Mechanical property study and analysis of a novel stone-polymer composite material using recycled granite slurry

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Introduction

Waste management of granite stone slurry is a challenge for society, ranging from governments to the factories themselves. Currently, such waste is dumped in open-air sites, which causes many environmental problems. Since Canada and the United States are among the pioneers of granite stone producers in the world, a waste management system for stone slurry is highly demanded in Canada. One solution to reuse such waste is to produce stone composite, which will reduce the production cost of raw materials for a wide range of applications from decoration to automotive industries. So such a product not only would be a solution to effectively manage stone slurry waste but also can bring economic benefit. In this project thermo-mechanical property including elastic and thermal conductivity of this composite was experimentally studied. Some samples of this composite was prepared and tested according to appropriate standards. This investigation provides feasibility study for the potential this kind of composite.

Experimental Method

Mechanical properties of stone composite including tensile, flexural, fracture, thermal conductivity, density, and hardness are reported in this document. Tests are conducted in CRN Lab of the University of British Columbia.

Density values are calculated according to ASTM 792-13. A densimeter is used, which is capable of calculating the weight of samples in the air and in water. Samples are suspended in water without any contact with the support according to the standard. The temperature of water was measured to be 23 ºC.

Tensile and flexural properties including strength and modulus of elasticity are determined through tensile and three point bending test according to ASTM D638-14 and ASTM D790, respectively. According to the standards, the test speed was set to 1 mm/min. The results are presented in the proceeding section. Fracture toughness and fracture energy are also calculated according to the ASTM 1820-16. Samples for fracture test are prepared according to this standard and the test speed of 1 mm/min was adjusted. Thermal conductivity of the stone composite is measured according to ASTM C518 using FOX 50 heat flow meter. Test setup for tensile, flexural, fracture, thermal conductivity and densimeter are illustrated in figure 1. Hardness was tested according to ASTM D2240 using a hardness tester machine.

Results and Discussion

A) Density

The density value is calculated from the following equation as proposed by ASTM 792.

$$\rho(\frac{g}{cm^3}) = \frac{W(g)}{W(g) - W'(g)} \times 0.9975 \quad (1)$$

In which W and W' are the weight of samples in air and water, respectively. Density values of this composite with three different inclusion contents are presented in Table 1, as well as the standard deviation of measurement.

Table 1: Summary of measured composite density

	$v1$	$v2$	$v3$
$\boldsymbol{\rho}$ (g/cm^3)	1.3750	1.4206	1.6390
Standard deviation	0.00596	0.01832	0.00400

B) Tensile properties

Tensile strength and modulus of elasticity are determined through tensile test according to ASTM D638-14. Test sample is depicted in figure 2. Graphs of strength and modulus of elasticity are presented in figure 3 and 4, respectively. Specific values of strength and modulus of elasticity are shown in these figures as well, which demonstrate the normalized values by the density. Data are sorted along the horizontal line in the rest of graphs in this report as the ascending inclusion content.

It was realized that, as the inclusion content increases the stiffness rises and the strength deteriorates. Modulus of elasticity has increased by more than twice and the specific modulus of elasticity has risen by 138%. Strength drops rapidly as a function of inclusion content.

C) Flexural properties

Flexural properties were tested through the three-point bending test with the speed of 1 mm/min according to ASTM D790. It was found that both flexural absolute and specific strengths decrease as the inclusion content increases. On the other hand, the modulus of elasticity increases significantly as a function of inclusion weight fraction.

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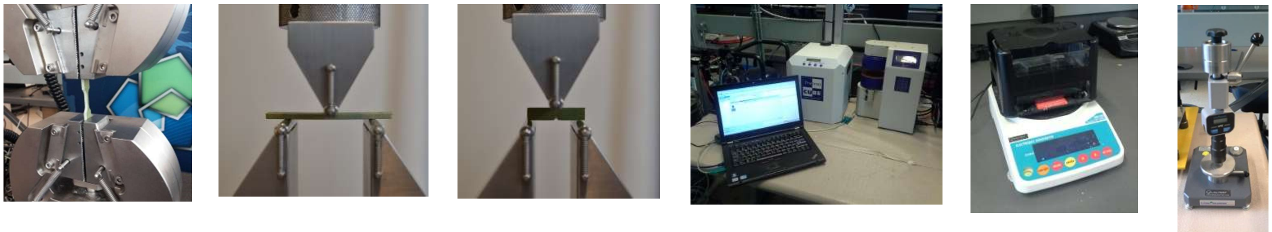

(a) (b) (c) (d) (e) (f)

Figure 1: The test setup for (a) tensile, (b) flexural (c) fracture, (d) thermal conductivity, (e) densimeter, and (f) hardness tests

Figure 2: Tensile test sample

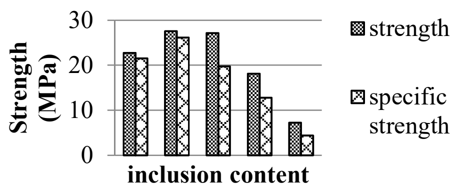

Figure 3: Tensile strength

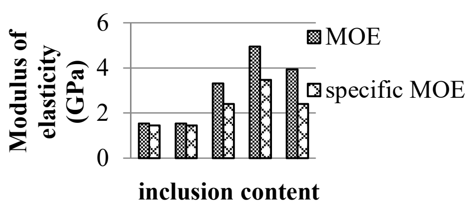

Figure 4: Modulus of elasticity

D) Fracture

According to the test results, it was realized that the fracture toughness decreases by increasing the inclusion content. Fracture energy falls dramatically as the weight fraction of stone increases. Figure 5 illustrates the fracture toughness values.

E) Thermal conductivity

Thermal conductivity and specific thermal conductivities of the composite with different inclusion content is shown in Figure 6. As it can be seen, absolute and specific thermal conductivity increases as the inclusion content of the composite increases.

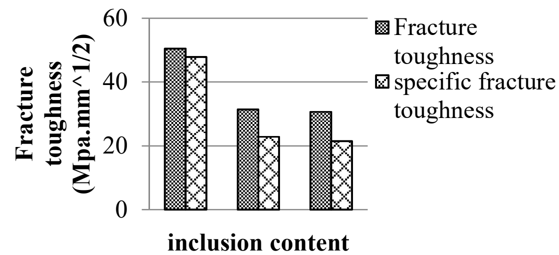

Figure 5: fracture toughness values

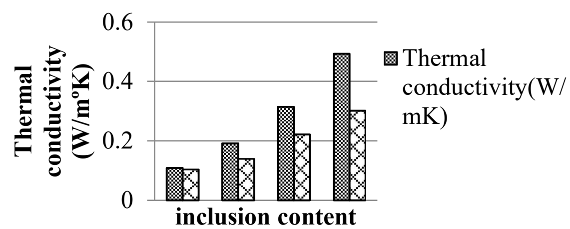

Figure 6: thermal conductivity values

F) Hardness

The hardness value was observed to be constant at 30 Shore and not varying with the inclusion content.

Conclusion

Results indicate that tensile strength decreases with increasing the volume fraction of stone, whereas the stiffness dramatically increases with increasing the percentage of the inclusion. Tensile stiffness doubles with 50%stone and the flexural stiffness also shows the same results. Fracture toughness and energy are significantly affected by the weight fraction; as it is increased, the fracture toughness and energy decrease remarkably. However, the thermal conductivity boosts because of the increase in inclusion weight fraction.

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