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On dissipated energy density in compression for concrete

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Abstract

An experimental investigation on drilled cylindrical concrete specimens in compression over a large scale range (1:19) has been carried out to evaluate the variation of some mechanical parameters by varying specimen size. The peculiarity of the present investigation consists in exploring very small specimen dimensions. The experimental results show scale effects on dissipated energy density rather than on uniaxial compressive strength. A theoretical explanation for such a phenomenon, based on fractal hypothesis, is presented and a comparison between experimental and theoretical values is discussed.

Keywords: Fracture mechanisms; Powder compaction; Concrete; Structures; Mechanical testing

1. Introduction

The advent of computers has considerably changed the capabilities in design and analysis of concrete structures. The extensive use of powerful computers and finite element codes in structural analysis is meaningful only if suitable and reliable constitutive laws for the material are available. In design, however, concrete is generally classified on the basis of its compressive strength. A correct evaluation is therefore fundamental.

In general, the constitutive relations and the mechanical parameters for concrete are obtained from standard specimens. The sizes and shapes of compressive strength test specimens of concrete vary from one country to another. Commonly used standard sizes are 150 mm for cubes and 150×300 mm for cylinders. The introduction of high-strength concrete, with compression strength up to five times the standard strength, suggests the use of smaller specimens, with the advantages of maintaining the standard test machines available in the laboratories, easy handling, and using less concrete. Another important application of reducing specimen sizes is constituted by the determination of the concrete strength for existing structures by drilling small specimens. This technique is very useful, the deterioration of the mechanical properties for concrete structures being one of the main problems in civil engineering.

The choice of the standard size is affected by the variation of the compressive strength with size and height/diameter (or slenderness) ratio. This variation is high when the rigid test machine platens are in direct contact

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Nomenclature

δ	displacements
ϵ	strain
ϵ_{peak}	strain at the peak stress
d	specimen diameter
h	specimen height chosen as the characteristic specimen size
ϵ_m	mean deformation
f'_c	compression strength
C1	smallest specimen set with $h = 10$ mm
C2	specimen set with $h = 23$ mm
C3	specimen set with $h = 46$ mm
C4	specimen set with $h = 100$ mm
C5	largest specimen set with $h = 190$ mm
C33	third specimen of the set with $h = 46$ mm
N	number of fragments in fragmentation process
r	characteristic linear dimension of fragments
B	constant of proportionality
D	fractal dimension of the fragmentation process
V_f	total volume (mass) of fragments
r_{max}	characteristic linear dimension of the largest fragment
r_{min}	characteristic linear dimension of the smallest fragment
k	constant of proportionality
V	volume of the un-fragmented specimen
A_f	total surface area of the fragments
C	geometrical factor depending upon the average shape of the fragments
W	energy dissipated to produce a new free surface in the fragmentation process
β_F	specific energy absorbing capacity
$\mathcal{G}$	elastic energy release rate or specific energy necessary to generate the unit area of fracture
d_ω	fractal dimension of the fragmented set = 3-D
h^*	measure of the fractal set representing the fragmented configuration
S	dissipated energy density
$\mathcal{G}_F^*$	fractal dissipated energy density parameter
ϵ^*	renormalized fractal strain
E^*	renormalized fractal elastic modulus

with the concrete specimen,the lateral deformation of concrete being restrained at the specimen ends. A wide investigation has been carried out by Carpinteri et al. [1].

Very interesting results have been obtained in a round robin test organized by the RILEM Committee 148 SSC "Strain-Softening of Concrete" [2], whose aim was to investigate the softening behavior of concrete by varying specimen dimensions, boundary conditions, feed-back signals and testing machine characteristics. They observed the independence of the slenderness (or size) on the compressive strength, when the boundary conditions of the concrete specimens were characterized by no friction (or reduced friction) at the ends.

The effect of size on the mechanical properties of concrete is also important when small scale models are used to predict the behavior of real structures. Early work on the size effect in compression dates back to the 1920s. Gonnermann [3] emphasized the size effects through an extensive investigation on the compressive strength of cylinders with a height/diameter ratio equal to two.

Many other authors fronted the problem of size effects on nominal strength for concrete in compression. Blanks and McNamara [4] performed tests on cylindrical specimens with slenderness of $h/d = 2$ in a large scale