Numerical analysis of fibre reinforced slabs under impact loads

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Abstract

The paper concerns the numerical analysis carried out on finite element models of circular plates made of fibre reinforced concrete with brick rubble aggregate. Adequate experimental tests have been performed in order to study the dynamic response of such plates to impact loads. Numerical models have been validated on the basis of experimental results, especially the description of material behaviour, contact between impacting weight (40 or 200 kg) and external surface of the plate, as well as contact between supports and concrete plate. The main scope of this study was to describe the damage mechanisms in plates with unconventional aggregate and reinforcement.

Keywords: impact loads, fibre reinforced concrete, rubble aggregate, numerical analysis

1. Introduction

The growing demand for concrete elements and structures meets with the limited resources of natural gravel, which is difficult to purchase in many regions of Poland. On the other side there is still an increasing volume of rubble produced due to wastes in production, demolitions, modernisation or other similar works carried out all over the country. Major part of this waste materials are used as the subsoil or base in roadworks or other civil engineering applications.

This waste material can be also applied as the substitute of natural gravel aggregate. Adequate addition of steel fibres increases the resistance of structural elements made of such a concrete, especially for impact loads.

Experimental tests performed on the series of circular plates subjected to impact loads allow to build and verify the adequate numerical models in Abaqus/Explicit environment. This also enables to define the best recipes (percentage of fibres, fractions of brick rubble, etc.) for concrete, in order to obtain the economic material, resistant to impact loads [1,2].

2. Experiments

The experimental tests have been performed on the series of circular plates (diameter 1 m, thickness 0.1 m), supported on three small areas spaced equally on the external circumference.

Impact loads have been realized by a free fall of weight 40 kg or 200 kg from various heights (from 0.2 to 1.0 m), in order to study the whole process of propagation of damages in the plate, from initial permanent deflections without cracks dividing the plate, to the total damage of the plate (see Fig. 1). Two different weights were applied due to the fact that for higher percentage of fibres and certain fractions of rubble aggregate the resistance of plates was too high and needed higher values of kinetic energy of the impacting weight, impossible to obtain using the smaller weight (40 kg).

Additionally the series of static tests on concrete samples have been carried out in order to define the basic characteristics of the material, with or without the addition of fibres. Also in this case the adequate numerical analyses were performed to check out the assumed material models.

Figure 1. The overall view of an example of the plate after the experimental test. In this case the total damage of the plate has been produced due to the impact of 40 kg weight from 1 m.

3. Numerical analysis

In this study the numerical analysis has a fundamental importance, due to the limited number of experimental tests possible to realize. The number of combinations between fibre percentage, fractions of rubble aggregate, water and sand volume in the mixture is very large – it is not possible to check experimentally the whole matrix of combinations.

Because of this, the discrete models of tested plates were built in the Abaqus/Explicit environment. To describe adequately the entire phenomenon of impact of the weight dropped from a certain height on the surface of the plate the contact algorithm available in Abaqus/Explicit has been applied.

The crucial factor in this analysis is the assumed material model for the concrete. On the basis of former studies [3-5] the CDP (Concrete Damaged Plasticity) model has been assumed also in this case with necessary calibration of parameters, allowing to capture the specific features of this kind of concrete (increased resistance in pure tension, etc.).

The examples of results are presented in Fig.2, for two analyses of two different configurations of plates.

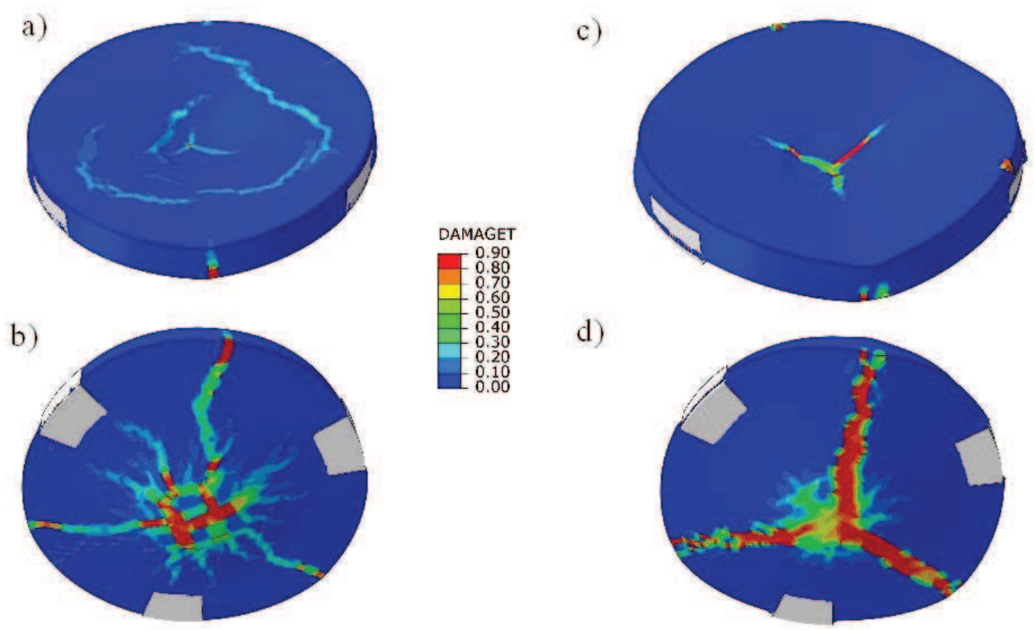

Figure 2: a) plate without fibres, impact of 40 kg (height 0.25 m) – upper view , b) bottom view;
c) plate with fibres, impact of 200 kg (height 0.25 m) – upper view; d) bottom view

Analysis of damages obtained for various configuration of plates (material and impact load intensity) shows the reduction of large crack zones for higher amount of fibres, the damages are distributed in large zones between supports. Also in this case the permanent deflections measured in the centre of the plate are smaller than for the plates without fibres or with low amount of fibres.

In the case of multiple loads exerted on the plate (i.e. many impacts with relatively low level of kinetic energy), also numerical analysis has been performed in many steps with repeated impacts and accumulated damages.

4. Conclusions

This study shows the necessity of experimental verification for numerical analysis performed with the use of advanced nonlinear finite element algorithms. Among many important factors for such analysis the assumption of adequate material model for concrete describing the entire dynamic response: from initial pure elastic behaviour until the total material damage is the most important factor for the adequacy of numerical results.

For lower values of fibre percentage in the material, the localization of large cracks has been observed. In this case the application of XFEM (eXtended Finite Element Method) is now under investigation in Abaqus/Standard environment.

The expected results of this investigation are not only limited to prepared recipes for the concrete, but also concern the elaborated and calibrated material models, applicable in nonlinear finite element computer codes.

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