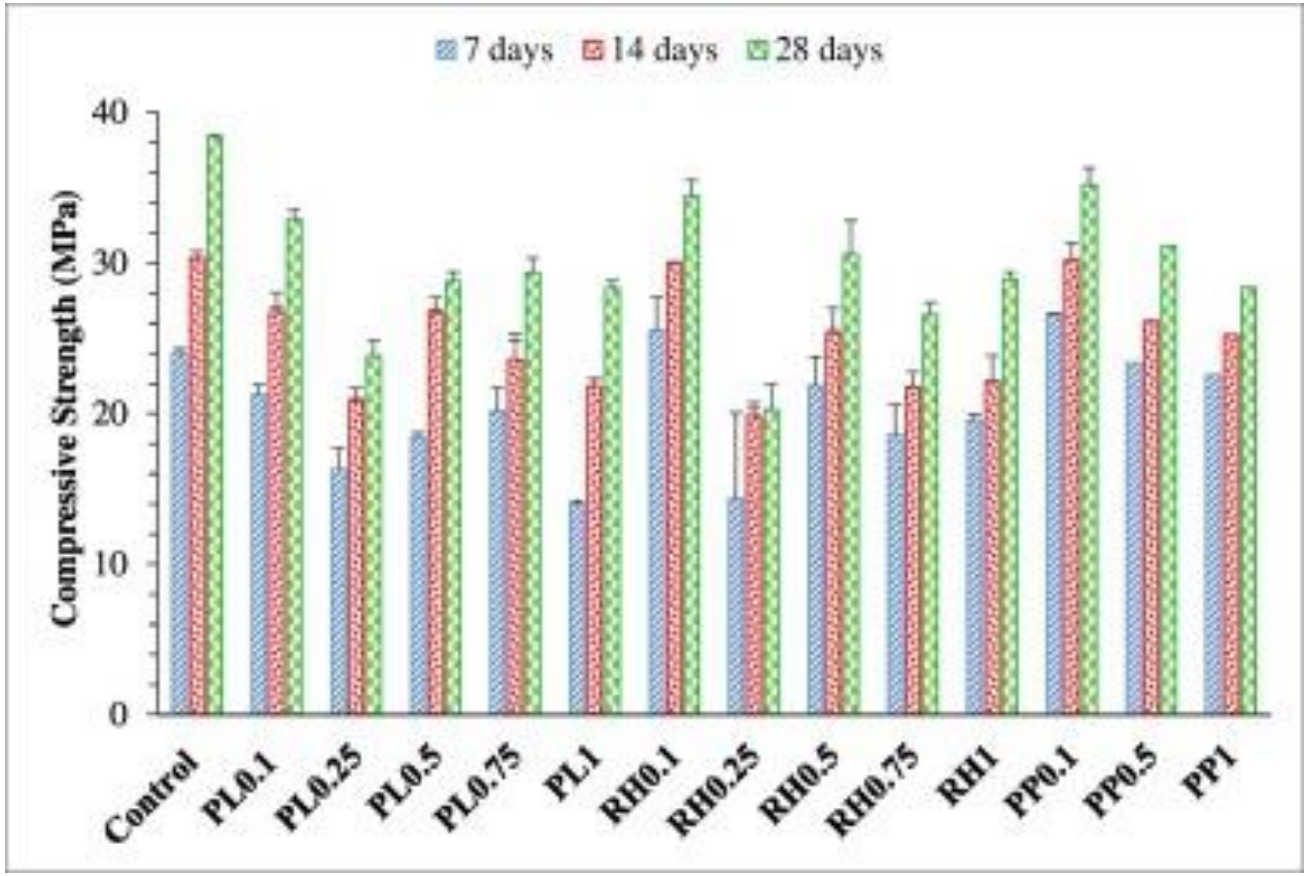
Accepted 30 October 2017

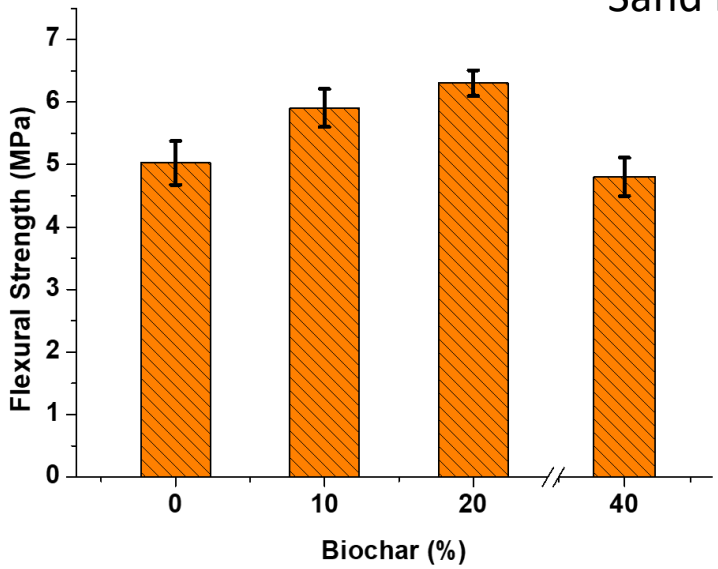
ABSTRACT

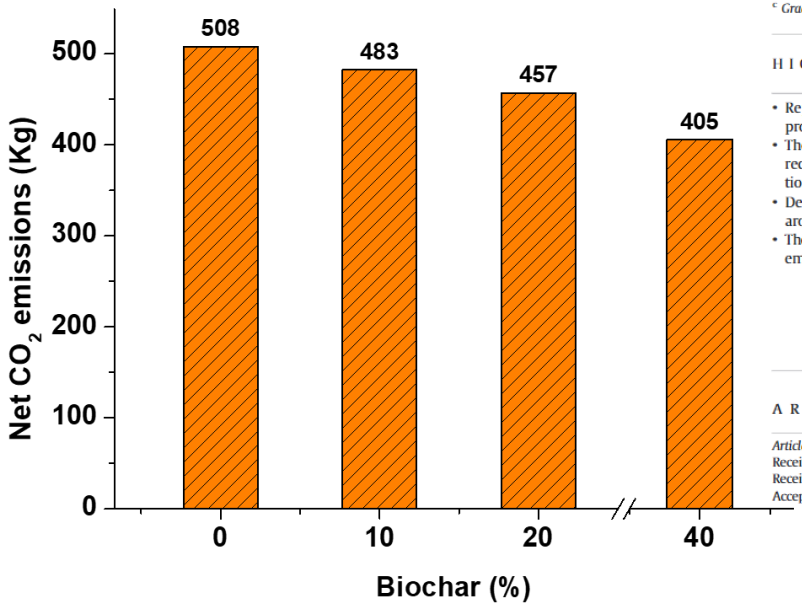
In this study, biochar, a carbonaceous solid material produced from three different waste sources (poultry litter, rice husk and pulp and paper mill sludge) was utilized to replace cement content up to 1% of total volume and the effect of individual biochar mixed with cement on the mechanical properties of concrete was investigated



Biochar-admixture light weight, tough and low thermal conductive cement mortars

Sand in the cement mortars is partially replaced with biochar





Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Biochar admixtured lightweight, porous and tougher cement mortars: Mechanical, durability and micro computed tomography analysis

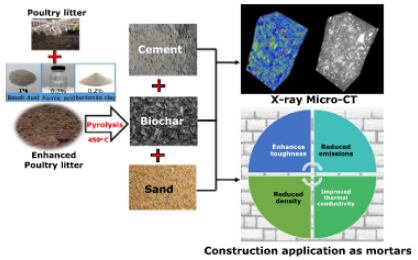
Sai Praneeth [a], Laureen Saavedra [a,c], Maria Zeng [a,c], Brajesh K. Dubey [b], Ajit K. Sarmah [a,*]

[a] Department of Civil & Environmental Engineering, The Faculty of Engineering, The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand
[b] Department of Civil Engineering, Indian Institute of Technology, Kharagpur, India
[c] Graduate Civil Engineer, AECOM, Auckland 1010, New Zealand

