Enhanced post-elastic behaviour of geopolymer concrete using chopped PVA fibres and Nano Silica Gel from Sugarcane Bagasse

By
Prof. Dr Nasir Shafiq
Director Sustainable Resources Mission Oriented Research

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Highlights of Presentation

- Background and Introduction
- Typical Urban Infrastructure
- Challenges and Issues
- Self Sensing or Piezo-resistive materials
- Material Properties
- Concluding remarks

Background and Introduction

Climate Change Effects and Challenges

Increasing Carbon Footprint

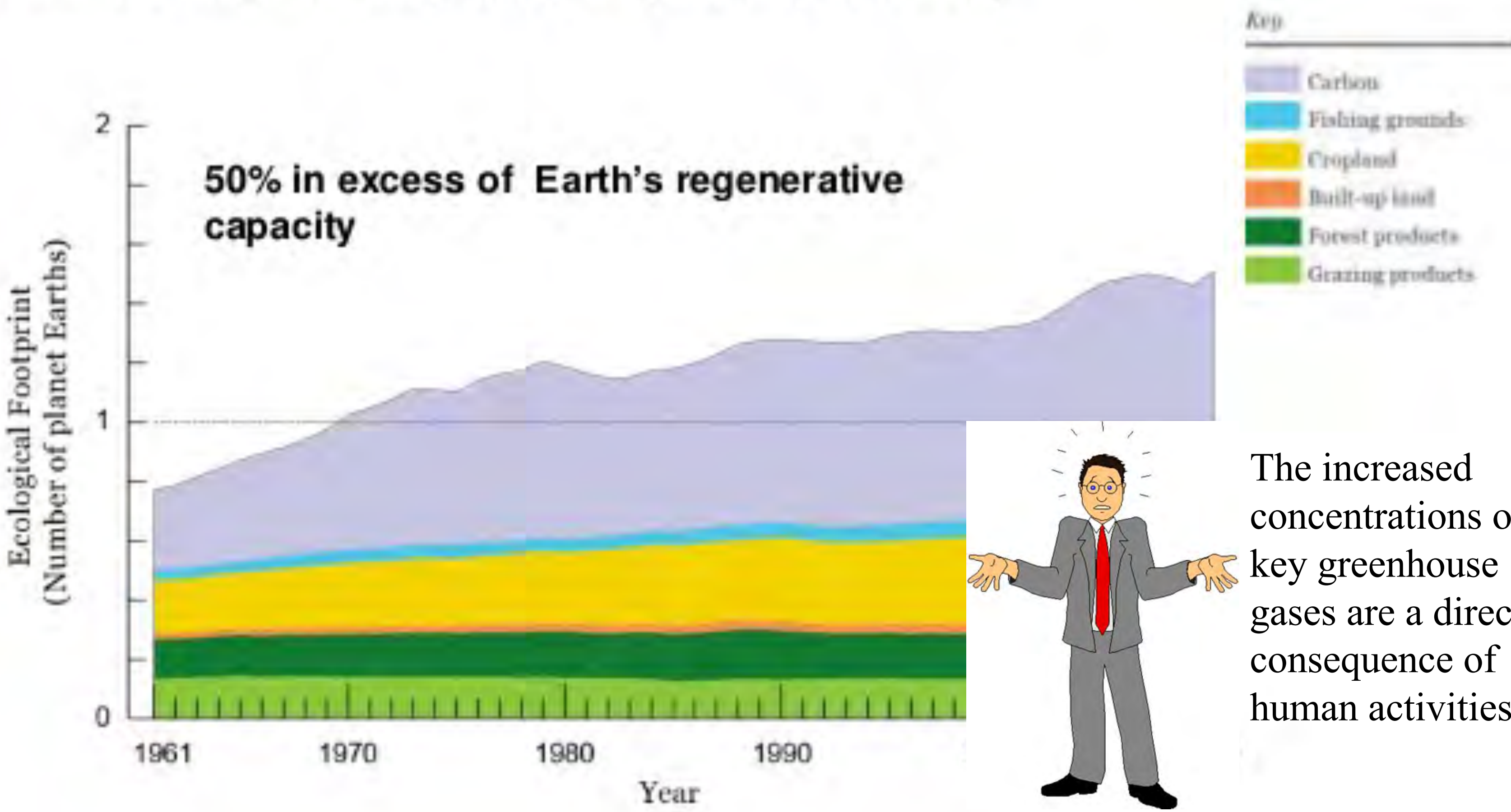
- Increasing urban sprawl – increased volume of built environment (infrastructure demand)
- Highly resource based – Concrete the second largest consumable material
  - Planet under intense pressure (1.57 planets needed)

What is the challenge?

- Managing a city's development that:
  - Maximizes low-carbon energy sources
  - Enhances efficiency in delivering urban services (disciplined resource consumption)
  - Moves towards carbon neutral intensity for a given unit of GDP

The state of the planet – Ecological Footprint

Global Ecological Footprint by component (1961-2010)



The increased concentrations of key greenhouse gases are a direct consequence of human activities.

