Laboratory Tests vs. FE Analysis of Concrete Cylinders Subjected To Compression

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Abstract. This paper presents the results of laboratory tests and a finite element (FE) analysis of concrete cylinders subjected to compression. The laboratory tests of concrete elements were conducted to determine the secant modulus of elasticity and a nonlinear stress-strain relationship for concrete. This relationship was used to validate the numerical model of the concrete cylinders subjected to compression. The comparison between the numerical and experimental results demonstrates that the adopted 3D model can capture the response of the concrete cylinders subjected to compression fairly well.

1. INTRODUCTION

The concrete damaged plasticity (CDP) model is often used to capture the behaviour of concrete. Jankowiak and Łodygowski presented the laboratory tests, which are necessary to identify constitutive parameters of this model [1, 2]. Kmiecik and Kamiński discussed the parameters needed to correctly model concrete using the CDP model [3]. Jankowiak and Madaj used this model for the analysis of a steel-concrete composite beam [4].

2. LABORATORY TESTS

The concrete cylinders were tested in accordance with the principles set out in the standards [5, 6] using the Instron 8500 Plus test machine, extensometers and strain gauges. Table 1 presents the results of these tests.

TABLE 1. Set of concrete samples, measured mean values

Parameter	Measured mean value
Initial secant modulus of elasticity $E_{c,0}$ [GPa]	33.51 ± 1.53 (4.58 %)$^{+}$
Stabilised secant modulus of elasticity $E_{c,S}$ [GPa]	37.33 ± 1.44 (3.86 %)$^{+}$
Compressive cylinder strength f_c [MPa]	61.82 ± 3.85 (6.22 %)$^{\#}$
Poisson's ratio v [-]	0.19 ± 0.03 (15.24 %)$^{+}$
Tensile strength of the concrete f_{ct} [MPa]	4.61 ± 0.75 (16.19 %)*
Compressive strain in the concrete at the peak stress e_{c1}[‰]	2.23 ± 0.52 (23.27 %)*

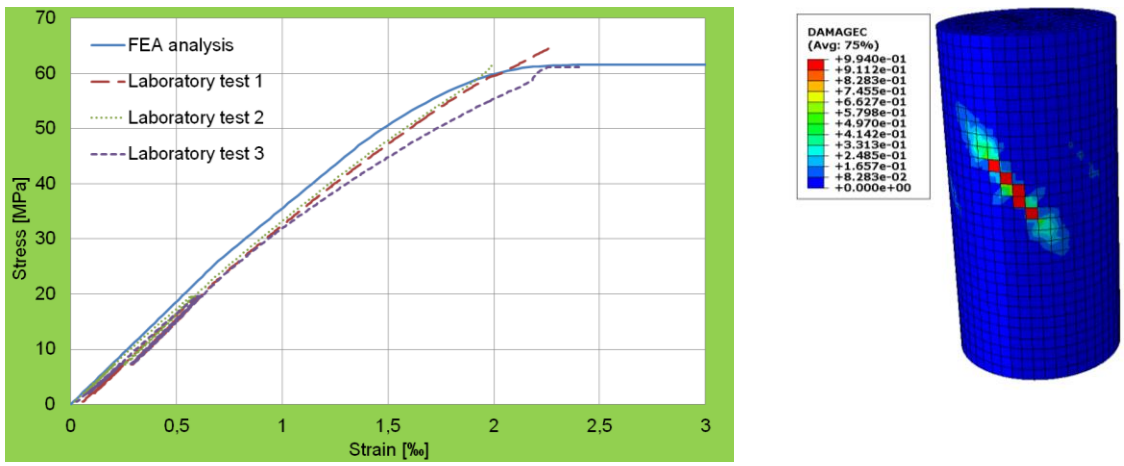
Measurement errors were calculated according to Student's t-distribution using *2, $^{+}$3 or $^{\#}$4 degrees of freedom and a confidence level of 0.95.

3. NUMERICAL MODEL

The authors of this paper prepared numerical models of the concrete cylinder in the Abaqus program. They divided the concrete cylinder into 8100 C3D8R linear hexahedral elements. The size of the mesh was 10 mm. The calculations were performed using the Newton-Raphson method. The dead load of the concrete cylinder was neglected. The displacement in three directions was blocked at the bottom of the cylinder. The stress-strain diagram for the analysis of the concrete subjected to compression was adopted from [7], and the stress-strain diagram for the analysis of the concrete subjected to tension was taken from [3]. The compressive strength, the tensile strength, and the secant modulus of elasticity of concrete, and the compressive strain in the concrete at the peak stress were based on own laboratory tests. The value of the fracture energy and the critical crack opening were calculated using the formulas presented in [8-10].

4. RESULTS

Figure 1 presents the results from the tests and the numerical analysis.



(a) (b)

FIGURE 1. Results: a) the nonlinear stress-strain relationships obtained from the laboratory tests and the FE analysis b) the concrete compression damage parameter D_c for the strain of 2.87 ‰.

The adopted 3D model captured the response of the concrete cylinders fairly well.

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