HIGHLIGHTS

- Replacing sand with 20% biochar improved the flexural strength up to 26%.
- Thermal conductivity of mortars can be reduced by 26% with 10% biochar addition.
- Density of the mortars decreased by around 20% with 40% biochar addition.
- There was a reduction of 20% in net CO_2 emission with 40% addition of biochar.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 28 July 2020
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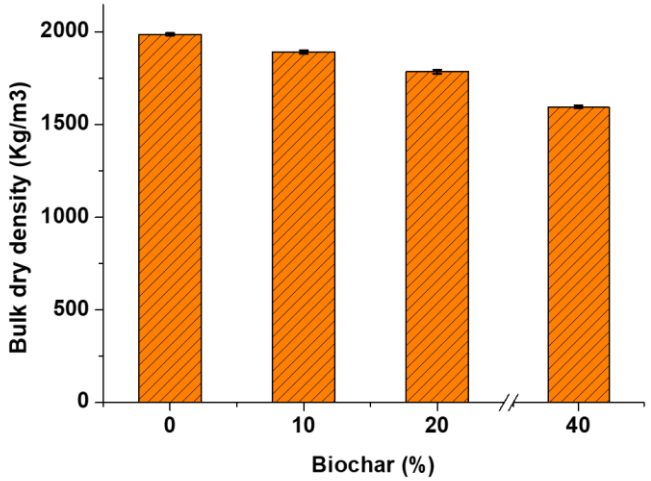
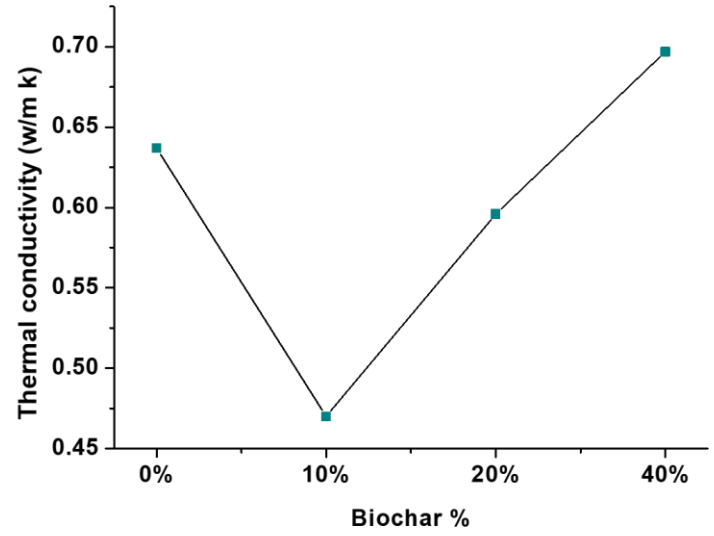
Accepted 8 September 2020

ABSTRACT

Currently, the global carbon footprint of cement industry is nearly 7 to 8% and this number is expected to grow in the near future given the continued global demand of cement usage in the construction and other sectors. Additionally, extraction of sand from the coastal and riverine environment is detrimental to ecosystem health and also





Accelerated carbonation of biochar reinforced cement-fly ash composites: Enhancing and sequestering CO_2 in building materials

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Accelerated carbonation of biochar reinforced cement-fly ash composites: Enhancing and sequestering CO_2 in building materials

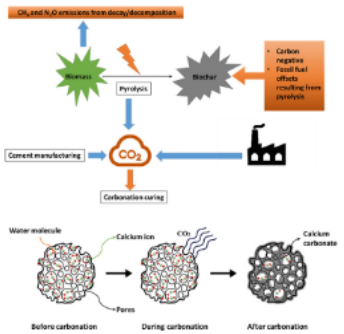
Sai Praneeth [a], Ruonan Guo [b], Tao Wang [b], Brajesh K. Dubey [c], Ajit K. Sarmah [a,*]

[a] Department of Civil & Environmental Engineering, The Faculty of Engineering, The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand
[b] State Key Laboratory of Clean Energy Utilization, Zhejiang University, Hangzhou, PR China
[c] Department of Civil & Environmental Engineering, Indian Institute of Technology, Kharagpur, India