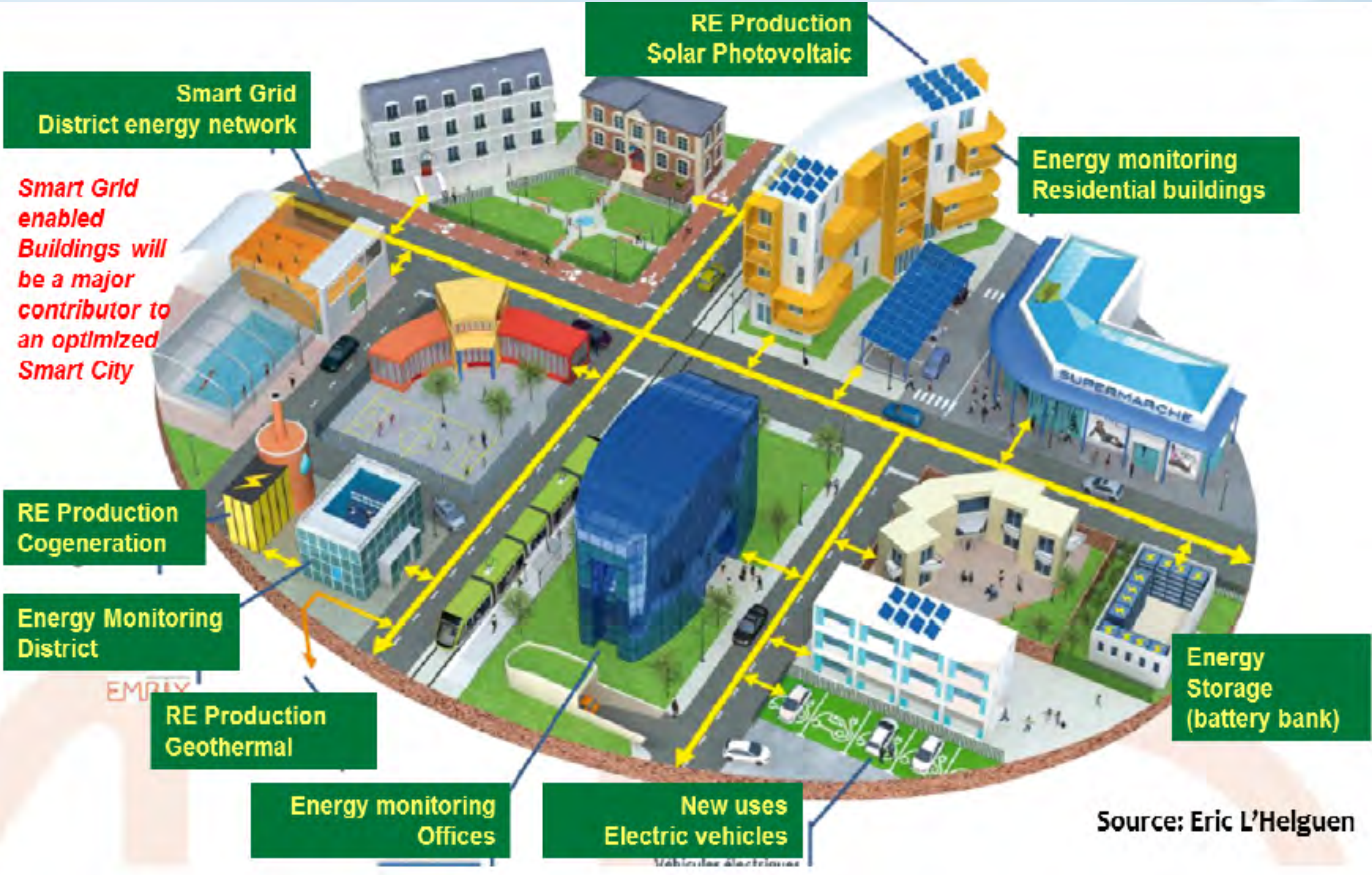
Bio-capacity potential = 1.7 gha

Actual production = 2.7 gha

WHAT DOES IT MEAN?

