EUROMECH Colloquium 460
Numerical Modelling of Concrete Cracking
Innsbruck, Austria, 2005

A model for shock-wave loaded concrete with discrete cracks

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If concrete is loaded by explosive or other high-dynamic loads material models for concrete developed for static analysis can not be used. Experiments with concrete under dynamic loading show an increased compression and tensile strength. The compression and tensile strength is increasing at strain rates higher than $10^{-1}s^{-1}$ because of the restriction of crack growing by inertia effects. The influence of other phenomena decreases at high strain rates. [1]

A possible concept to create a material model for concrete under explosive loading is to reduce the material model to a simple form and add discrete cracks. A possible simple material model is for example the material model proposed by Ockert [4] who splits the stress into an hydrostatic and a deviatoric part. The known Hugoniot-curve is used for the yielding surface.

Calculating discrete cracks in computational mechanics is a multiple task for an engineer because of the discontinuous displacement field. There are two possibilities to include discrete cracks in the ordinary finite element method.

Moes et al. [3] described a possibility for modelling cracks by adding new degrees of freedom with a jump function. He has also added new degrees of freedom for the crack tip with crack functions derived from J-Integral. This method is called the extended finite element method (X-FEM).

The level set method (LSM) uses distance fields to the crack and the crack tip to gain all necessary information about the crack. Stolarska et al. [5] combined the level set method with X-FEM. The effect is an easy detection of the bisected elements and the elements with a crack tip. It is also very easy to implement crack growth with LSM.

Belytschko et al. [2] proposed the element-free Galerkin method (EFG). He approximates a field (e. g. a displacement field) by using moving least-squares (MLS). Cracks can be implemented in EFG by cutting off the shape functions at the location of the crack.

Concrete under tensile load fails very fast by building cracks. In the presented work the cracks affected by the tensile failure criteria were modelled on the one hand with EFG and on the other hand with XFEM to compare both possibilities of crack modeling. The direction of main stresses was used to identify the direction of the crack. The tensile strength and also the compression strength increasing with high strain rates. This strain rate effect is considered in the presented material model.

Nonlinear volumetric stress-strain-relation is the cause for the shock-waves. Increasing hydrostatic pressure destructs the micro-pores. The stiffness is decreasing. After destruction of the micro-pores the stiffness of concrete is getting higher by compacting. This effect is considered by an stiffness coefficient Y that is multiplied with the elastic modulus. The increased stiffness is the basis for the development of the shock-waves. The deviatoric part of the stresses is the cause for the damage of concrete. The cracks from this effect are also modelled by EFG and XFEM.

The results for both possibilities for modelling discrete cracks were compared. It can be shown, that the advantage of X-FEMs is the fast calculation, the advantage of EFG is the good adaptive remeshing.

The aim of the presented research is the simulation of blasting of concrete. The results of this calculations will be compared with experimental data that will also be gained in Karlsruhe.

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