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Discussion: Effect of strain rate on splitting tensile strength of geopolymer concrete

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Contribution by Martí-Vargas

The discussed paper (Feng *et al.*, 2014) presents test results on the effects of strain rate on the splitting tensile strength (f_t) of geopolymer concrete (GC) and geopolymer mortar (GM). Three GC mixes based on sodium (NaGC), potassium (KGC) and sodium/potassium (Na/KGC), one sodium-based GM (NaGM) and one ordinary Portland cement (OPC) concrete mix were tested at strain rates of 10^{-7} to 25/s. The dynamic increase factors of f_t (DIF_{ft}) were measured and compared using the equations proposed by Malvar and Ross (1998), which were found to underestimate the DIF_{ft} for GC. The authors should be complimented for producing this interesting paper, which provides new equations for GC. This is acknowledged by the discusser, who would like to offer some comments for the authors' consideration and response.

Regarding the references cited in this paper, the discusser would like to point out that ACI 318-08 (ACI, 2008) and the CEB-FIP Model Code 1990 (CEB, 1993) are referenced by the authors, whereas there are later editions that were available prior to the paper submission date. In particular, equations for DIF_{ft} according to Model Code 2010 (FIB, 2010) are not included, whereas the modified CEB recommendations (CEB, 1993) by Malvar and Ross (1998) are presented and used for comparison purposes. The equations in the aforementioned sources are similar in structure, but they differ in some parameters and in the threshold of strain rate considered, which is 30/s in Model Code 1990, 1/s in Malvar and Ross (1998) and 10/s in Model Code 2010.

The authors stated that, under a high strain rate loading (5–25/s), GC and OPC show similar values of DIF_{ft}. However, Figure 6 shows DIF_{ft} values of around $3 \pm 0{\cdot}5$ for OPC, 2–5 for NaGC, around $5 \pm 0{\cdot}5$ for KGC and 3–5 for Na/KGC. Therefore, it seems that there is a general trend for GC to reach greater DIF_{ft} values, and even greater for GM (from 4 to 6). Also, in Figure 6, for all cases the predictions by Malvar and Ross (1998) were shown for comparison purposes. The discusser is confused about the apparent bilinear shape seen beyond a strain rate of 1/s, which it seems does not correspond to the power function according to the modified CEB recommendation based on Equation 2.

The typical failure modes of NaGC are shown in Figure 8, some of them for a strain rate loading of 25/s. However, the discusser notes that this strain rate does not appear in Figure 7(a). Perhaps the highly stressed volume (HSV) parameter (Martí-Vargas, 2014) could be used for complementary analyses.

Authors' reply

The authors thank Professor Martí-Vargas for his comments on the discussed paper. The points mentioned in the discussion are important and worthy of clarification.

(1) In the discussed paper, the so-called modified CEB recommendations proposed by Malvar and Ross (1998) were adopted for comparison purposes. These modified CEB recommendations have been widely accepted and documented in the literature. In contrast, validations and applications of the Model Code 2010 FIB (2010) recommended by the discusser are still relatively limited. Therefore, the modified CEB recommendations were used in the discussed paper.
(2) The authors agree that there is a general trend to reach greater DIF_{ft} values for GC, and even greater for GM, when compared with the modified CEB recommendations. However, the sample size of the geopolymer specimens tested was very limited, and further tests are expected to confirm this trend.
(3) As shown in Figure 6 in the discussed paper, beyond 1/s the continuous power function is discretised into two data points (strain rates 10 and 100/s) and connected with a linear function for simplicity. Figure 6(a) is reproduced as Figure 9 in this reply. The solid line is the power function according to

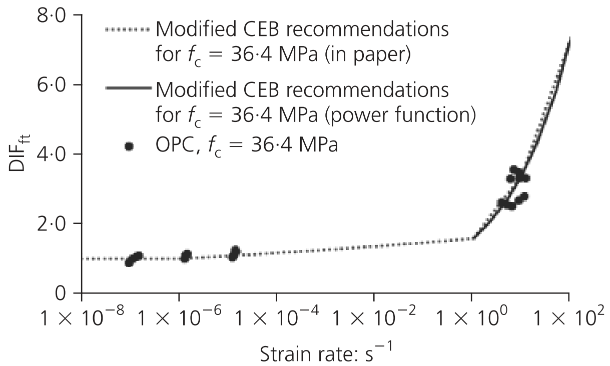

Figure 9. Reproduction of Figure 6(a) with the power function curve

the modified CEB recommendation. It can be seen that the power function and the bilinear curve are identical at strain rates of 10 and 100/s.

(4) As stated in the paper, three strain-rate ranges were defined: below 10^{-7}/s for quasi-static loading, 10^{-6} to 10^{-5}/s for lower strain rate loading, and 5 to 25/s for high strain rate loading. As the failure modes were similar in each loading condition, the upper limits of each strain-rate range (10^{-7}, 10^{-5} and 25/s) were chosen to represent different loading conditions in the caption to Figure 8.

(5) An interesting comment raised by the discusser relates to the highly stressed volume (HSV) approach. One of the concerns about this approach is the definition of HSV, which appears to be strain-rate dependent, as shown in Figure 8 in the discussed paper. Further research is needed to examine the application of HSV over a wide range of strain rates.

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