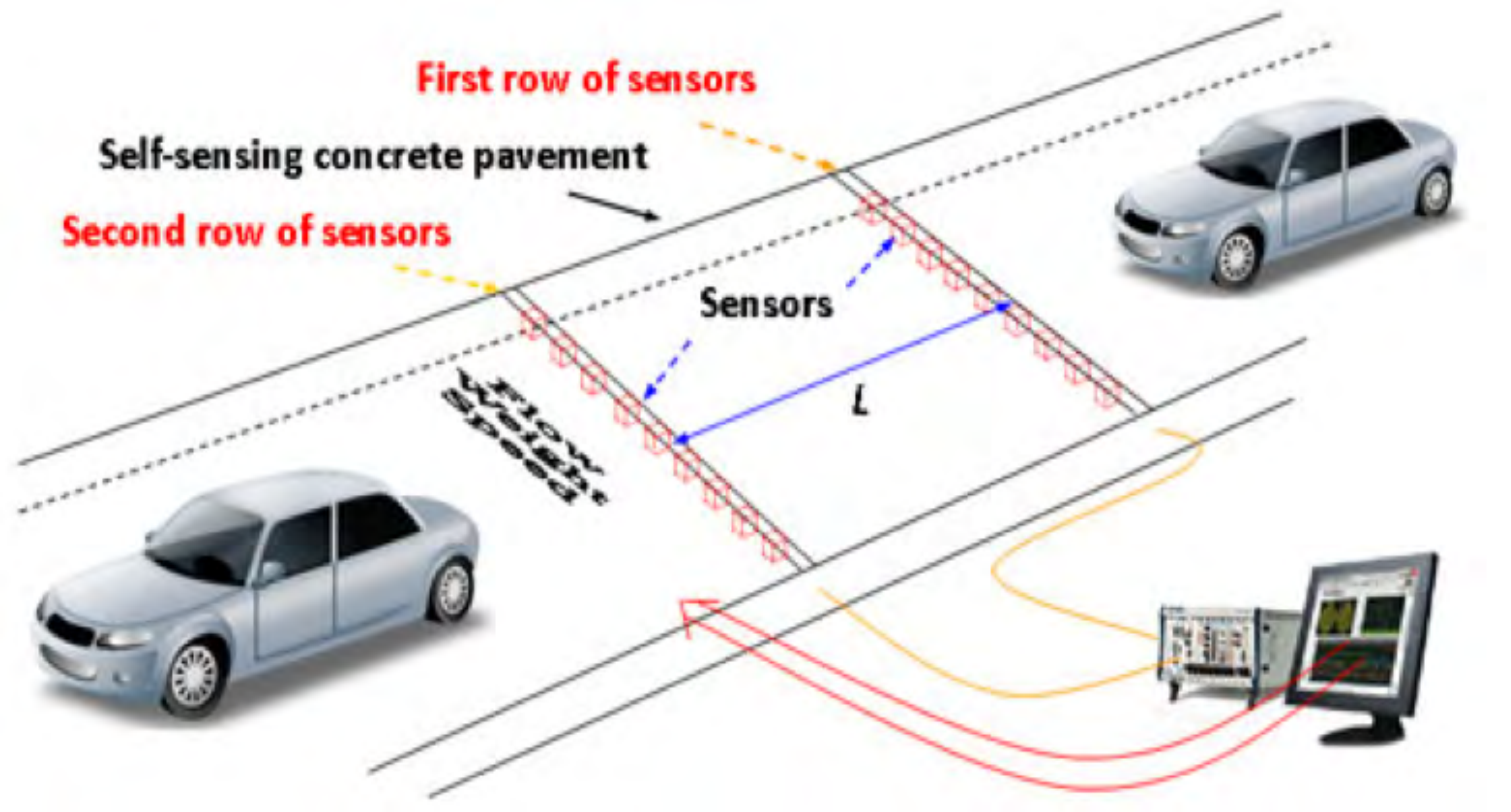
Source: Global Footprint Network, 2014

Future Urban Setting: Self-Sustaining and Carbon Neutral



Source: Eric L'Helguen

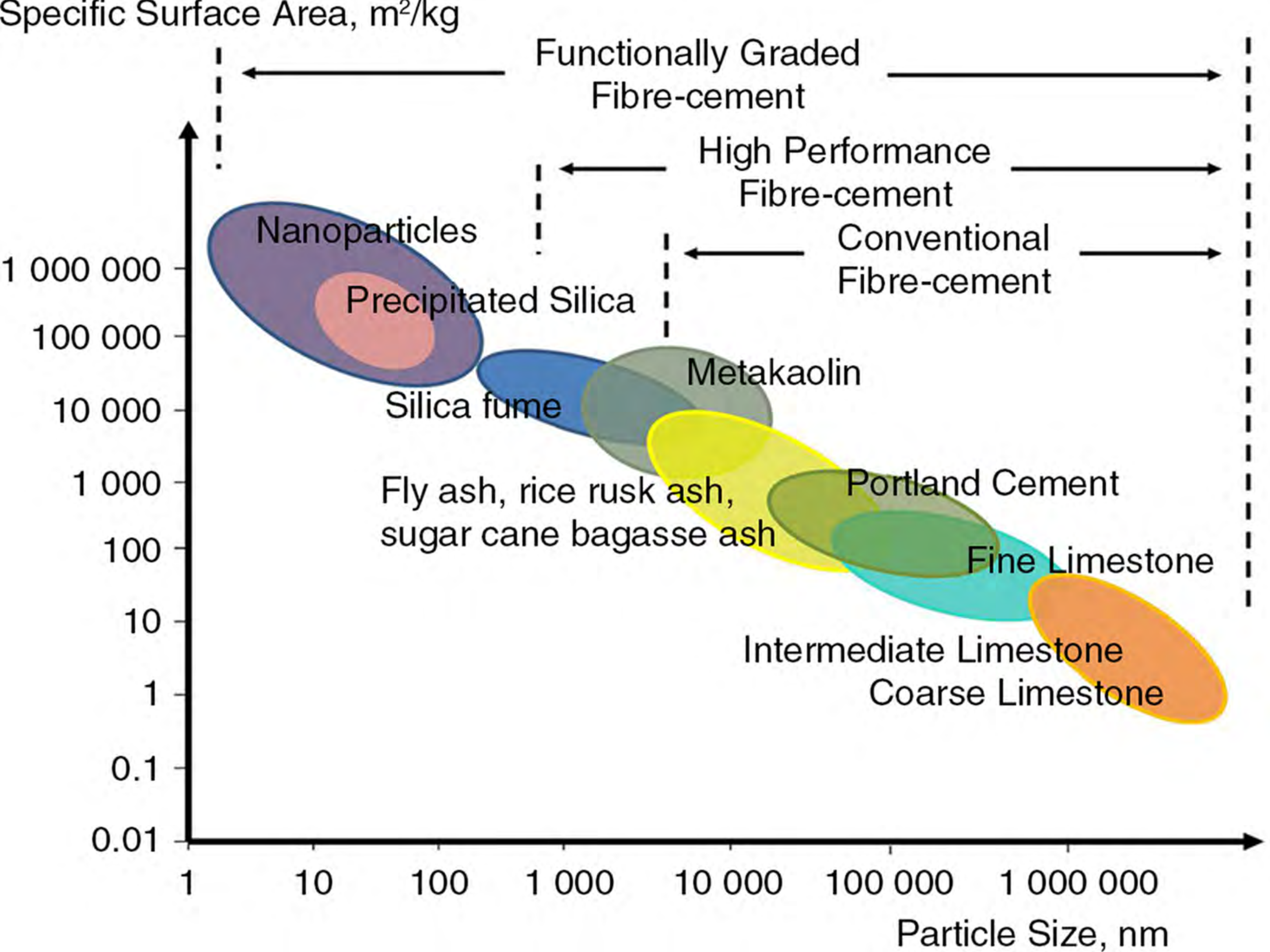
Self-sensing nano-cementitious composite have been developed for traffic monitoring by using piezo-resistive multi-walled carbon nanotubes (CNTs) as an admixture. Response of the piezo-resistive properties of composite to compressive stress and due to vehicular loading was made using self-sensing CNT/cement composite for traffic monitoring.



Some Developments

- Intelligent facades
- Self Cleaning concrete
- Self Healing concrete
- Low carbon concrete (Novacem)
- Lightweight stronger concrete with nanotubes
- Plastic electronics
- Low energy lighting

Innovations in Geopolymer Concrete for Self-Sustainable Building and Infrastructure


Specific Surface Area, m²/kg
Functionally Graded
Fibre-cement
High Performance
Fibre-cement
Conventional
Fibre-cement
Nanoparticles
Precipitated Silica
Metakaolin
Silica fume
Fly ash, rice rusk ash,
