Microstructural analysis of high-dynamic strength tests on cementitious materials

Eva Binder[*], Herbert A. Mang[*,†], Yong Yuan[†] and Bernhard Pichler[*]

[*] Institute for Mechanics of Materials and Structures
TU Wien – Vienna University of Technology
A-1040 Vienna, Austria
{eva.binder, herbert.mang, bernhard.pichler}@tuwien.ac.at, http://www.tuwien.ac.at

[†] College of Civil Engineering
Tongji University
Shanghai 200092, China
yuany@tongji.edu.cn, http://geotec.tongji.edu.cn/en/

ABSTRACT

Concrete structures must also withstand exceptional loading events such as e.g. impact and blast loads. As for tunneling, such loads may result from traffic accidents, e.g. from cars crashing into a tunnel lining, or from detonation of explosive devices. It is well known from comprehensive material testing that the macroscopic strength of cementitious materials increases with increasing loading rate. The underlying microstructural reason, however, is not yet fully understood. This is the motivation for the present contribution. Following Fischer et al. [1], high-dynamic strength tests are analyzed. The model was originally developed for high-dynamic uniaxial compressive strength of cement pastes and mortar, where it is considered that also under dynamic loading axial splitting starts once the increasing stress becomes equal to the quasi-static uniaxial compressive strength. The latter is standardly determined with prescribed strain rates equal to 10^{-5} /s. Because of crack propagation in the loading direction, the material beside the first crack remains intact. This renders an increase of the stress in uncracked regions possible. Increasing stress levels, in turn, may result in additional cracks, nucleating and propagating in the loading direction. Thereby, the speed of model I crack propagation along nanoscopic material interfaces is equal to the Rayleigh wave speed [2]. Knowledge of the latter allows for quantifying the period of time it takes for the first crack to split the specimen. During that time period, the stresses increase in the uncracked regions of the tested specimen, i.e. between the cracks. The strength of the material is reached, once the first crack splits the sample such that it disintegrates into pieces. In the present contribution both the experimental validation of the model and its range of applicability to high-dynamic tensile strength tests are extended. This requires careful evaluation of the available protocols from experimental tests and investigation of the observed failure mechanisms. It is concluded that tunnel linings are damaged during high-dynamic loading events, if the maximum stress exceeds the quasi-static strength of the cementitious material of the lining. Therefore, linings require careful inspection, even after non-catastrophic high-dynamic loading events.

ACKNOWLEDGMENT

Financial support by the Austrian Science Fund (FWF), provided within project P 281 31-N32 "Bridging the Gap by Means of Multiscale Structural Analyses" is gratefully acknowledged.

REFERENCES

[1] I. Fischer, B. Pichler, E. Lach, C. Terner, E. Barraud and F. Britz, "Compressive strength of cement paste as a function of loading rate: Experiments and engineering mechanics analysis", *Cement and Concrete Research* **58** 186-200 (2014).

[2] F.F. Abraham and H. Gao, "How Fast Can Cracks Propagate? ", *Physical Review Letters* **84** (14) 3113-3116 (2000).