International Conference
ENGINEERING MECHANICS 2010
Svratka, Czech Republic, May 10 – 13, 2010

FRACTURE PARAMETERS OF NATURAL AND ARTIFICIAL SANDSTONE: EXPERIMENT VS. NUMERICAL MODEL

T. Pail*, M. Štafa*, H. Šimonová*, P. Frantík*, Z. Keršner*

Summary: *The results of fracture experiments and numerical model with sandstone specimens are presented in this paper. The aim is the comparison of selected mechanical/fracture parameter values of Mšeno sandstone specimens and artificial sandstone prepared from quartz sand and geopolymer matrix. The relative values of elasticity modulus/stiffness and fracture energy/work of fracture are introduced using fracture test results as well as results of numerical simulation by the simple bending fracture model (SimBeFraM software).*

1. Introduction

A restoration of stone buildings/objects often needs to get re-profiling the material on the surface to obtain the original shape. To this end, different mixtures are used for the manufacture of artificial stone. One option for material for re-profiling of shape, or for producing replicas of existing stone monuments are newly developed geopolymer matrix based materials. As natural stone, which was imitated, was chosen Mšeno sandstone (see Keršner et al., 2010), one of the most important stone in the past in works of art, especially in Central Bohemia, also for its good machinability.

Three point bending test of central notched specimen is usually used for determination of fracture properties values of quasi-brittle materials like sandstone. The properties (e.g. effective fracture toughness and effective crack length, fracture energy and also modulus of elasticity) can be calculated on the base of load–defection diagrams from mentioned fracture experiment.

2. Natural and artificial sandstone

The natural Mšeno sandstone was supplied by the company *Mšenské pískovce, s.r.o.* It was a random sample from which the test specimens were cut out by a saw with a diamond blade.

Artificial sandstone was prepared by filler *PETRA* from the company *AQUA obnova staveb, s.r.o.* As a binder was used geopolymer cement *Baucis K 125* activated by potassium activator *Baucis LD 85* (*České lupkové závody, a.s.*). The binder was mixed with filler in a weight ratio of 1:4. Mixture has been tramping in the form of size 550×200×70 mm and after one month of hardening the artificial stone was cut out to test specimens. See Keršner et al. (2010) for more details.

* Ing. Tomáš Pail, Ing. Michal Štafa, Ing. Hana Šimonová, Ing. Petr Frantík, Ph.D., doc. Ing. Zbyněk Keršner, CSc.: Ústav stavební mechaniky, Fakulta stavební, Vysoké učení technické v Brně; Veveří 331/95; 602 00 Brno; tel.: +420 541 147 116; e-mail: Tomas.Pail@seznam.cz, stafa@centrum.cz, simonova.h@fce.vutbr.cz, kitnarf@centrum.cz, kersner.z@fce.vutbr.cz

3. Fracture experiments

Selected mechanical/fracture parameters of sandstone specimens were studied. The effective fracture toughness was measured using the Effective Crack Model. A three-point bending (3PB) test of beams with a central edge notch is used in this approach. The nominal size of all sandstone beams was 40×40×160 mm, the depth of the central edge notch about 1/3 of the depth of the specimen, and the loaded span was equal to 120 mm. The notch was made before testing. Three specimens were used from each sandstone material. A continuous record of the load–deflection (*l*–*d*) diagram was obtained for computation of mechanical/fracture parameter values – work of fracture and specific fracture energy (RILEM method). See e.g. Karihaloo (1995) for more details and Keršner et al. (2010) for experimental results.

4. *SimBeFraM* software

An approximation of recorded *l–d* diagram is possible to use for estimation of above mentioned mechanical/fracture parameter values. Often used modelling tools are very time-consuming. In order to simplify and avoid useless complexity, *Simple Bending Fracture Model* was developed, simply calls *SimBeFraM*. This tool uses genetic algorithms and has been evolved as GUI software. See Štafa & Frantík (2010) in this proceeding for more details.