sugar cane bagasse ash
Portland Cement
Fine Limestone
Intermediate Limestone
Coarse Limestone
1 000 000
100 000
10 000
1 000
100
10
1
0.1
0.01
1
10
100
1 000
10 000
100 000
1 000 000
Particle Size, nm

This Study

- Material Properties

Table 1: Chemical composition of fly ash as determined by XRF

Oxide (%)	By mass
Silicon Dioxide (SiO_2)	51.3
Aluminum Oxide (Al_2O_3)	30.1
Ferric Oxide (Fe_2O_3)	4.57
Total $SiO_2 + Al_2O_3 + Fe_2O_3$	85.97
Calcium Oxide (CaO)	8.73
Phosphorus Pentoxide (P_2O_5)	1.6
Sulphur Trioxide (SO_3)	1.4
Potassium Oxide (K_2O)	1.56
Titanium Dioxide (TiO_2)	0.698

Sodium Silicate (Grade A53 with SiO_2 = 29.43%, Na_2O = 14.26% and water = 56.31%) obtained from Malay-Sino Chemical Industries Sdn Bhd, Malaysia was used in solution form while Sodium hydroxide supplied by Quick-Lab Sdn Bhd, Malaysia was in pellets form with 99% purity. To prepare sodium hydroxide solution, sodium hydroxide pellets were dissolved in ordinary drinking water. Both the liquid solutions were mixed together and alkaline solution was prepared.

