Development of Nano-Reinforced Green Alternative to Cementitious Matrix for Structural Composites using Rice Husk Ash

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Introduction

- The worldwide growing demand of rice raises a deep concern about the management of non-bio degradable rice husk .
- Current Worldwide rice production is ~530 million Tons.
- Rice husk makes up ~20 wt% of the total rice, which totals ~100 million Tons.
- The rice demand is expected to 700 million Tons by year 2020.
- Rice Husk Ash (RHA) is the source of pure and pozzolanic Silica.
- Kaolin is Aluminisilicate rich abandoned earth's material and Source of Metakaolin
- Most promising application of RHA and Kaolin is green cementitious composite.

Rice Husk Ash

- Residues from high temperatures calcination of rice husk, is called Rice Husk Ash (RHA), reactive SiO_2.
- In alkali medium, these SiO_2 make strong bonds with Meta-kaolin (an earth crust material rich in Silica and Alumina) in alkali condition, which results in Geopolymer cement.
- This technology is blessing to environment
  - It helps recycle bio-waste,
  - Lowers greenhouse gas emission
  - Lowers processing temperature.

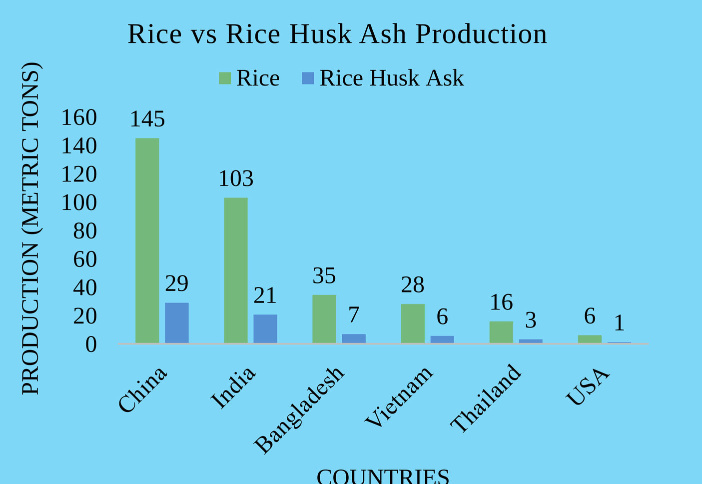
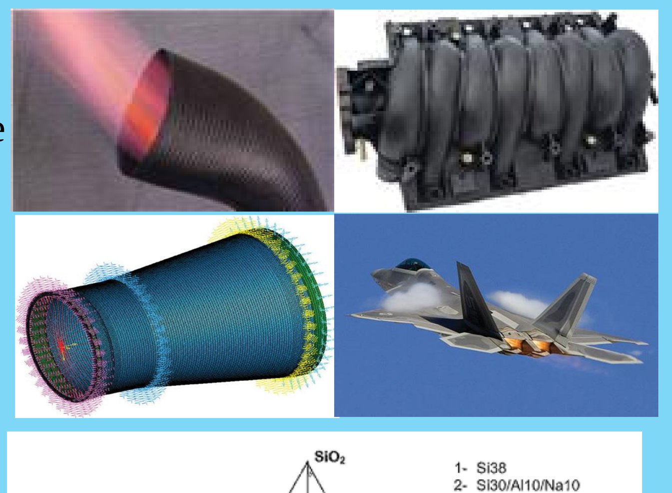


Fig. 1 The production of rice vs rice husk ash in world

Geopolymer Composite

- Pozzolanic RHA -
  - A potential nanofiller for matrix of high temperature fiber reinforced composites
  - Not only reduces the environmental impact, also improves the mechanical performance.



- Geopolymers are a group of inorganic polymers-
  - Dissolution of Metakaolin, in Alkali medium.
  - $M_n\{-(SiO_2)z-(AlO_2)\}_n.wH_2O$
  - Ratio of Na_2O, Al_2O_3 and SiO_2 dictates
    - Geopolymer strength
    - Thermal stability
    - Indicated in the ternary diagram
  - RHA improves consolidation, porosity and strength
  - Silicon carbide whisker (SCW) increases shear resistance and flexural strength

