Identification of initial stresses in rock by measurements of water pressure during the excavation of tunnels.

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## ABSTRACT

In the last decades, within the world of civil engineering, as well as in other fields of study, the methods of identification of parameters have been improved. This technique of study is based on making an inverse analysis, which is normally carried out by means of probabilistic techniques, although there are other techniques to approach the inverse problem. The final objective of the identification of parameters is, through a series of measurements, to create the inverse analysis and finally to identify which value of a parameter adjusts better to the obtained measurements.

Most of the works associated to the construction of tunnels have used the measurements corresponding to the displacements to formulate the identification problem. Within the present degree dissertation I would like to deepen in a route of investigation which has not been developed very much, which is linked to the measurements of water pressure in the construction of tunnels. The measurements of displacements can present greater deviations than the measurements of water pressure, since the auscultation techniques cause a greater distortion of the initial conditions in the case of the displacements.

The objective, therefore, of this dissertation is to make a study of viability of the use of measurements of water pressure to identify the initial stresses in rock tunnels and which factors can influence in the obtained results. The parameter that has been identified has been the Ko of the terrain. For the case of 3D, I have attempted to identify the Kox and the Koz, corresponding to the horizontal axis. In order to fulfil these objectives a series of systematic studies have been made. In the first place, an analysis of the direct problem in two dimensions has been carried out, considering in the existing analytical solutions. Secondly, the analytical results have been compared with diverse numerical calculations using two programs of finite elements (Code Bright and Plaxis). Within this phase minor divergences have appeared between the analytical solution, in displacements and stresses, and the results obtained with the programs.

Next, the inverse analysis for the case has been made in two dimensions. In this section differences have been found in the direct problem, that lead to different results within the inverse problem. The following section has been the resolution of the inverse problem in three dimensions. Since no analytical solution exists for the problem of excavation of a tunnel in 3D, the direct problem has been solved with the program Code Bright, but in this case a control element does not exist like the analytical solution for the case in two dimensions. The importance of this study is in the great three-dimensionality of the problem associated to the excavation of a tunnel. Another aspect that has been studied is the influence of the construction by stages with respect to the measurements of water pressure in fixed points. Within the study in three dimensions better results for the identification of a sole parameter have been obtained, that in the study of two parameters. Finally a study has been made for a real case in three dimensions, analyzing the data available on the Febex tunnel in Switzerland. I have tried to identify the Kox parameter and the obtained results have been coherent with a previous study. In this case I can say that the inverse analysis can be a new way to calculate the Ko, complementary to the tests in situ made in the Febex tunnel.

The conclusions of this dissertation affect the two aspects of the inversion of parameters: the direct problem and the resolution of the identification. Within the direct problem, the most outstanding aspect is the existing divergence between the analytical and numerical solutions for the stresses and water pressures produced by the excavation of the tunnel, caused to a large extent by the size of the mesh and other effects. It has not been possible to verify the direct problem in three dimensions, since an analytical solution does not exist. Within the identification, in the 2D case, the objective function for the analytical and the numerical data differs a great deal. In the three-dimensional case, in the identification of a parameter the method has worked correctly. In the case of two parameters, it has been possible to identify one of them with great reliability, but not the second parameter.