PRODUCTION OF SILICA GEL FROM SUGARCANE BAGASSE

Extraction : Clean SCB + NaOH

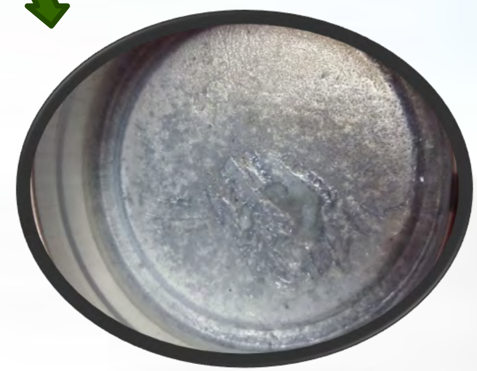
Gelification: Sodium silicate solution + acid

Sugarcane Bagasse

Heating, agitation, cooling and filtering

Sodium Silicate

Drying with ethyl alcohol at 110ºC

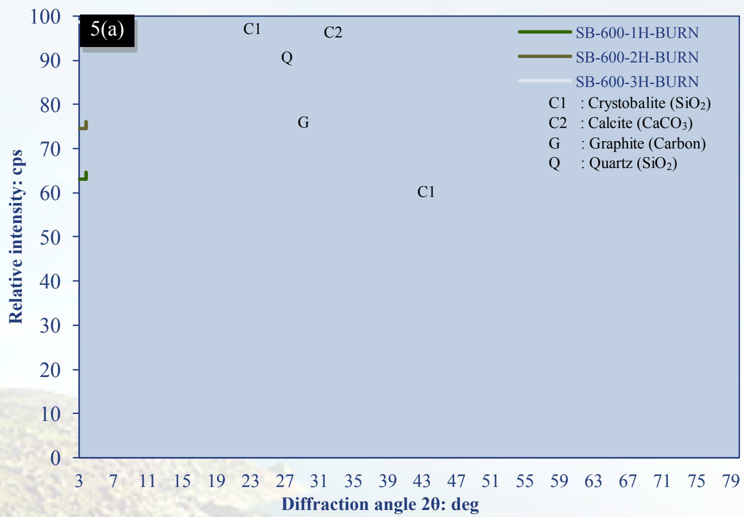


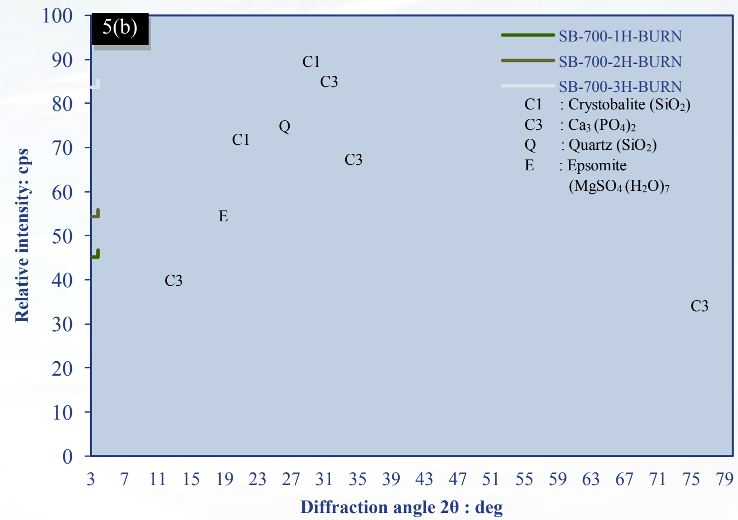
Silica Gel

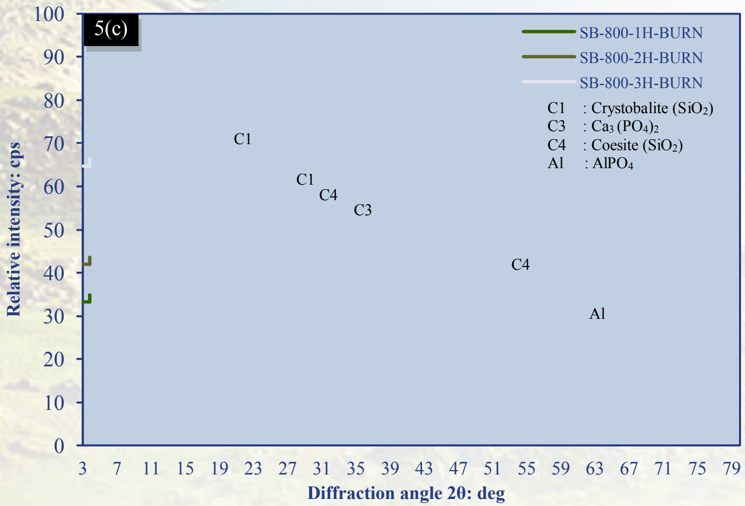
Samantha [22]

The researcher claims the pozzolanic activity of the silica gel is similar to the silica fume and nano-silica activities produced by another amorphous pozzolana.