As an input data for numerical solution were taken the data from mentioned experiment. It was necessary to reduce the number of *l–d* diagram points by specific transformation methods – see Frantík et al. (2008) for more details. The numerical approximation was applied for all testing specimens (see Fig. 1) for consecutive comparison of both solving strategy.

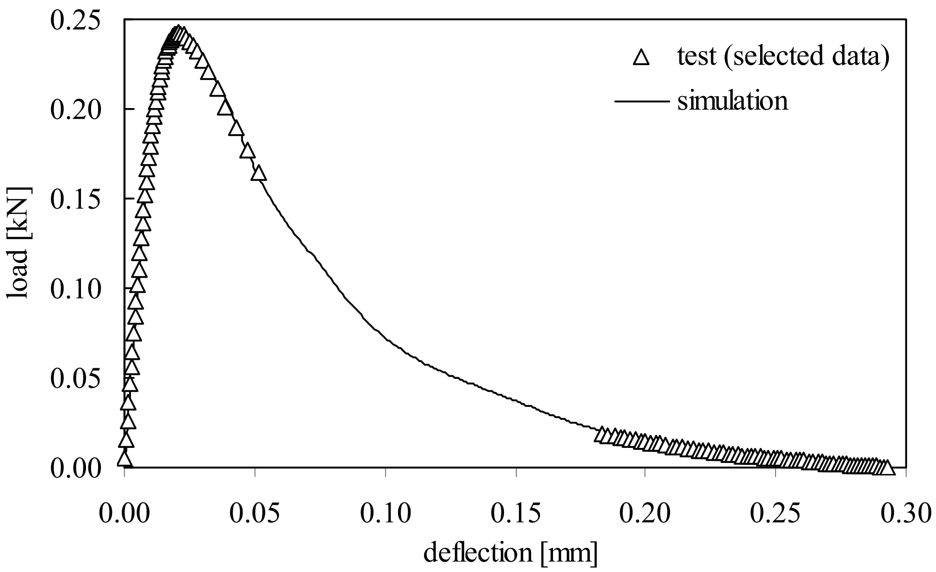

Fig. 1 Illustrative numerical approximation of selected load–deflection diagram

5. Results and discussion

Relative mean values and relative standard deviations of selected parameters of both studied sandstones are introduced in Figs. 2, 3. Each corresponding parameter was evaluated in two ways: 1) Values of modulus of elasticity and specific fracture energy were taken from evaluation of fracture tests (in the figure denoted as the "test"); 2) Values of stiffness and work of fracture were taken from numerical simulations using *SimBeFraM* software (the "simulation").

The comparison is presented relatively by reason that the both mentioned procedures give us different output data. However in the terms of mechanical description of response of sandstone specimens both outputs are comparable – e.g. elasticity modulus and stiffness. From the results we can see mutual harmony for both materials and referenced parameters.