HIGHLIGHTS

- Increased CO_2 uptake in biochar-cement-fly ash carbonated blocks was observed.
- 28 days compressive strength of un-carbonated blocks increased with biochar addition.
- $CaCO_3$ content increased in biochar reinforced composites.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 20 August 2019
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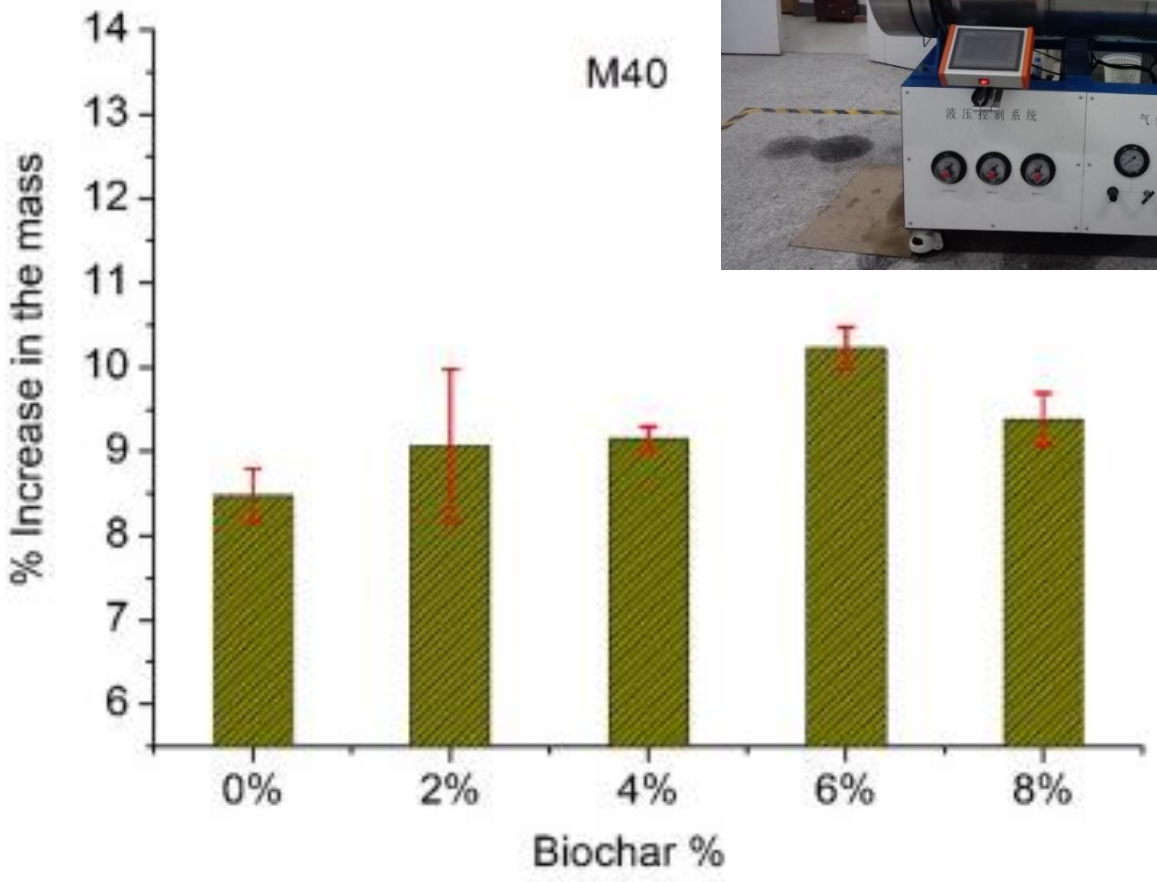
Accepted 4 February 2020
Available online 14 February 2020

