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Parametric Study for Obtaining the Structural Response of Segmental Tunnels in Soft Soil by Using No-Linear Numerical Models

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Abstract : In recent years, one of the methods most used for the construction of tunnels in soft soil is the shield-driven tunneling. The advantage of this construction technique is that it allows excavating the tunnel while at the same time a primary lining is placed, which consists of precast segments. There are joints between segments, also called longitudinal joints, and joints between rings (called as circumferential joints). This is the reason because of this type of constructions cannot be considered as a continuous structure. The effect of these joints influences in the rigidity of the segmental lining and therefore in its structural response. A parametric study was performed to take into account the effect of different parameters in the structural response of typical segmental tunnels built in soft soil by using non-linear numerical models based on Finite Element Method by means of the software package ANSYS v. 11.0. In the first part of this study, two types of numerical models were performed. In the first one, the segments were modeled by using beam elements based on Timoshenko beam theory whilst the segment joints were modeled by using inelastic rotational springs considering the constitutive moment-rotation relation proposed by Gladwell. In this way, the mechanical behavior of longitudinal joints was simulated. On the other hand for simulating the mechanical behavior of circumferential joints elastic springs were considered. As well as, the stability given by the soil was modeled by means of elastic-linear springs. In the second type of models, the segments were modeled by means of three-dimensional solid elements and the joints with contact elements. In these models, the zone of the joints is modeled as a discontinuous (increasing the computational effort) therefore a discrete model is obtained. With these contact elements the mechanical behavior of joints is simulated considering that when the joint is closed, there is transmission of compressive and shear stresses but not of tensile stresses and when the joint is opened, there is no transmission of stresses. This type of models can detect changes in the geometry because of the relative movement of the elements that form the joints. A comparison between the numerical results with two types of models was carried out. In this way, the hypothesis considered in the simplified models were validated. In addition, the numerical models were calibrated with (Lab-based) experimental results obtained from the literature of a typical tunnel built in Europe. In the second part of this work, a parametric study was performed by using the simplified models due to less used computational effort compared to complex models. In the parametric study, the effect of material properties, the geometry of the tunnel, the arrangement of the longitudinal joints and the coupling of the rings were studied. Finally, it was concluded that the mechanical behavior of segment and ring joints and the arrangement of the segment joints affect the global behavior of the lining. As well as, the effect of the coupling between rings modifies the structural capacity of the lining.

Keywords : numerical models, parametric study, segmental tunnels, structural response
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