X-RAY DIFFRACTION (XRD)







Sugarcane bagasse for this incineration process was pre-treated using optimum pre-treatment parameters, which was a combination of 0.1 M HCl solution and 1 h soaking period. Figure above shows XRD profiles of ashes obtained after various incineration temperatures (600, 700, and 800 °C) and durations (1 h, 2 h, and 3 h). It is apparent in this figure that incinerated ash has reached the transition line of amorphous-crystalline phase after 3 h burning in 800 °C.

EFFECT OF TEMPERATURE AND TIME

Temperature (˚C)	Durations (h)	Chemical Composition (%)									
		SiO_2	P_2O_5	CaO	K_2O	Al_2O_3	SO_3	MgO	Fe_2O_3	Na_2O	LOI
600	1	64.9	4.7	1.9	1.9	0.5	0.6	0.7	1.5	0.1	1.8
	2	74.8	6.2	2.1	2.6	2.2	0.7	1.2	0.4	0.3	0.5
	3	71.5	8.3	3.0	3.4	0.6	0.8	1.4	1.4	0.5	0.2
700	1	65.9	7.4	2.6	2.7	1.4	0.7	1.0	1.8	0.3	0.2
	2	72.0	5.9	2.2	2.5	1.0	1.0	1.2	1.4	0.2	0.2
	3	84.8	6.0	2.2	2.6	1.2	1.0	1.2	0.4	0.3	0.2
800	1	84.1	7.3	2.5	2.5	0.9	0.5	1.2	0.4	0.3	0.2
	2	84.3	5.6	1.9	2.9	1.1	0.5	1.4	1.7	0.3	0.1
	3	82.9	5.1	2.0	2.3	1.6	0.3	1.2	3.4	0.2	0.1

- Extending burning duration from 1 h to 3 h in 600 °C was able to generate 10% increment to the extracted SiO_2 content. The increment rate was intensified in 700 °C where the extension of burning duration was able to generate 29% increment to the SiO_2 proportion.
- In 800 °C, the SiO_2 content insignificantly shifted even after the extension of burning duration. However, as indicated in XRD result, the amorphousness phase has rapidly shifted towards crystalline phase after 3 h burning at 800 °C. For the subsequent analysis, 800 °C and 1 h burning duration was adopted as the optimum burning variable due to its amorphous and high silica content.
- Consideration to discard 700 °C – 3 h, 800 °C – 2 h, and 800 °C – 3 h pairs were due to the extensive energy consumption in these longer burning duration.

BET SURFACE AREA & BJH VOLUME OF PORES

Sample	Ball Mill Grinding (min)	Particle Size (μm)			BET Surface Area (m^2/g)	BJH Volume of Pores (cm^3/g)
		D(0.1)	D(0.5)	D(0.9)		
Cement Type I	n/a	2.8	18.3	49.5	1.9	0.00571
SCBA Non-Treated	n/a	2.0	30.7	155.4	8.2	0.02157
SCBA Treated	n/a	2.4	18.2	77.0	45.1	0.13643
SCBA Treated 15	15	1.5	17.4	117.7	41.8	0.14737
SCBA Treated 30	30	1.4	17.3	112.2	40.3	0.12567
SCBA Treated 45	45	1.0	8.6	36.7	44.1	0.14324
SCBA Treated 60	60	1.0	10.5	52.0	49.5	0.14383

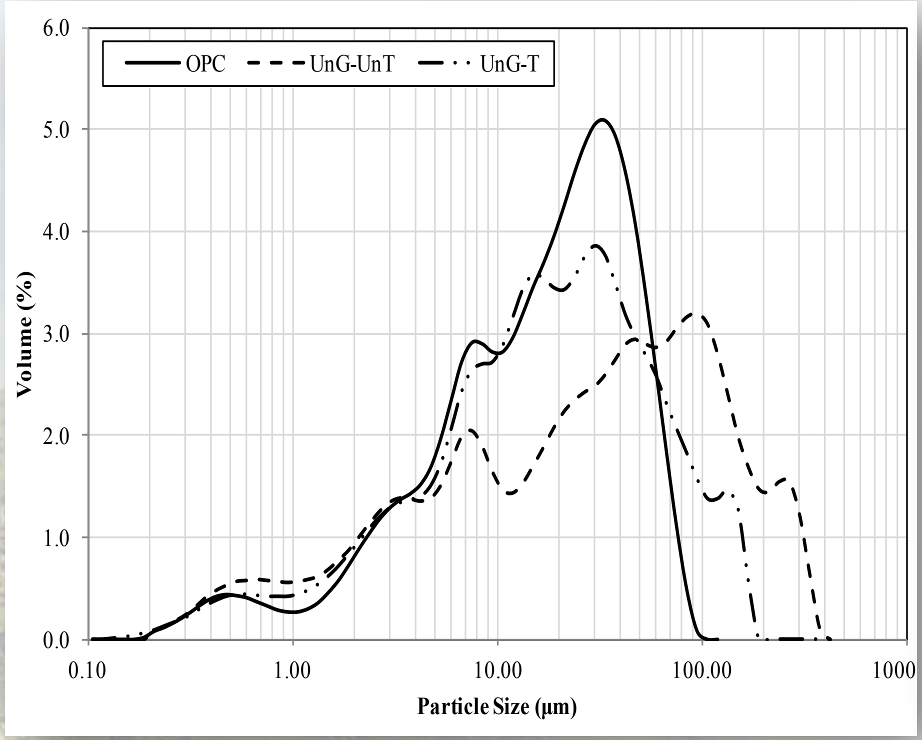
- Pre-treatment process remarkably increased the surface area of SCBA up to 5 times higher than untreated SCBA. It is supported by immense escalation of BJH pores volume from untreated to pre-treated SCBA.

