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Discussion: Mechanical behaviour of different types of concrete under multiaxial compression

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The discussed paper presents an experimental comparative study into the strength of several concrete types under multiaxial (biaxial and triaxial) compression loading at different stress ratios by using the same testing machine and the same friction-reducing measure in all cases (Shang and Ji, 2014).

The authors should be complimented for producing this detailed paper, which provides theoretical and experimental foundations for strength analysis of concrete structures. This is acknowledged by the discusser, who would like to offer some comments for the authors' consideration and response.

The discusser is confused about the sign criteria and notation used by the authors. On the one hand, the authors detailed that the relationship of principal stresses is $\sigma_1 \geq \sigma_2 \geq \sigma_3$ (compression denoted as positive), whereas it seems that all stress ratios are referred to σ_3, and σ_1 has not always been applied, which would correspond to $\sigma_1 \leq \sigma_2 \leq \sigma_3$. On the other hand, triaxial compression stress ratios are expressed as $\alpha = \sigma_1$: σ_2: σ_3, and biaxial compression stress ratios are determined as $\alpha_2 = \sigma_2/\sigma_3$ and expressed as $\alpha_2 = \sigma_2$: σ_3 or as $\alpha_2 =$ 'number'. In the last case, the 'number' is the result of σ_2/σ_3, and individual information about σ_2 and σ_3 is not included. Besides, a designation $\alpha_1 = \sigma_1$: σ_3 is also used, but it seems this does not represent a biaxial loading condition tested. Perhaps the consideration of direction 1 as the reference to establish the stress ratios, together with the consistent use of the $\sigma_1 \geq \sigma_2 \geq \sigma_3$ relationship, would allow a better understanding.

The authors stated that, for concrete under triaxial compression with $\alpha_1 = 0{\cdot}1{:}1{\cdot}00$, the tensile strain will be caused in the σ_1 direction under the common action of σ_2 and σ_3 when $\sigma_2 > 0{\cdot}5\sigma_3$. However, in the discusser's opinion, this cannot be stated based only in terms of stress ratio. Poisson ratio, which is a measure of the Poisson effect in terms of negative strain ratio (transversal–lateral as opposed to longitudinal–axial), should also be considered. Poisson ratio value depends on several factors such as concrete type, specimen size and shape, and loading conditions, among others. Therefore, the discusser believes that it is possible that a tensile strain may be caused in the σ_1 direction under the common action of σ_2 and σ_3 for σ_2 values of less than $0{\cdot}5\sigma_3$.

Finally, the authors concluded that, for different types of concrete, the difference in increase of multiaxial (biaxial and triaxial) compressive strength over uniaxial compressive strength (UCS) can be attributed to differences in concrete composition. However, the proposed Equation 1 does not include any specific parameter in this sense. As a result, some inconsistencies can be observed in Table 6: values of b decrease when the water to cement (w/c) ratio of normal concrete types NC increases (UCS decreases), whereas values of a present a maximum for the intermediate w/c ratio or UCS; and contrarily, values of a decrease when the UCS of wet-screened concrete types increases, whereas values of b present a maximum for the intermediate UCS.

Authors' reply

The relationship of principal stresses is $\sigma_1 \leq \sigma_2 \leq \sigma_3$ (compression denoted as positive); biaxial compression stress ratios are determined as $\alpha_2 = \sigma_2/\sigma_3 = \sigma_2$: $\sigma_3 =$ 'number'; $\alpha_1 = \sigma_1$: σ_3 does not represent a biaxial loading condition tested, but only represents the ratio of the stress σ_1 and σ_3.

The discussion that, for concrete under triaxial compression with $\alpha_1 = 0{\cdot}1{:}1{\cdot}00$, the tensile strain will be caused in the σ_1 direction under the common action of σ_2 and σ_3 when $\sigma_2 > 0{\cdot}5\sigma_3$ is obtained according to the experimental data in Table 2, or the discussion is used to explain the experimental data in Table 2.

The proposed Equation 1 was used to express the relationship between stress ratio $\beta = \alpha_2 = \sigma_2$: σ_3 and σ_3/f_c of a certain kind of concrete. *a* and *b* are regression coefficients. In other words, for other types of concrete the proposed Equation 1 is applicable, but *a* and *b* will change with different types (*w*/*c* ratios) of concrete.

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