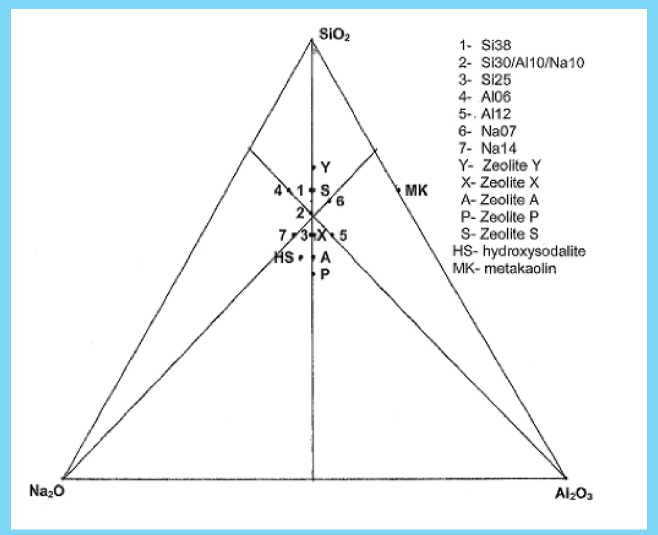


Fig. 2 The ternary diagram on Na_2O. Al_2O_3 and SiO_2

Experimental Procedure

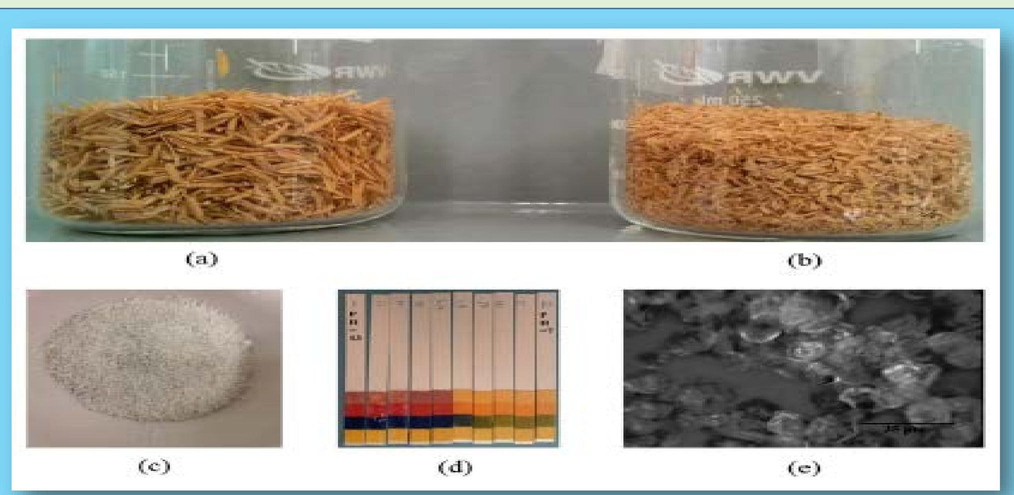
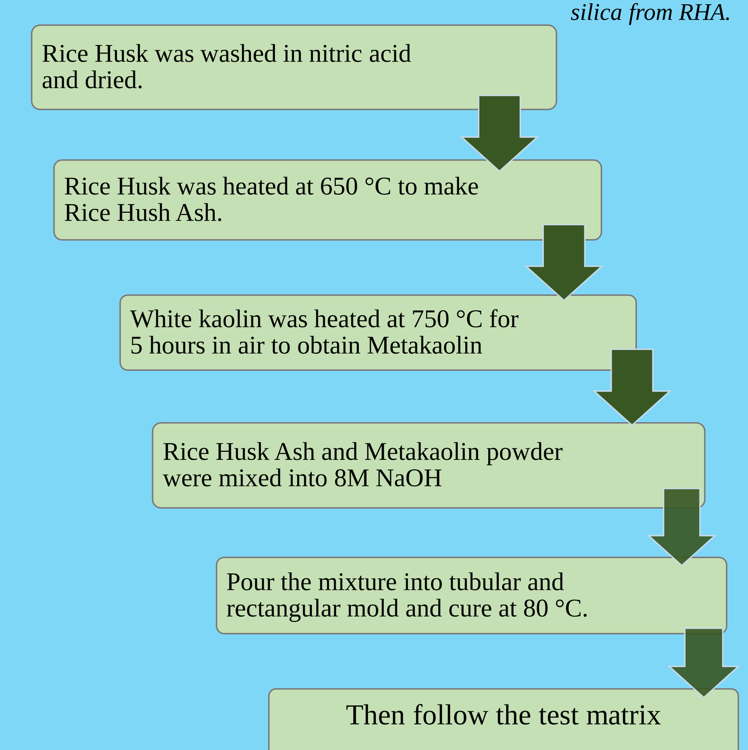
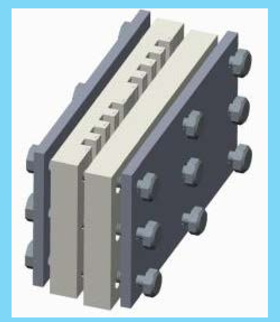


