Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 83 (1999)

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DOI: https://doi.org/10.5169/seals-62888

Size Effect in Concrete Structural Members

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Summary

This paper reviews some recent theoretical and experimental results on the size effect in brittle failure of concrete structures caused by the release of stored energy. The fracture mechanics size effect for geometrically similar structures is simulated in a numerical model developed by the first author. The example presented shows the importance of the size effect in concrete design. In the conclusions, the authors refer to some revisions that should be taken at the Brazilian concrete design code.

Keywords: concrete; fracture mechanics; numerical modeling; plasticity; size effect.

Abstract

The size effect is generally ignored by the current design codes, but recent tests have shown it strong enough to be considered in projects involving large structural members. Most of the recent experimental tests on size effect were conducted by Bazant at the Northwestern University [2]. The tests have been carried out in order to overcome the limitations of previous experimental evidence found in literature.

The size effect phenomenon can be represented by theoretical models that account for the dissipation of strain energy into the fracture process zone. In this study it was used a 2D numerical model developed by the first author[4] that combines finite element analysis routines with interactive computer graphics. The concrete behavior is modeled through the energy-based plasticity formulation of Pramono and William [5]. This formulation covers the full load-response spectrum of the concrete behavior in tension as well as in compression. The concrete model is based on the non-associated flow theory of plasticity, with hardening in the pre-peak regime and fracture energy softening in the post-peak regime.

A numerical simulation was carried out for the three-point symmetric notched beams of various sizes, tested experimentally by Bazant and Pfeiffer [3]. The beams are geometrically similar with the same mesh configuration. The ultimate loads were obtained for the characteristic dimension of the structure d equals to 38, 76, 152 and 304 mm. The material fracture parameters and the width of the fracture process zone were adjusted in the constitutive model in order to obtain the finite element fit over the test data. In Figure 1, the results of the finite element analysis are compared with the mean experimental results obtained by Bazant and Pfeiffer. The nominal stresses were calculated as a strength parameter, using the elastic stress formula ($\sigma_N = 3.75\ P_{max} / b\ d$, *where* P_{max}

is the maximum concentrated load at midspan). The analytical results, obtained substituting the material parameters in an equation that relates the nominal stress to the characteristic dimension of the structure, are also plotted in Figure 1. The plotted values indicate a good agreement between the results.

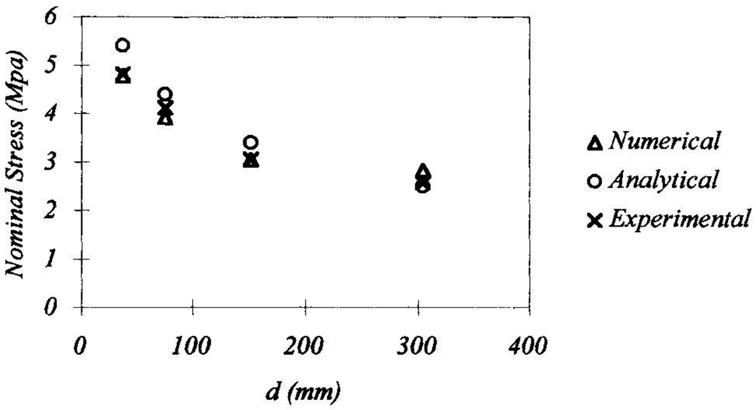

Fig. 1 Results on size effect for three-point bend notched beam

The results show that with the appropriate adjustment of the fracture parameters, the size effect phenomenon can be adequately represented by numerical models that account for the dissipation of the fracture energy.

The size effect should be taken for further development on the Brazilian concrete design code, as it has been done into the ACI Code and CEB-FIB Model Code. An example for code revision can be suggested concerning the minimum tension reinforcement specified in section 6.3.1 of the Brazilian code NBR-6118 [1]. According to the results presented, the minimum reinforcement ratio of 0.0015 specified for CA-50 and CA-60 bars is not sufficient for larger structures, and this value should be revised based on experimental evidences. This example shows that the code must exhibit the transitional size effect between plastic limit analysis and linear elastic fracture mechanics.

References

[1] ABNT, *NBR-6118 - Projeto e Execução de Obras de Concreto Armado*, 1980, 76 pp.

[2] Bazant Z. P., "Should Design Codes Consider Fracture Mechanics Size Effect," *Concrete Design Based on Fracture Mechanics ACI SP-134-1*, 1992, pp. 1-23.

[3] Bazant Z. P., and P. A. Pfeiffer, "Determination of Fracture Energy from Size Effect and Brittleness Number," *ACI Materials Journal*, Vol. 84, Nov.-Dec. 1987, pp. 463-480.

[4] Einsfeld R. A., A. E. Elwi, T. N. Bittencourt, and L. F. Martha, "Numerical Simulation of Fracturing in Concrete Structures Using a Combination of Smeared and Discrete Approaches," *International Journal of Rock Mechanics and Mining Sciences*, Vol. 34, No. 3-4, 1997, pp. 552.

[5] Pramono E., and K. Willam, "Fracture Energy-Based Plasticity Formulation of Plain Concrete," *ASCE Journal of Engineering Mechanics*, Vol. 115, No. 6, 1989, pp. 1183-1204.