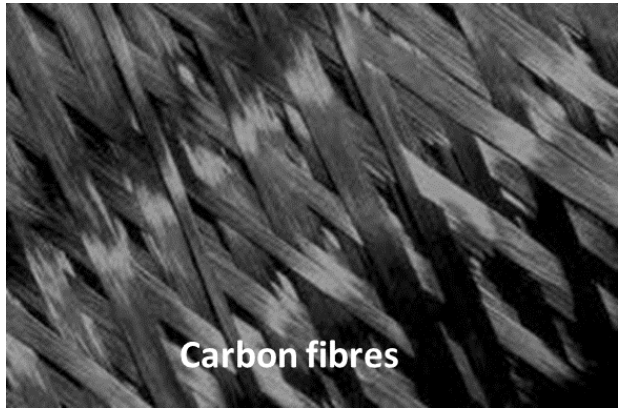
Keywords:
CO_2 sequestration

ABSTRACT

Biochar produced from the pyrolysis of corn stover biomass was added as a filler material in the cement-fly ash blocks as 2%, 4%, 6% and 8% of total weight. The resultant blocks were subjected to two hours mineral carbonation at (3 day) after demoulding to enhance the CO_2 uptake and sequester carbon in the blocks. Along with that, 28 days compressive strength of un-carbonated blocks was determined to gauge the effect of biochar as the filler material on the strength of the specimens. Results showed that there was an enhanced CO_2 uptake on 3 days compressive strength and biochar dosage was optimised at 4% and 6% depending on the chosen mix. The 28 days compressive strength of un-carbonated blocks showed that



