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# CORRELATION BETWEEN ENHANCED MECHANICAL STRENGTH AND MICROSTRUCTURE RELIABILITY OF GEO-COMPOSITE

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**Abstract:** *A correlation between increase in mechanical strength and the microstructure reliability of fabric reinforced geo-composite is established in elevated temperature range. The mechanical strength of the fabric reinforced geo-composite is investigated at elevated temperature in terms of physical, fire testing and thermal conductivity. The strength of carbon based geo-polymer increased towards higher temperature that strongly correlated with development of various microstructures. Fire testing was conducted on 15 mm thick panels with surface exposure of region 100 x 100 mm. The fires rating more than half an hour were achieved with resistance to shrinkage cracking exhibited as important parameter. The microstructure of geo-composite shows large pores towards 600 ºC, that indicated lower in mechanical strength. On increasing the temperature, microstructure of carbon based geo-composite shows oxidized layer and very homogenous layer with less porosity. As a result the mechanical strength increases on increasing the temperature and developing oxidized layer. Fiber reinforced composites may be considered as an alternative to improve flexural strength and fracture toughness at elevated temperature. The carbon reinforced geo-composite proves as one of the suitable candidate for the high temperature applications such as thermal barrier and fire resistant panels.*

**Keywords: Mechanical strength, Geo-composite, Carbon fabric, Geo-polymer, High temperature.**

## 1. Introduction

Materials designed for the high temperature application should withstand for prolonged period of time (Davidovits, 1991, 2008a, 2008b). Geo-polymers are the most promising green and eco-friendly alternatively to cementatious materials due to their proven durability, mechanical strength, and thermal properties with economically lower in cost (Barbosa and MacKenzie, 2003). However, despite these features the poor tensile and bending strengths has been exhibited by the materials due to their brittle nature that leads to the main obstacle at high temperature applications (Pachego-Torgal et al., 2008; Xu, Van, 2000). Fiber reinforced polymer can replace as the better alternative for improved mechanical strength and fire resistant properties with better thermal behavior (Giancaspro et al., 2009, 2010).

This study investigates the effect of various fibers reinforced in a geo-polymer matrix at elevated temperature. High Tenacity (HT) carbon, E-glass and basalt were chosen and several tests have been carried out in order to determine the adhesion of fiber to the matrix and their ability to improve the mechanical, fire testing and thermal properties of the geo-composite.

A correlation between fiber types and the microstructure evolution is investigated for the performance of geo-composite at elevated temperature.

## 2. Methods

Tab. 1 represents the fabrication of geo-composite. Compressive strength testing was conducted on samples (with dimension (3 × 15 × 220 mm) using universal tester TIRA test 2810 (U.K.) and INSTRON model 4202. Firing test was conducted in accordance with the standard ASTM C1314-06. The test was performed in the electric furnace from the temperature varies in the range 200 to 1000 °C with a 25 kW/ $m^2$ heat source for a duration of 30 min. The samples were of dimension 3 × 14 × 90 mm with the

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geo-polymer matrix and with fabric reinforcement volume ratio around 40 %. The surface morphology of the samples was carried out by scanning electron microscope (SEM, ZEISS) with field emission source.

## 3. Results

Based on the following equation, using the value of the deflection, we can calculate the stress, strain and modulus of elasticity of a beam

$$\sigma = \frac{3.P.S}{2.b.t^2} \qquad (1)$$

$$\varepsilon = \frac{6.D.t}{S^2} \qquad (2)$$

$$E = \frac{\Delta\sigma}{\Delta\varepsilon} = \frac{S^3}{4.b.t^3}.\frac{\Delta P}{\Delta D} \qquad (3)$$

where: σ - maximum stress in the outer fiber,

S - support span,

b - width,

t - thickness of the sample,

D - deflection of the beam center,

ε - maximum strain in the outer fiber,

E - modulus of elasticity in bending,

ΔP/ΔD - ratio of force difference and deflection difference at the beam center, measured at the linear segment of the graph.

