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SIZE EFFECTS OF COMPOSTE CEMENT AND FUNCTIONALIZED PLASTIC BEAMS: TOWARDS INCREASED DUCTILITY AND ENERGY ABSORPTION

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Abstract

Polyethylene Terephthalate (PET) plastic particles, having been functionalized using a simple, cost-effective, and scalable treatment technique, presented in patented application 17484834, were used as a cement replacement ingredient in plain cement beams. The functionalization increases the affinity of PET to water, and thus their hydrophilicity, enabling the particles to form bonds with Ordinary Portland Cement (OPC) hydration products. The particles were randomly distributed into cement powder during the mixing process. Size effect beams of 4 different geometrically similar sizes were cast in three different percentages (families) of cement replacement with functionalized PET in notched beams to be tested in three-point bending. Bažant's Type 2 Size Effect Law was used to elucidate the size effects and initial fracture energies (G_f) of all families. The Hillerborg Work-of-fracture method was used to find the total fracture energy (G_F). Preliminary results indicate that beams with adequately bonded PET demonstrated improved ductility, caused by crack bridging, as well as increased i) fracture process zone (FPZ) size, ii) G_f and iii) G_F, compared to reference OPC beams, while closely preserving the bending strength for larger sizes.

1. Introduction

The primary goals of this study are to i) determine what percent of cement replacement with functionalized PET can yield the highest G_F and ii) elucidate the change in fracture properties of OPC beams due to the addition of functionalized PET. To accomplish this, a total of 96 geometrically similar beams of 4 different sizes were cast using 3 different mix families. Each mix family contained 32 beams, 8 from each size. The span to depth ratio of all beams were 4 with depths equaling 13.5, 27, 54 and 108 mm respectively, corresponding to a size range of 1:8. All specimens had an initial notch of length 0.3 times the depth of beam. Three different mix families were cast, including: 1) plain OPC beams (to be used as reference) and two additional families (b & c) made of compositions that yielded the highest G_F.

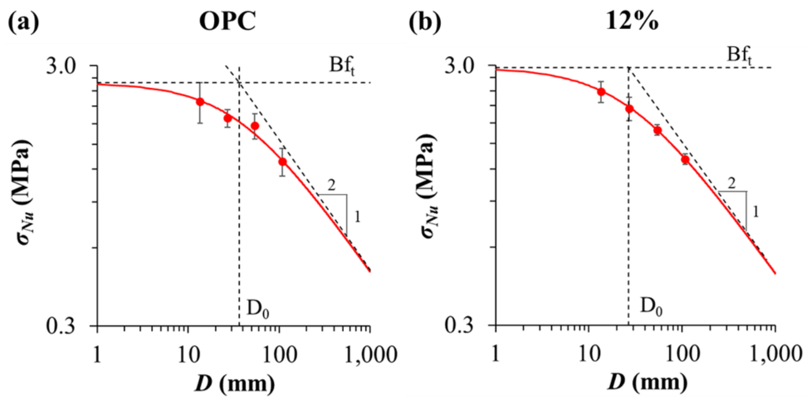
2. Results

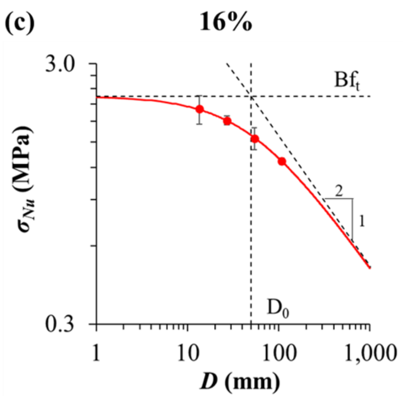
Goal (i) was met by performing a series of tests with 4,8,12,16 and 20% PET replacement and calculating G_F using the RILEM recommendations [1], eq (2). Using just the 3rd largest size beam, the highest improvement in G_F was seen in the beams with 12% & 16% PET (see Figure 1e). These percentages formed families (b & c). All three families were then cast and tested for their size effect behaviors. Measured strength data (σ_{Nu}) of the beams agreed well with type 2 size effect law [2–4] as shown in Figure 1(a-c). Size effect parameters were calculated by optimum fitting of the mean σ_{Nu} values. G_f was found using:

$$G_f = \frac{(Bf_t')^2 D_0 \; g(\alpha_0)}{E'} \tag{1}$$

$$G_F = \frac{W_F}{bD\,(1-\alpha_0)} \tag{2}$$

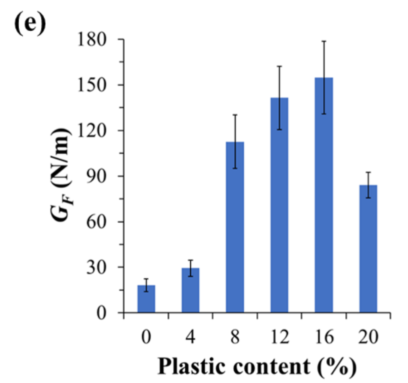
Preliminary results showed that addition of PET improves the initial and total fracture energy. Total fracture energy were improved to 7.7 and 8.4 times that of OPC with the addition of 12 & 16% PET. Similarly, improvement in initial fracture energy were 1.4 and 2.5. Increase in the energy absorption capacities showed an improvement in ductility of the beams.





(d)

Plastic content (%)	D mm	σ_{Nu} MPa
0	13.5	2.19
	27	1.89
	54	1.76
	108	1.29
12	13.5	2.38
	27	2.05
	54	1.70
	108	1.31
16	13.5	2.01
	27	1.82
	54	1.55
	108	1.27



(f)

Plastic content (%)	G_f N/m	G_F N/m	G_F/G_f N/m
0	15.6	18.3	1.2
12	21.9	141.4	6.5
16	39.0	154.9	4.0

Figure 1: (a-c) Size effect plots for varying PET %, (d) Mean nominal strength (σ_{Nu}) for each family of beams (e) Total fracture energy of beams with varying plastic content and (f) fracture energies G_f and G_F.

3. Conclusions

Functionalized PET bonded to the cement enables stress transfer (bridging) across crack faces, allowing the beams to absorb more energy before total failure. The PET also improves the initial and total fracture energy of the beams, thus increasing their energy absorption capacity and ductility.

Acknowledgements

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