Green asphalt binders: a biochar admixture asphalt mixture for pavement



Production difficulties

Poor interaction

Not Sustainability

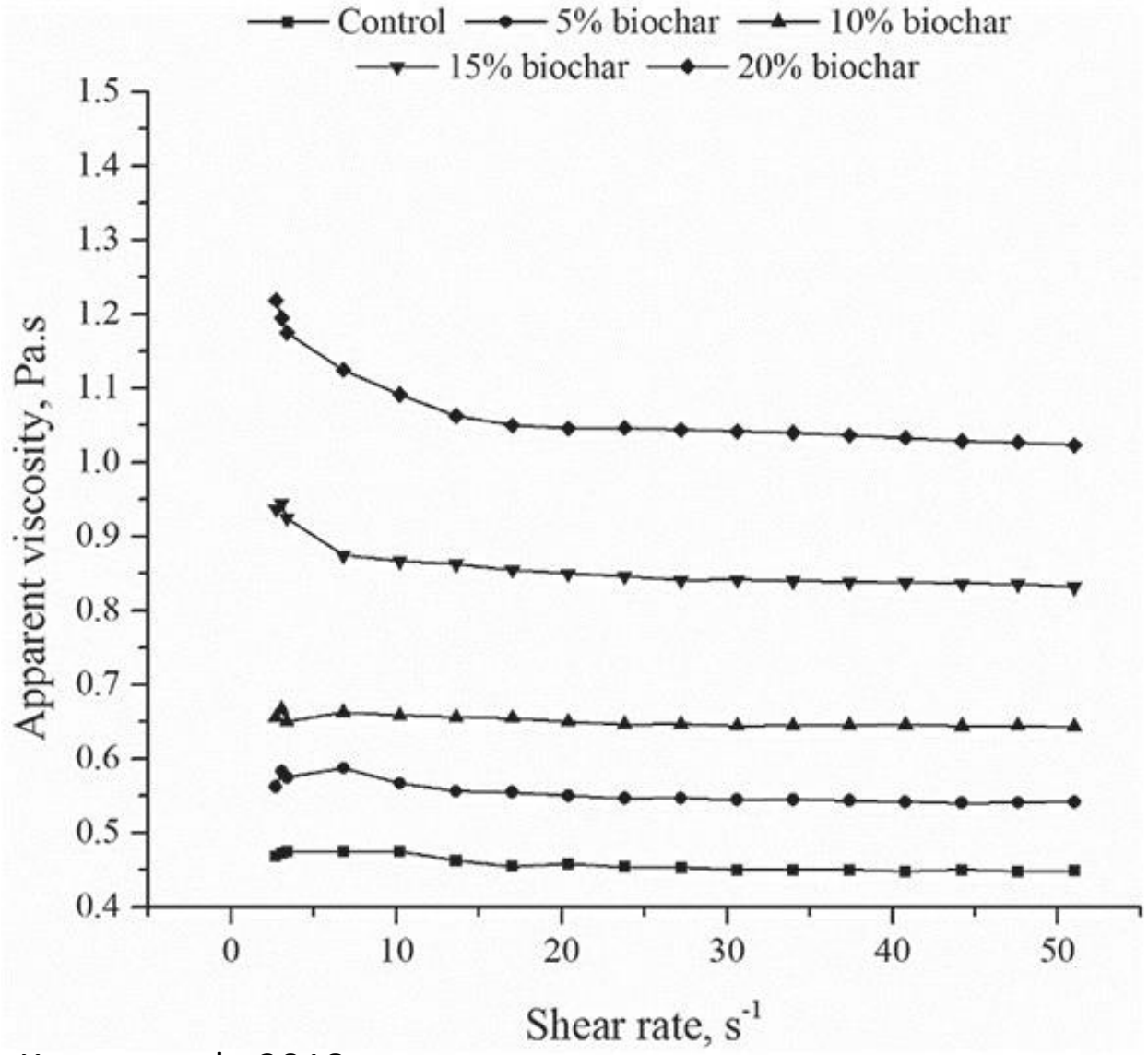
Economic

Improved fatigue

Electrical properties

Mechanical properties

Green asphalt **(Bio-asphalt)** binders: a biochar admixture asphalt mixture for pavement