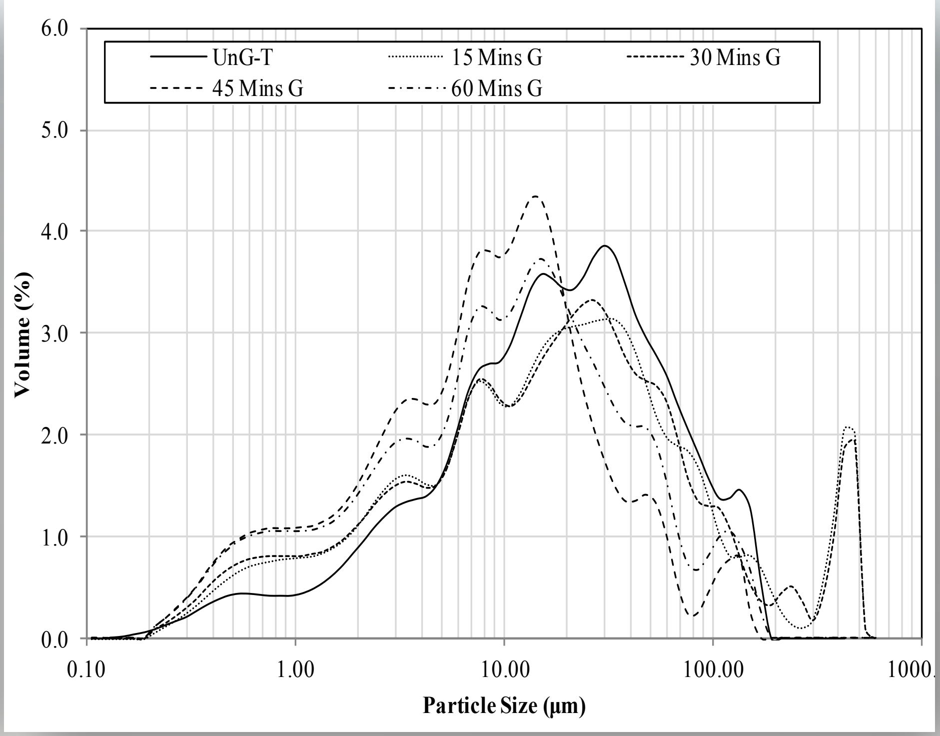
- Additional effort to increase the surface area by grinding the ashes up to 60 min provided inconsiderable improvement to the surface area properties. Reduction on the surface area was even detected in the grinding time of 15 – 45 min.

- Cellular structure of sugarcane bagasse ash appeared to be ruptured by grinding process, which may reduce its pozzolanic reactivity feature. This reduction can also be explained as the effect of coalescing of fine particles.

- Immediate transition to finer particle after short grinding process resulted in coarser particles due to coalescing fine ash. It could be prevented by increasing the grinding duration; however the impact energy will be unnecessarily used to refine the coalesced particle.

