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SEISMIC BEHAVIOUR OF TUNNELS IN SAND

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Summary. During seismic events circular tunnels lined with precast concrete segments may suffer large displacements with possible opening of the joints between the segments. In order to understand such a complex soil-structure interaction, numerical modeling can be helpful. As shown in this work, it must include an accurate 3D geometrical layout of the structure and a suitable constitutive model for the soil.

1 INTRODUCTION

This research was aimed at defining a procedure of analysis for the safety evaluation of circular tunnels lined with precast concrete segments in highly urbanized seismic area. During seismic events such underground structures may suffer large displacements with possible opening of the joints between the segments of the lining. This condition can be particularly critical when the tunnel crosses discontinuities characterized by strong seismic impedance differences [1]. Moreover, in highly permeable soils the opening of joints may cause severe inflow from groundwater or even trigger fast raveling from the surrounding ground. For a better understanding of the behavior of segmental tunnel lining under seismic shaking, numerical modeling may be adopted. As shown in this work, in order to model such a complex soil-structure interaction, the numerical models must include an accurate 3D geometrical layout of the structure and a suitable constitutive model for the soil, thus achieving realistic prediction of the ground displacement field during shaking.

2. NUMERICAL SIMULATIONS

A three-dimensional finite-element model has been calibrated against the results of an experimental campaign of centrifuge tests on a model tunnel in a layer of dense dry sand subjected to transversal dynamic loading, carried out at the Schofield Centre of the Cambridge University Engineering Department [2]. This case history has been considered since already used as a benchmark in a number of plane-strain numerical analyses for class-C predictions. They were performed with different numerical codes and constitutive models, as reported by Bilotta et al. [3].

Unlike the continuous tunnel lining adopted in the experiments, the focus of this work was on the behaviour of segmental linings (Figure 1). Hence the lining was modelled in the analyses by taking into account the actual layout of longitudinal and circumferential joints in a typical segmental precast reinforced concrete support system (Figure 2).

Realistic modelling of the construction process under static conditions is preliminary to the dynamic calculations and its influence was also discussed.

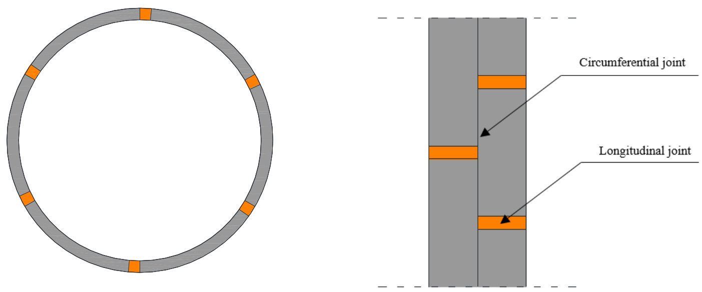

Figure 1. Segmental lining geometry

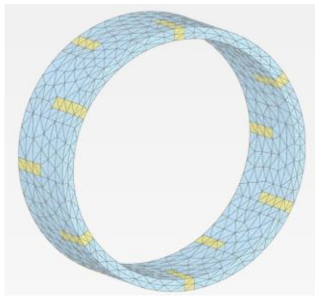

Figure 2. 3D Numerical model of the lining

The numerical analyses were performed with the commercial FE code Plaxis 3D, using an elastic-plastic constitutive model with strain hardening [4] and a small strain overlay able to model the cyclic behavior of the soil [5]. The main factors affecting the dynamic response of such systems (the frequency content and intensity of the earthquake, the stiffness contrast between tunnel lining and the surrounding ground, the coverage/diameter ratio and the number of joints in the transverse section) were taken into account and varied parametrically. In addition to the artificial signals applied in the original centrifuge tests, a number of natural input signals have been also applied.

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