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# Ground Improvement for a High Speed Railway near Madrid (Spain)

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**Abstract**

For the extension of the lines of the Spanish high speed railway system, a new junction has recently been created to the south of Madrid (Spain). The objective of these works was to connect the lines Madrid-Valencia and Madrid-Seville in order to be able to go directly from Seville to Valencia. The work has been undertaken in the zone of Torrejón de Velasco (Madrid province). The ground of this zone is formed by: a) Anthropic fills. b) Very soft quaternary sediments, mainly clayey soils. c) Hard clay (near substratum). The height of the necessary embankments is variable (to from 2 m to 15 m). For this reason (and proximity to the high speed railway in operation) it has been necessary to design a major ground improvement under the embankments. This paper describes: a) The geotechnical properties of the soft soil (by means of field embankment tests and other field tests). b) The design of the ground improvement. c) The instrument field data obtained during the treatment.

*Keywords:* Ground improvement, Soft soils foundations, Controlled Modulus Columns (CMC)

# 1 Introduction

In order to increase the functionality of the high speed railway lines between Valencia, Madrid and Seville (Spain), a connecting branch was designed between the High Speed Lines (HSL) Madrid-Levante and Madrid-Seville. For this, ADIF (Ministry of Public Works) constructed this branch line in Torrejón de Velasco (about 30 km south of Madrid) in order to permit travel between Valencia and Seville without passing through Madrid.

Within this branch the creation of two single tracks for speeds of 160 km/h has been considered. The track in the direction of Valencia has a length of 5593 m and the track for Seville 5702 m.

As far as approximately kp 2+800 both tracks run in parallel along the actual railway in service, with most of it being done in stretches of embankment (see Figure 1). From that kilometer point as far as the end, both tracks are laterally backed on to the current Madrid-Seville HSL railway roadbed. In

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this last sector most of the stretch is located practically level or on an embankment running along the alluvial plain of the Guatén River.


**Figure 1: Simplified situation of the described works**

# 2 Geomechanical Framework

The zone of action lies on the alluvial deposits of the Guatén River, between the towns of Torrejón de Velasco and Yeles/Esquivias. Although we are concerned with a tributary of the Tajo river, with a small extent in plan view, these soft alluvial deposits have very considerable thicknesses owing to their geological history, since they used to form the old river bed of the Manzanares (the river that flows through Madrid), with detected thicknesses of 6 to 12 m, and with particular zones where they reach as much as 17 m.

The substrate of the zone consists of the formation of gypsum clays of the Vallecas Unit, where important accumulations of very much softened and altered black clays have been detected in its roof, possibly related to the existence of a gypsum paleokarst.

In the design phase, a field research studies by mechanical boreholes was conducted in order to be able to correctly define the thicknesses of alluvial deposits, detect the zones of softened clays that can be associated with the karstification processes and locate the contact with gypsum formation. This research studies that was completed with piezocones (CPT with water pore pressures control) and dynamic continuous penetrometers.

The alluvial soils consist of an alternation of plastic clays (CH) and organic clays (MH-OH), with bands of inorganic silts (ML) and clayey sands (SC). These are soft to very soft soils, with standard penetration blows ($N_{SPT}$) of less than 8, with deformation moduli of around 6-20 MPa and vertical consolidation coefficients from $10^{-3}$ to $10^{-5}$ $cm^2/s$ depending on the fines content and plasticity.

Lying beneath this thickness of alluvial soils are some black silty clays (known locally as "peñuelas") with the presence of completely altered gypsum and thicknesses of about 5 m, though very variable from some zones to others. In the dynamic penetration tests, blows of 4 to 8 were recorded for the most altered horizons, and blows of 10 to 30 for the most compact horizons. In the pressuremeter tests, pressuremetric moduli (Ep) of 23 to 107 MPa were obtained, along with limit pressures with values from 2.76 to 3.32 MPa.

The representative section can be seen in the Figure 2 (ARCOS & MONTEJANO, 2013) and Figure 3, with the stratigraphy characterized by the values of the continuous static penetration tests, as can be seen in Figure 3. The resistance at the tip of the static penetrometer ($q_p$) is less than 1 MPa,