Fig. 3 (a) Acid washed RHA type B-11(b) RHA type B-28 (c) RHA after calcination at 650 °C in air for 5 hours (d) Transformation of basic to neutralization during the silica extraction reaction (e) Particles of the extracted silica from RHA.



(a)



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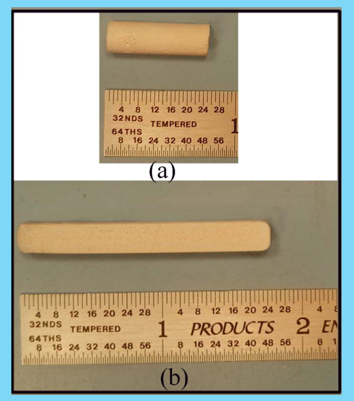


(c)

Fig .4 (a) Geopolymer processing scheme using Metakaolin and RHA (b) Molds for flexural samples (c) Samples

Table 1 The recipes of the neat Geopolymer matrix

Recipe 1	Weight, gm	Molar Equation	Ratio	Recipe 2	Weight, gm	Molar Equation	Ratio
SoSi	3.5	Na_2O/Al_2O_3	1.29	SoSi	3.75	Na_2O/Al_2O_3	1.72
NaOH	0.5	SiO_2/Al_2O_3	3	NaOH	1.5	SiO_2/Al_2O_3	3.07
Metakaolin	2.5	H_2O/Na_2O	9	Meta	2.5	H_2O/Na_2O	9.29
Water	0	Na_2O/SiO_2	0.43	Water	0	Na_2O/SiO_2	0.56

Table 2 The test matrix of the samples of the Geopolymers

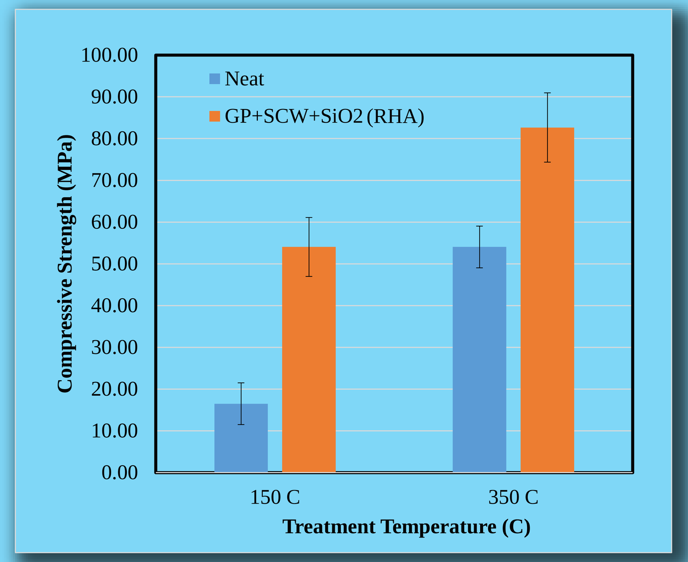
Samples	Compression Test			Flexural Test	Shear Test
Temperature	80°C	150°C	350°C	350°C	350°C
Neat	+	+	+	+	+
Neat + 4wt% RHA + 4wt% SCW	+	+	+	+	+

(a) (b)

