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ANANLYSIS OF ROCK BOLTS AND INHOMOGENEITIES IN TUNNELING WITH THE BEM

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ABSTRACT

To analyze inifinite and semi-infinite domain problems as it is assumed in underground engineering structures, the boundary element method (BEM) is particular suitable. Only the excavation surfaces have to be discretized resulting in increased user friendliness, efficiency and accuracy of results because no discretisation erros are introduced inside the domain.

In underground structure different kinds of inclusions play an important role: General inclusions like inhomogeneities in geologie, or reinforcement of the ground by rock bolts. The analysis of domains containig rock bolts is very time consuming. In particular, in the finite element method a very fine mesh is necessary to handle the local stress concentrations. This fact is a huge disadvantage especially for large scale problems like in underground excavation where a very fine mesh is not practicable.

In this work a method is presented that allows to model rock bolts and inclusions efficiently in large-scale problems and in connection with elasto-plastic material behavior, with the boundary element method. General inclusions are modelled by volume-cells and the rock bolts are modelled by line-cells with a predifined cross-section (see figure 1). It is assumed that the rockbolts are in continuous contact with the ground (fully grouted) and that the displacements have a quadratic variation over the length.

The idea for both (general inhomogeneities and rock bolts) is to start with an analysis assuming that the whole domain has the same homogeneous material without any inclusions. After solving this system the strains will be computed at the cell-nodes. According to the strains ϵ the correction of the system (the residual stresses $\Delta\sigma$) can be calculated as:

$$\Delta\sigma = (\mathbf{D_1} - \mathbf{D_2})\,\epsilon \tag{1}$$

Where $\mathbf{D_1}$ and $\mathbf{D_2}$ are the constitutive matrices of the rock mass and of the inclusion respectively. In the next iteration step the residual stresses $\Delta\sigma$ are applied to the system as loading on the cells. With this

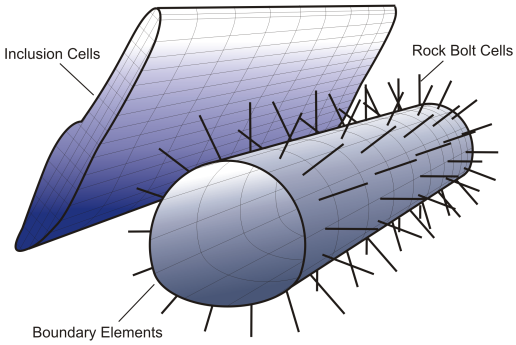

Figure 1: Tunnel with Rock Bolts and Inhomogeneity

additional loading a new strain field in the domain is computed and new residual stresses are obtained. The iteration proceeds until residual stresses vanishes.

Since the system is solved iteratively, the domain terms (the stresses at the cells) are treated as an additional right-hand-side to the system of equations. Hence the system itself has no additional degrees of freedom based on the inclusions, it has only the size of the boundary nodes from the excavation surface. Such problems could also be solved with a multi-region approach or by using the cell-integration technique with a direct calculation without iterations. But in both cases the degrees of freedom in the system of equations increase. Especially for large scale problems it is important to avoid the increase of the system of equation. Since the calculation of elasto-plastic material behavior needs an iterative procedure anyway this method produce not much additional expense in comparison to a system without inhomogeneities and rock bolts.

Examples of application will be presented.

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