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DEGRADATION OF ELASTIC MODULUS IN CONCRETE DURING CYCLIC COMPRESSION TESTING

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1. Introduction

Concrete is a heterogeneous quasi-brittle material whose response under cyclic compressive loading is characterized by nonlinear stress–strain behavior, residual strain accumulation, and progressive stiffness degradation. Previous studies have shown that repeated compressive loading produces stress–strain hysteresis loops, whose shape reflects the development of irreversible deformation and internal damage in concrete [1–3]. These effects are commonly associated with the initiation and propagation of microcracks in the cement matrix and at the aggregate–cement paste interface.

The degradation of stiffness can be interpreted within the framework of damage mechanics, in which the reduction in elastic modulus is related to the evolution of a damage variable [4]. The aim of this paper is to present a brief experimental analysis of the cyclic compressive response of concrete, with particular attention to hysteresis loops, energy dissipation, residual deformation, and stiffness degradation.

2. Experimental setup and testing programme

Concrete specimens were tested under cyclic compression using a MATEST servo-controlled compression testing machine. The specimen was placed between two steel compression platens, as shown in Fig. 1. During the test, load, deformation, time, axial strain, and lateral strain were

continuously recorded by the data acquisition system.



Fig. 1. Concrete specimen during compression testing

The main parameters of the experimental setup and testing programme are summarized in Table 1.

Table 1. Main parameters of the cyclic compression test

Parameter	Value
Testing machine	MATEST servo-controlled compression testing machine
Cross-sectional area, A_0	22500 mm ²
Axial gauge length, l_0	50 mm
Lateral gauge length	50 mm
Control mode	Displacement control
Recorded data	Load, deformation, time, axial and lateral strain

The stress and axial strain were calculated, according to Eq. (1) and Eq. (2), as:

$$\sigma = \frac{F}{A_0}, \quad (1)$$

$$\varepsilon = \frac{\Delta l}{l_0} \quad (2)$$

where F is the measured load, A_0 is the initial cross-sectional area of the specimen, Δl is the measured deformation, and l_0 is the initial gauge length.

For a quantitative assessment of stiffness degradation, the elastic modulus was evaluated for each loading cycle using the slope of the corresponding stress–strain response, according to Eq. (3):

$$E_i = \frac{\sigma_{i,\max} - \sigma_{i,\min}}{\varepsilon_{i,\max} - \varepsilon_{i,\min}} \quad (3)$$

Based on the obtained modulus values, the damage variable D_i was calculated as a measure of elastic modulus degradation, according to Eq. (4):

$$D_i = 1 - \frac{E_i}{E_{ref}} \quad (4)$$

where E_i is the elastic modulus in the i -th loading cycle, and E_{ref} is the reference modulus. The reference modulus was taken as the maximum stabilized modulus obtained during the initial loading cycles.

3. Results and discussion

The experimentally obtained stress–strain response of the concrete specimen under cyclic compression is shown in Fig. 2. The diagram shows the formation of hysteresis loops during loading and unloading. The area enclosed by each loop represents dissipated mechanical energy, which is mainly associated with internal friction, microcrack development, and progressive damage of the concrete structure.

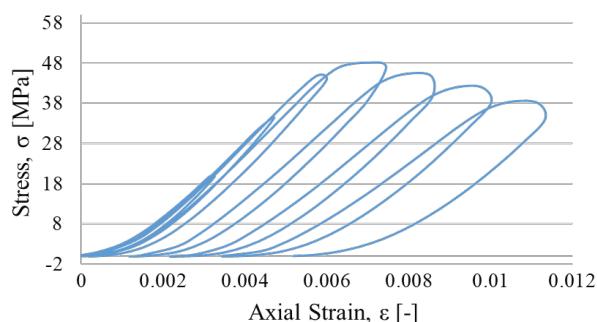


Fig. 2. Stress–strain hysteresis loops

A gradual shift of the stress–strain loops towards higher strain values indicates residual strain accumulation after unloading. During cyclic loading, the maximum axial strain increased up to approximately 0.011, while the peak stress decreased from about 48 MPa to about 38 MPa, indicating material softening. The change in the slope of the loading and unloading branches

confirms progressive stiffness degradation of concrete.

The degradation of elastic modulus was further evaluated through the damage variable D_i , calculated using Eq. (4). The evolution of D_i with loading cycle number is shown in Fig.3.

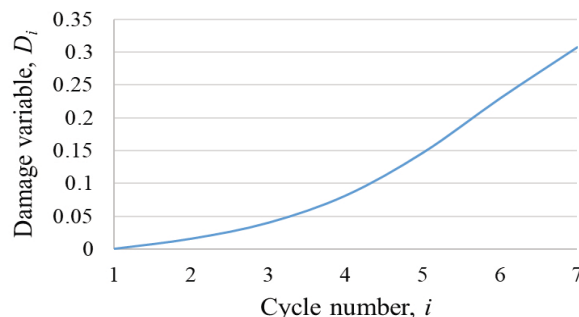


Fig. 3. Evolution of damage variable D_i during cyclic compression

The obtained trend confirms that elastic modulus degradation becomes more pronounced in the final loading cycles, which is consistent with the observed softening of the stress–strain response.

4. Conclusions

This paper presented a short experimental analysis of the cyclic compressive response of concrete. The stress–strain diagram showed pronounced hysteresis loops, confirming energy dissipation, residual strain accumulation and material softening during loading and unloading. The evolution of the damage variable D_i confirmed progressive degradation of the elastic modulus during cyclic compression, with more intensive damage accumulation in the final loading cycles.

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