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SIMULATION OF SHOCK WAVE LOADED CONCRETE WITH DISCRETE CRACKS

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Summary. *The aim of the presented research is to simulate the blasting of concrete. The element-free Galerkin method is used to describe discrete cracks in the concrete. The cracks are developed by using a simple Rankine criterion. The nonlinear behavior of concrete is described by a cohesive crack model. In consideration of the strain rate effect and the Hugoniot-curve shock waves in concrete and the damage and fragmentation are calculated.*

1 INTRODUCTION

Simulation of high dynamic loading of concrete needs special material models. The development of shock waves has to be considered and with them the discontinuity in front of the shock wave. Another problem is how to calculate the fragmentation of the concrete.

The idea of this work is to use discrete cracks with a cohesive crack model instead of a damage material model. The results of these calculations will be compared with experimental results of blasting of concrete.

2 ELEMENT-FREE GALERKIN METHOD

Belytschko [1] proposed the element-free Galerkin method (EFG) which approximates a field by using a moving least-squares interpolation. Cracks can be implemented in EFG by cutting off the shape functions at the location of the crack.

There are two possible ways to integrate over the domain. The integration with a background mesh is easy to implement but with this integration method the computing time is high. The nodal integration needs less computing time and is used therefore in the presented work.

Another question is the size of the radius of influence. A smaller radius gives a singular matrix; a bigger radius gives a high computing time and a bad convergence. The influence of the size of support is shown in the work.

3 MATERIAL MODEL

You can distinguishtwo general material models for concrete: smeared and discrete crack models. Smeared crack models often have a problem to identify when a crack is going through the material and fragmentation is beginning. A discrete crack model helps to consider the fragmentation of the concrete for example after the high dynamic loading. In the presented work discrete cracks are implemented with EFG. The use of discrete cracks with a cohesive zone makes it possible to use a material model without damage formulation.

For the high dynamic loading there are also two effects to consider for the calculation: the building of shock waves and the strain rate effect.

3.1 Nonlinear stress-strain relation

Concrete responds very nonlinear to loading. A linear fracture mechanic is not usable. In this work cohesive cracks are implemented to describe the effects in the meso and micro scale cracking. In a zone – called fracture process zone (FPZ) – the stresses between the crack sides is falling down from the tensile strength to zero. The length of the FPZ can be calculated from the crack energy. With a FPZ no damage formulation is necessary.

A Rankine criterion is used to identify a growth of the crack. The direction of the crack growth is orthogonal to the direction of the principle strain. An easy contact algorithm completes the material model for static loading. The numerical results of the implemented static material model are compared with test results of standard beams.

3.2 Hugoniot

The nonlinear volumetric stress-strain relation is the cause for shock waves. After the destruction of the micropores (decreasing stiffness) the stiffness of concrete is getting higher by compacting of the material (Hugoniot). The increased stiffness is the reason for the development of the shock waves.

In the presented work a Y-function is used to consider the increase of stiffness. The young's modulus has to be multiplied with this function. The shape of the Y-function is shown by Schmidt-Hurtienne [4]. Other problems with shock waves (using artificial viscosity) are discussed.

3.3 Strain rate effect

The tensile and the compression strength are increasing with the strain rates. This has been shown in a lot of experiments for example from Bischoff [2]. If concrete is blasted the strain rate reaches values of $10^6\,\text{sec}^{-1}$. It is not possible to get experimental values for strain rates over $100\,\text{sec}^{-1}$. So the strength factor for strain rates over this point is hypothetical. In contrary to the CEB Bulletin [3] the strength factor should be limited. The high pressure as a result of the high strain rate cause high temperature and with the high temperature the strength is descreasing.

4 RESULTS

The proposed material model with EFG is implemented in an explicit time integration code. The results show the development of the cracks near the shock wave.

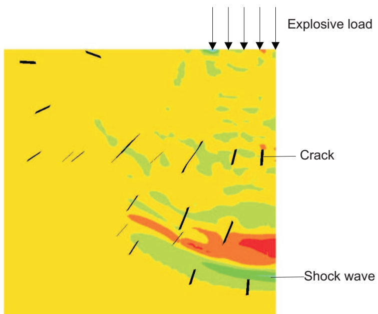

Figure 1: Cracks by blast loading of concrete

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