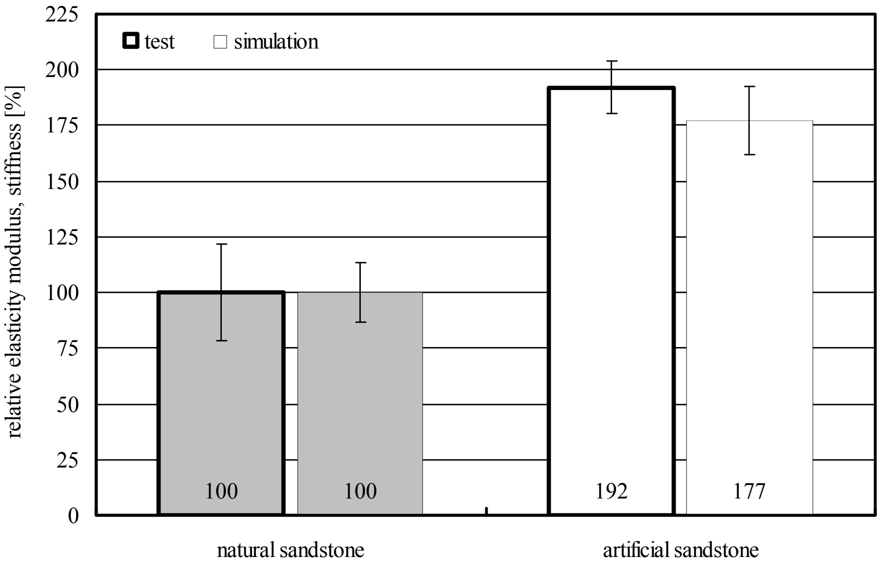

Fig. 2 Relative values of elasticity modulus/stiffness of sandstones

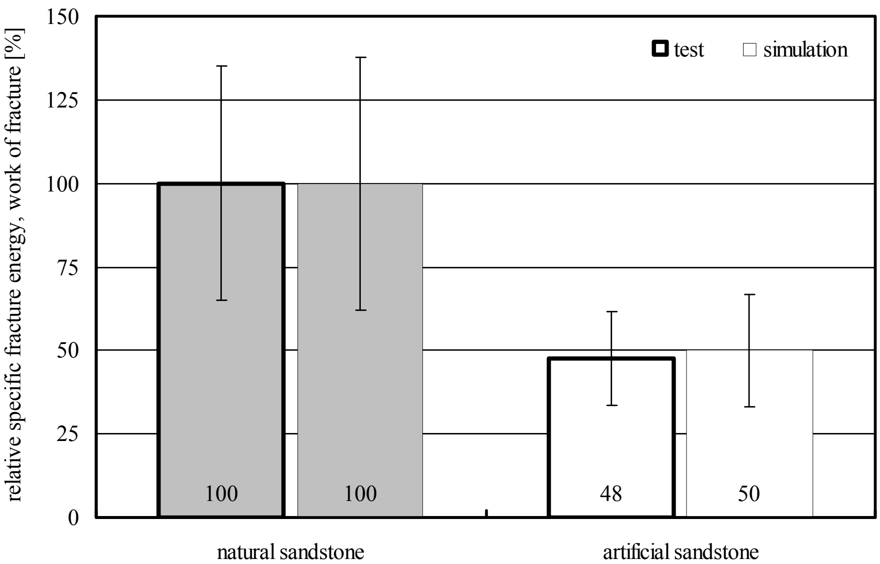

Fig. 3 Relative values of fracture energy/work of fracture of sandstones

6. Conclusion

The comparison of relative values of selected mechanical/fracture parameters of specimens of two sandstones – natural and artificial – was introduced in the paper. The procedure was based on results of the fracture tests with the results of simple bending fracture model (*Sim-BeFraM* software) using genetic algorithm method.

From the results we can conclude good agreement of relative values (and also relative standard deviations values) of elasticity modulus/stiffness and specific fracture energy/work of fracture for both sandstones.

7. Acknowledgement

This outcome has been achieved with the financial support of the Ministry of Education, Youth and Sports, project No. 1M0579 (CIDEAS). In this undertaking, theoretical results gained in the project Czech Science Foundation, No. GA CR 103/08/0963, were partially exploited.

8. References

Frantík, P., Lehký D. & Keršner, Z. (2008) Vyhodnocení lomových experimentů: efektivní náhrady zatěžovacíh diagramů, in: *Zborník príspevkov z medzinárodnej vedeckej konferencie 70 rokov SvF STU*, Slovenská technická univerzita v Bratislave, Stavebná fakulta (Alžběta Grmanová & Michal Minařík eds), Bratislava, 6 pp., in Czech.

Keršner, Z., Rovnaníková, P., Schmid, P. & Koutník, P. (2010) Fracture parameter values of natural and artificial sandstone, in: *Proc. of Seminar on Metakaolin 2010* (Z. Keršner & P. Rovnaníková eds), Brno University of Technology, Faculty of Civil Engineering, Institute of Chemistry, pp. 35–40, in Czech.

Karihaloo, B. L. (1995) *Fracture mechanics of concrete*. Longman Scientific & Technical, New York.

Štafa, M. & Frantík, P. (2010) Model for high precision approximation of load–deflection diagrams, in: *Proc. of Conf. on Engineering Mechanics 2010*, Svratka.