DANUBIA ADRIA

36th Danubia-Adria Symposium on Advances in Experimental Mechanics

24–27 September 2019, Plzeň, Czech Republic

FACULTY OF APPLIED SCIENCES UNIVERSITY OF WEST BOHEMIA

FRACTURE SURFACE OF NORMAL STRENGTH CONCRETE UNDER VARIOUS LOADING RATES

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1. Introduction

The aim of this paper is to compare the fracture areas of normal strength concrete that were subjected to various loading rates. The main objective of this paper is a presentation of measured data, which can be used to determine the speed of the applied loadings using reverse engineering. The main hypothesis is that under quasi-static loading the cracks have time to propagate along the path of least energy consumption i.e., around aggregate particles and through the weakest zones of the matrix (Figure 1a) while under impact loading the crack are forced to develop along straight paths throughout the stronger matrix zones and some aggregate particles (Fig. 1b) leading to the higher measured strengths and lower superficial area [1].

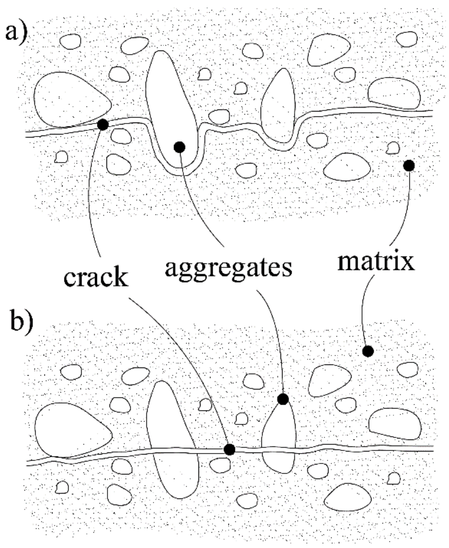

Fig. 1. Crack propagation through NSC.
a) quasi-static loading; b) increased rate loading.

2. Theoretical background

Strain rate $\dot{\varepsilon}$ can be defined as the strain that is applied to the structure over the time (Eq. 1). Unit of this value is second to the minus first (s^{-1}). The strain rate can be, therefore, defined as follows:

$$\dot{\varepsilon} = \frac{d\varepsilon}{dt} = \frac{d}{dt}\left(\frac{l-l_0}{l_0}\right) = \frac{1}{l_0}\frac{dl}{dt} = \frac{v}{l_0} \qquad (1)$$

where l is the length of the specimen after the loading was applied, l_0 is the initial length of the specimen and v is the speed of loading (mm/s). It is a well-established fact that both tensile and compressive strength increase with incrasing strain-rate [2]. This phenomenon is quantified via the dynamic increase factor (DIF), which expresses the ratio of strength measured under increased strain rate loading conditions to the strength measured under quasi-static loading conditions. It is also known that tensile mechanical properties are more sensitive to the strain rate in comparisson to the compressive mechanical properties [3].

3. Experimental part

Concrete prismatic specimens 100 mm × 100 mm × 400 mm in size were subjected to the three-point bending tests under various loading rates ranging from quasi-static to impact. Quasi-static loading rates were realized by hydraulic loading machine and impact loading was performed by using an impact pendulum device [4]. The impactor mass was 37 kg and its head was round with a diameter of 50 mm. Support rollers with a diameter of 50 mm were used, which are similar as for quasi-static loading in order to eliminate differences arising from diffrerent support or loading geometry. From each test, both halves of the prisms were scanned by the 3D laser scanner (Fig. 2) and evaluated in the graphics programme. For every loading rate, at least 16 superficial areas were evaluated. Normal strength concrete with a target compressive strength of 37 MPa was used with a maximal aggregate size of 8 mm.

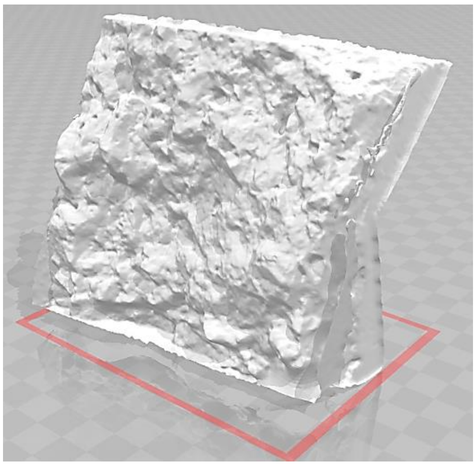

Fig. 2. Scanning of the superficial area of NSC.

4. Results and discussion

It was found out that an increase in the loading rate leads to a decrease in the fracture surface. The dependence of the superficial area on the loading rate is depicted in Fig. 3. It must be noted that a significantly large scatter of the measured data was obtained. This is caused by the natural non-homogeneity of the concrete which results from the non-uniform placement of the aggregate over the cross-section. However, it seems that with an increase in the loading rate the fracture surface area decreases. This may support the assumption that in case of impact loading, the crack does not have enough time to pass through the areas of least resistance as during the quasi-static loading. On the contrary, it follows the shortest possible path, possibly through zones with higher resistance, which yields a lower superficial area.

5. Conclusions

The major aim of this paper was to quantify the fracture surface in terms of superficial area under various loading rates. It was found, despite the significant scatter obtained, that higher loading rates yield lower superficial area in comparison to the quasi-static loading.

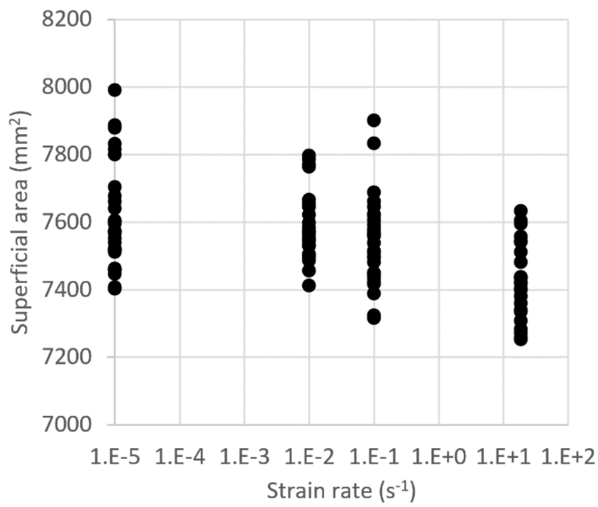

Fig. 3. Development of superficial area of NSC under various loading rates.

Acknowledgement

This work was supported by the Ministry of Interior of the Czech Republic [grant number VI20172020061]. The authors also acknowledge assistance from the technical staff at the Experimental Centre, Faculty of Civil Engineering, CTU in Prague; and the students who participated in the project.

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