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PENETRATION OF STEEL ANCHOR INTO A CONCRETE BLOCK – NUMERICAL CONTACT SIMULATION

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ABSTRACT

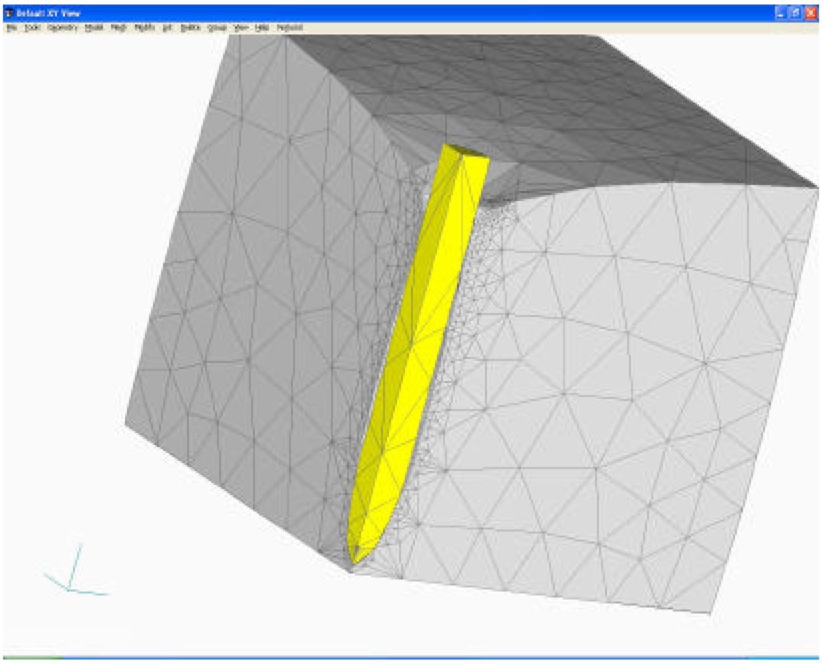
This work is a reflection of the current status of the attempt to numerically model penetration of a nail into a concrete block. We have accounted for large displacements and strains, effect of the loading rate on the material response and contact detection algorithms. Special care had to be placed on robustness of the contact algorithm since it cannot be predicted what shape concrete block will take during crushing in front of a nail. Large displacement and strain formulation is needed in order to realistically model behavior of concrete on the front of the nail were displacements and strains are large. Dynamic analysis is needed in order to account for the transformation of nail's kinetic energy into strain energy of concrete block (that then causes damage and crushing of concrete) as well as to take into account the influence of inertia forces on the concrete response. Inclusion of the effect of rate of loading will contribute to more realistic description of behavior of concrete under sudden (impact) loading that happen in contact problem.

Contact problem is characterized by non-linear geometrical constraints imposed as boundary conditions [2,3]. Formulation of that problem is known as Signorini problem for a solid body (first formulated by Antonio Signorini) and consists of equilibrium condition, compatibility condition (as a source of geometrical nonlinearity), constitutive equation (as a source of material nonlinearity) and prescribed Dirichlet (on displacements) or Neumann (on tractions) boundary conditions. Additional (impenetrability) constraints that are imposed on standard finite element equations could be based either on Lagrange method or on penalty method or on the combination of the two (like augmented Lagrangian). Adopted approach is the one with Lagrangian multiplicators that in our example take the role of the contact forces.

Since we would like to account for dynamic forces the governing system of equations is combination of dynamic equations and contact conditions expressed through Lagrange multipliers. After rewriting the system using discrete time increments it can be solved using either implicit or explicit procedure. The adopted approach is based on the explicit method that in its usual formulation results in singular coefficient matrix. Specially formulated numerical procedure is needed for stable and accurate explicit solution method [4]. The adopted explicit integration method enables

displacement and internal force vector calculation on the element level without any global matrix generation.

Concrete material model that is going to be employed in nail penetration analysis is the same one that is currently implemented in MASA computer code, the *microplane constitutive model*. The main idea behind the model is to form a finite number of planes around the finite element *Gaussian integration points* (forming a discrete "sphere") and than calculate the macroscopic stress tensor as an integral over contributions from all the (*micro*) planes. The normal microplane stress and strain components have to be decomposed into volumetric and deviatoric parts. The nonlinear behavior of the material (concrete) is formed from uniaxial stress-strain relationships for volumetric, deviatoric and shared components of each (micro) plane orientation. To enable cracking of concrete the effective microplane strains are introduced through application of the discontinuity function that simulates the discontinuity of the microscopic strain field (cracking) on each microplane [1] .



Presented procedures have been implemented into computer code and numerical examples have been calculated. The following figure demonstrates some of the code capabilities.

Fig.1. Result of numerical simulation of nail penetration into a concrete block.

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