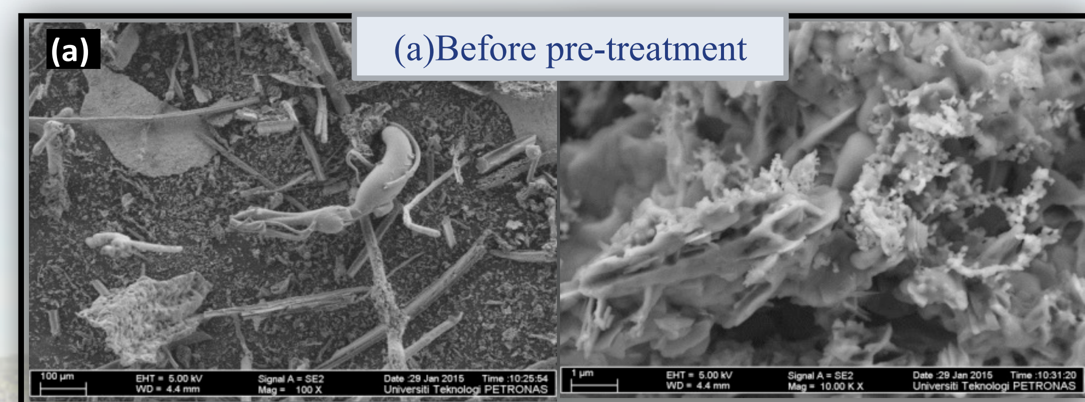
PARTICLE SIZE ANALYSIS



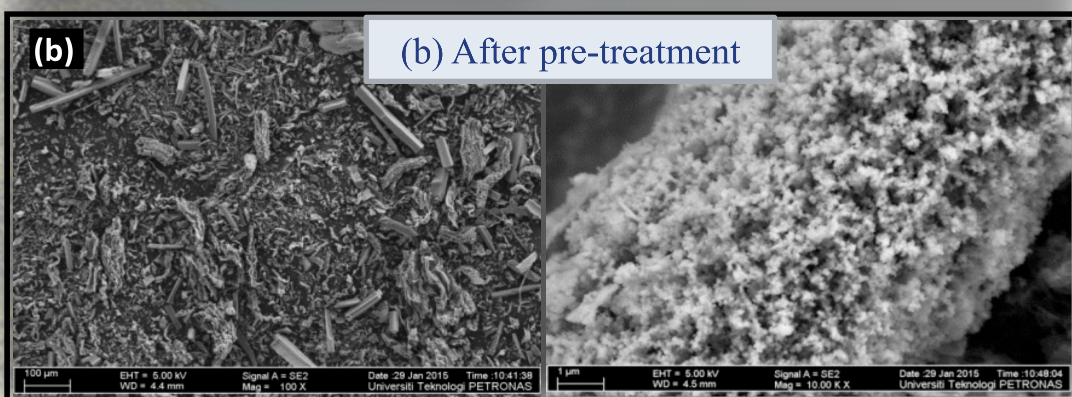


- Based on this figures, particles of OPC accumulated at certain size, while SCBA has wider particle size range. Additional grinding process did not contribute significantly to the improvement of particle size's range of the treated SCBA.
- However, regardless of coarser particle, treated SCBA has higher surface area than OPC and untreated SCBA, which was contributed by fine particles and porous structure of larger particles. The trend is also displayed by FESEM images where the large particles are scarcely detected and replaced with finer particles

MICROSTRUCTURE ANALYSIS : FESEM



(a)Before pre-treatment



(b) After pre-treatment

- It appears that HCl acid has ruptured large fraction of solid cellulose and transform it to fine silica during the combustion process.

- Figure (a) illustrates the transformation of outer fibre into ash, yet leave the inner fibre in a non-fully decomposed state. It is entirely different with pre-treated specimen where the internally porous particle would provide a large surface area to assist the pozzolanic reactivity.

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Effectiveness of low-concentration acid and solar drying as pre-treatment features for producing pozzolanic sugarcane bagasse ash

Rahimah Embong [a, b, *], Nasir Shafiq [a], Andri Kusbiantoro [b], Muhd Fadhil Nuruddin [a]

[a] Civil and Environmental Engineering Dept., Universiti Teknologi PETRONAS, Malaysia
[b] Faculty of Engineering Technology, Universiti Malaysia Pahang, Malaysia

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ABSTRACT

In the production of sustainable concrete, it is quite essential to develop highly reactive silica rich materials to substitute cement. Sugarcane bagasse ash as one of the agricultural based pozzolan gained less popularity due to its relatively low amorphous silica content after incineration process (<50% silica). Therefore, an alternative approach was studied in this research to extract high proportion of amorphous silica from sugarcane bagasse that fulfils the minimum requirement of pozzolanic standard. The process was divided into three stages, which were obtaining optimum pre-treatment variables, obtaining optimum burning variables, and substantiation of pozzolanic feature. Pre-treatment were done to remove all impurities and deleterious material from the ash. It involved soaking of bagasse in different concentrations of hydrochloric acid solution for different interval of time after which it was dried in a dedicated solar drying chamber. Bagasse treated with optimum parameter would then undergo burning process with various temperatures and durations. The produced ash was characterized by determining different oxides composition, particle size analysis, mineralogical characteristics and micro-structure using X-ray fluorescence, nitrogen adsorption, X-ray diffraction, and field emission scanning electron microscope, respectively. The production process was considered environmentally friendly because the ash was produced with optimum parameters (lowest acid concentration and solar drying). The ash obtained using the appropriate pre-treatment and incineration parameters was found to be amorphous, chemically stable, and ultra-fine. Pozzolanic reactivity test also revealed that the ash possessed quite high pozzolanic reactivity index and suitable to be used as cement replacement material. It is evident that the ash enhances the mechanical properties of the mortar specimens tested.

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PVA Fibres

Properties			
Length (mm)	10	20	18
Diameter (µm)	200	200	200
Aspect Ratio (l/d)	50	100	90
Density (g/cm^3)	1.3	1.3	1.3
Tensile strength (MPa)	1000	1000	1000

Results Summary

- Compressive Strength = 60 Mpa
- Maximum Deflection = 3.1 cm

Thank you - Any questions?