Kumar et al., 2018

Reduction in carbon foot print

Improved rutting resistance of asphalt mixture

Improve the cracking resistance

Reduce the temperature susceptibility of asphalt

Reduce the stripping potential

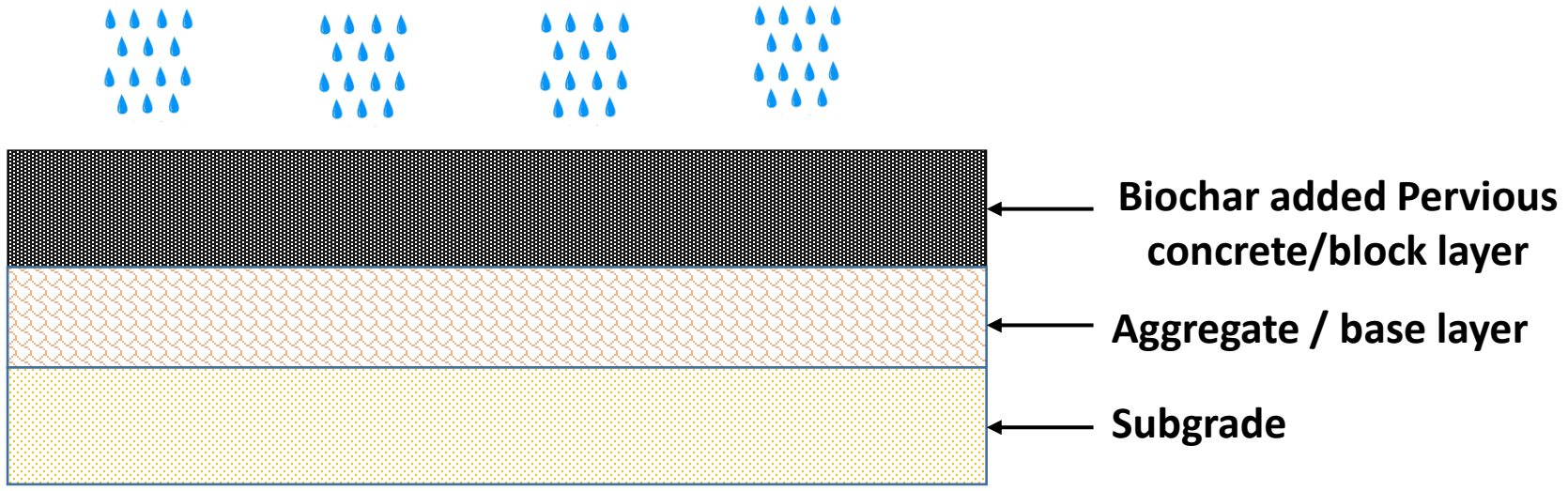
