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Application of Hyperstatic Reaction Method for Designing of Tunnel Permanent Lining, Part II: 3D Numerical Modelling

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Abstract

Underground structures often have abrupt changes in structural stiffness or ground conditions such as junctions of tunnels, tunnel portal in slopes, and niches in road tunnels. At these locations, stiffness differences may subject the structure to differential movements and generate stress concentrations. Because of adversity in these issues, they need a three dimensional analysis. This paper proposes a numerical approach to the Hyperstatic Reaction Method (HRM) for three dimensional analysis of permanent tunnel linings Designing is done for Manjil-Rudabar freeway project, Tunnel No. 2. The numerical analyses performed for Operational Design Earthquake (ODE) and Maximum Design Earthquake (MDE) loading conditions. Then, an interaction diagram between axial force and bending moment was used for investigating the capacity of tunnel lining. The numerical results showed that although more axial forces are created in tunnel lining for ODE condition (due to higher load factors in this condition), the points inside the P-M diagrams are located in the furthest distance to the border (tunnel supporting system); because the little bending moment in this condition. Therefore, the safety factor in ODE condition is more than MDE condition. This numerical processing presented that the HRM is a proper, fast, and practical method for tunnel designers.

Keywords: Hyperstatic Method; Tunnel Lining; 3D Numerical Modeling; Static Analysis; Dynamic Analysis.

1. Introduction

The most important goal of a tunnel design is to provide the designer with an understanding of the mechanism of behaviour during tunnelling, including the possibility of risks and where they could occur, and a basis for producing a robust and safe design and, finally, a basis for interpreting the monitoring results [1]. Because of the uncertainties concerning the properties of the ground and the induced loads on the lining, it is important to highlight that there is not a single analysis method that can be used for all tunnels, and very often the precision of the available analytical and numerical tools is much greater than the reliability and the accuracy of the data obtained from site investigations and rock mass characterization.

Therefore, designers are obliged to undertake sensitivity analysis of the ground–support interaction model in order to understand the influence of the input parameters.

The most frequently used lining design methods in tunnelling practice are AFTES (1976), USACE (1997), and BTS (2004) [1-3].

Underground structures often have abrupt changes in structural stiffness or ground conditions. Some examples include: (a). connections between tunnels and buildings or transit stations; (b). junctions of tunnels; (c). traversals between distinct geologic media of varying stiffness; (d). tunnel portal in slopes; and e) niches in road tunnels. At these locations, stiffness differences may subject the structure to differential movements and generate stress concentrations. The design will also have to account for potential of pounding between the structure and the connecting tunnel due to differential movement. Because of adversity in these issues, they need a three dimensional analysis. In this paper, special topics of 3D of tunnels are presented by using hyperstatic reaction concepts for simulating of complex sections of tunnel linings. This method has frequently been used, despite the structural

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