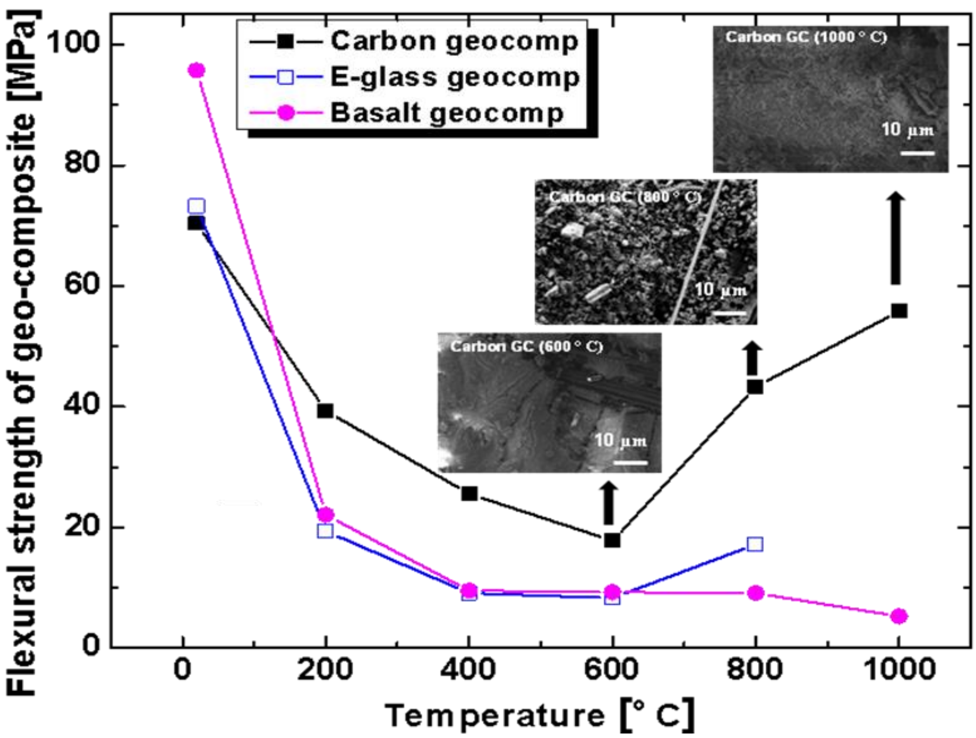


*Fig. 1: Flexural strength of fabric reinforced geo-composite as the function of firing temperature. (Inset: microstructure of carbon fabric reinforced geo-composite with respect to temperature 600, 800, and 1000 °C.).*

*Tab. 1: Fabrication of fabric-in-plane reinforced geo-composite synthesis.*

| **Sample** | **Matrix (polymer) content (Vol. %)** | **Fiber content (Vol. %)** | **Void content (Vol. %)** | **T (°C) (cured)** |
|---|---|---|---|---|
| Carbon GC | 40 | 39 | 21 | 70 |
| E-glass GC | 37 | 41 | 22 | 70 |
| Basalt GC | 45 | 40 | 15 | 70 |

Fig. 1 presents residual mechanical properties of various composites with exposure to different temperature ranges. Carbon reinforced geo-composite maintains the strength at 400 °C. The remaining strength increases with increase in the temperature. This may be attributed towards the good wetting properties exhibited between carbon fiber and polymer matrix. In case of E-glass and basalt fabric, a strong interactionexhibited and dissolution of the fiber inside the geocomposite observed at elevated temperature at 1000 ºC.

## 4. Micro-Structural Evolution

Fig. 1 (inset) shows the microstructure of the geo-composite after fire test around 600, 800 and 1000 °C. After fire test, the porosity enlarges and wettability between the matrix and the fiber varies widely. The gap between the fiber and the matrix increases during the firing due to the shrinkage and dehydration of the moisture from the matrix. Carbon fiber exhibits good adhesion between the fiber and the matrix. Thermal stability in carbon reinforced geo-composite increases with the temperature with increasing the homogenities of the matrix within the fiber distribution. The carbon induced the mechanical strength of the composite with increasing temperature, although some mass loss was observed during the high temperature. After the firing, the binding phase appeared more homogeneous and dense due to the sintering at high temperatures. Oxidized layer creation at elevated temperature prevents further disintegration and degradation of the fabric in carbon based geo-composite.

## 5. Conclusion

Carbon-reinforced fiber was found to have good adhesion properties, being able to control micro-cracks propagation along the matrix and creating a favorable bridging effect. At elevated the temperature carbon reinforced geo-composite exhibited higher strength, better homogenity, and most suitable geo-composite for high temperature application. The creation of oxidized layer improves the bridging and prevents the degradation of fabric. The mechanical strength increases on increasing towards elevated temperature around 1000 °C. Carbon-reinforced geo-composite may be suitable candidate for thermal insulation with wide potential application in industrial fields at elevated temperature.

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