Changes the viscous properties

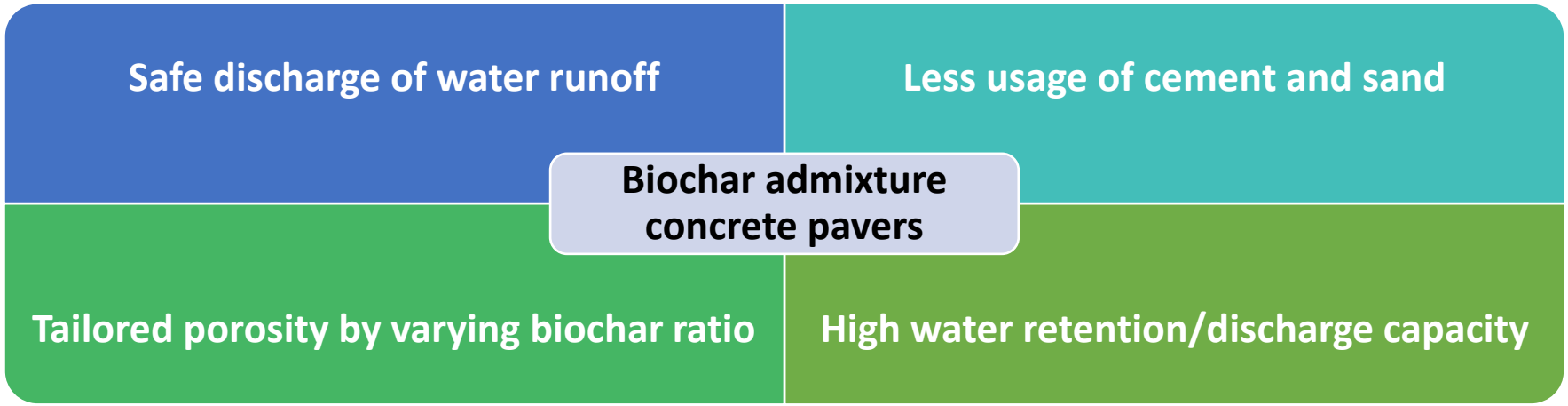
Improve the permanent deformation

Biochar admixture permeable/pervious concrete pavers

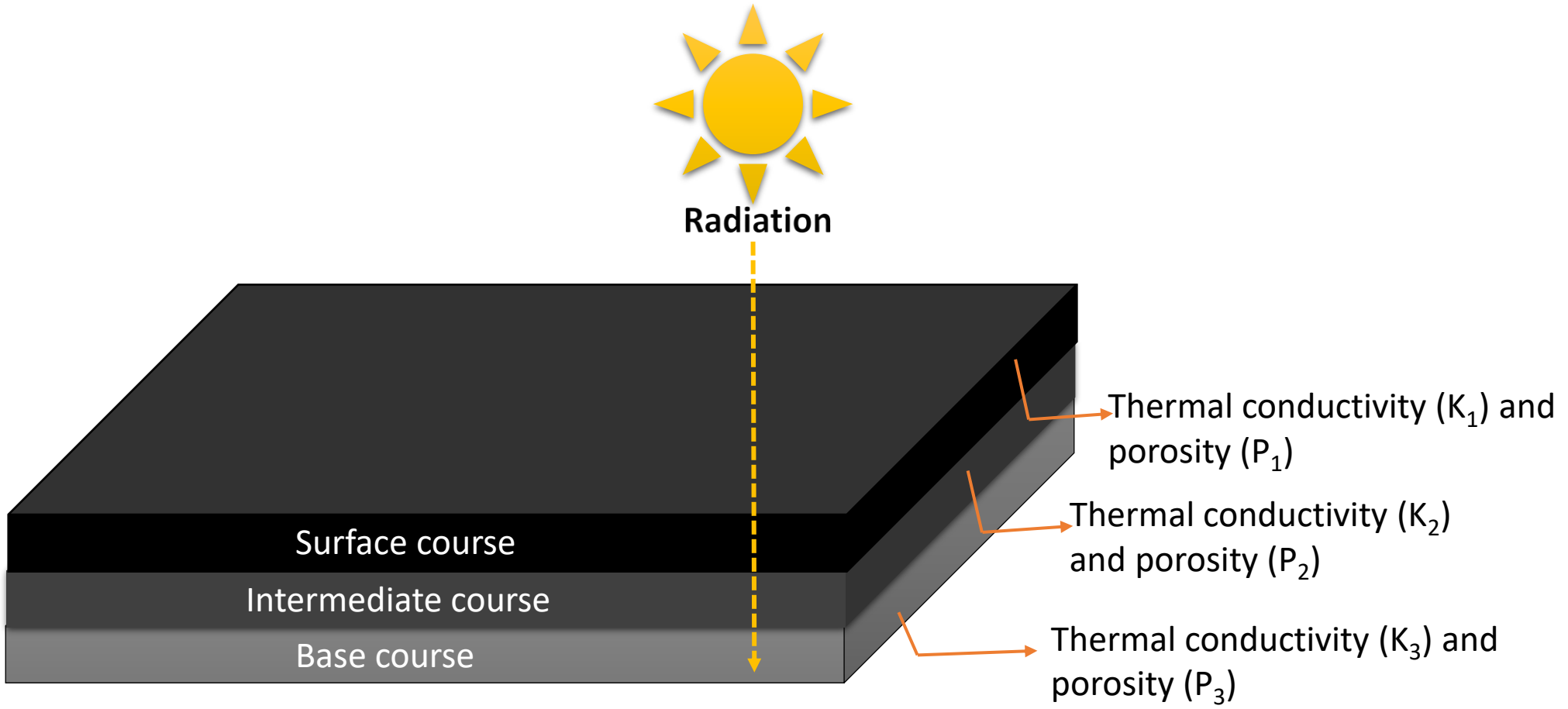
1. The biochar is added as admixture in making pervious top layers