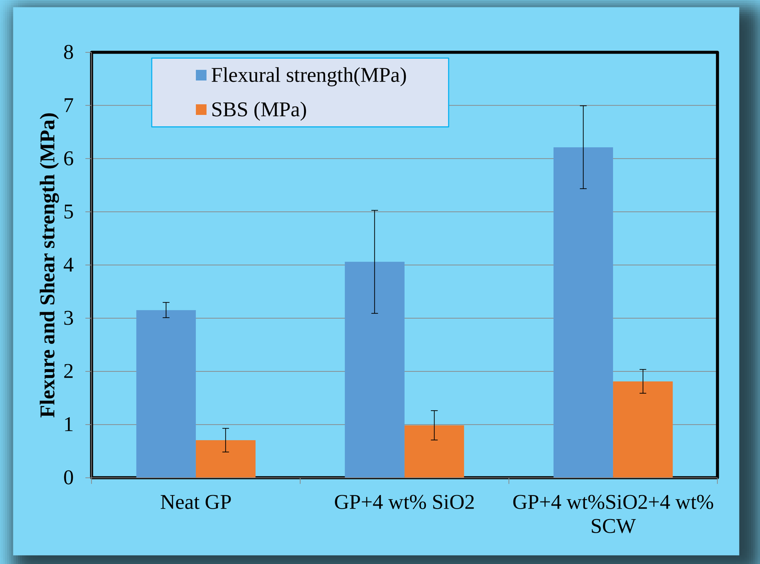
Fig. 6 Neat Geopolymer with (a) Inappropriate ratio and incomplete curing (Recipe 1) and (b) Optimum ratio and cure schedule (Recipe 2)

(a) (b)

Fig. 7 Post compression test (a) Neat Geopolymer and (b) Geopolymer with 4 wt% RHA and SCW



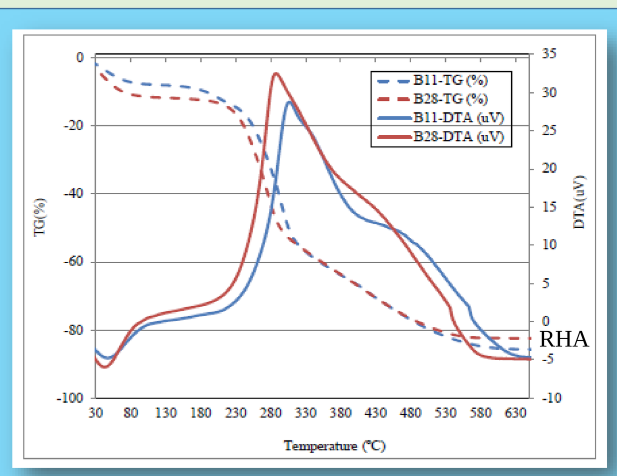
(a)



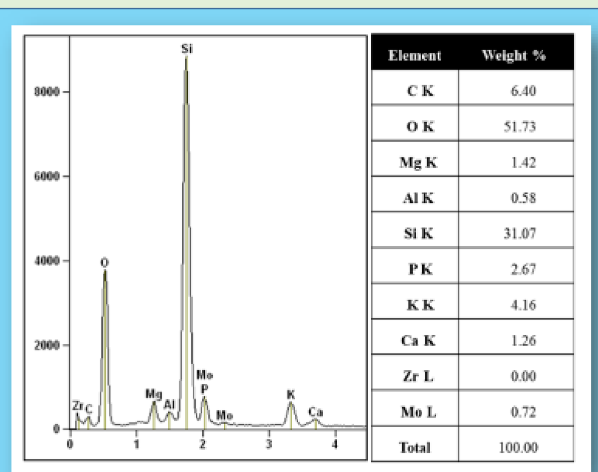
(b)

Fig. 8 (a) Compressive strengths of the Geopolymers and (b) Flexural and Shear strengths of the Geopolymers at 350 °C.

Analysis of Results



(a)



Element	Weight %
C K	6.40
O K	51.73
Mg K	1.42
Al K	0.58
Si K	31.07
P K	2.67
K K	4.16
Ca K	1.26
Zr L	0.00
Mo L	0.72
Total	100.00

(b)

Fig. 5 (a) Tg and DTA of rice husk and (b) EDS spectrum and elements of RHA

Discussion

- Optimal processing scheme increased structural integrity and resulted in the crack free specimens
- The additions of RHA derived SiO_2 reduced nano-porosities and increased compressive strength.
- Both flexural and shear strengths of neat and RHA+SCW reinforced Geopolymer also increased.
- Flexural and shear strengths were increased by 97% and 158%.

Future Directions

- Processing and evaluation of fracture toughness of the cementitious matrix system using RHA.
- Incorporate continuous fiber (between 40-60 vol%) into the developed matrix system.