2. It can be used as sand replacement in the subgrade region





Thermally conductive green pavers

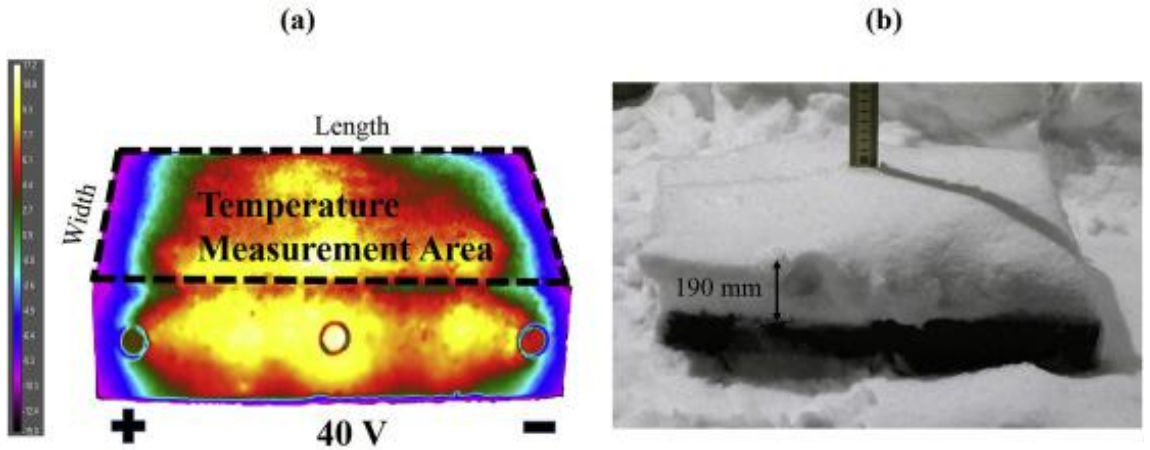


Electrically conductive green pavers

Conductive asphalt concrete, offers another means for automating winter maintenance operations.

Biochar produced at high temperature can potentially act as conductive fillers

Highest skeletal conductivity of carbon in biochar can be increased to 430 S/m



Ali et al., 2018

Food for thought

- ❑ Chemistry of bioasphalt binders
  - to understand the modified asphalt microstructure, modification mechanisms, and their relationship to rheology.

- ❑ Performance of the bioasphalt binders
  - thermal storage stability,
  - aging resistance,
  - performance at high, intermediate and low pavement service temperatures.

- ❑ Characterization of bioasphalt mixes
  - rutting,
  - moisture-induced damage,
  - fatigue cracking,
  - thermal cracking