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Geological engineering problems associated with tunnel construction in karst rock masses: The case of Gavarres tunnel (Spain)

S. Alija [a,1], F.J. Torrijo [b,*], M. Quinta-Ferreira [c,1]

[a] Geosciences Center, University of Coimbra, 3000-272 Coimbra, Portugal
[b] Department of Earth Engineering, Universidad Politécnica de Valencia, 46022 Valencia, Spain
[c] Department of Earth Sciences, Geosciences Center, University of Coimbra, 3000-272 Coimbra, Portugal

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ABSTRACT

A representative example of the problems associated with the excavation and support of tunnels in karst ground is presented. It is a peculiar case in terms of heterogeneity and spatial distribution of zones of poor geotechnical quality, requiring the need to define, preferably in the study phases, adequate site investigation, suitable design procedures, efficient construction techniques and appropriate ground treatment. The difficulties associated with the instability of the karstified ground, and the presence of cavities, wholly or partially filled with soils of low cohesion, are discussed via retrospective analysis. The solutions adopted to solve the problems encountered during the tunnel construction enabled a systematic approach, useful for new construction projects in limestone terrains of medium to high karstification.

1. Introduction

The design and construction of tunnels in karst terrains is fraught with problems associated with the unexpected location, irregular geometry and unpredictable dimensions of the karst structures.

In a karstified terrain, prospection and regular testing campaigns should be supplemented with other techniques adapted to locate and anticipate the problematic zones. It must be taken into account that no site investigation technique is one hundred percent accurate, and therefore several techniques should be used, adapted to each specific situation, taking into consideration the budget for the work and the risks that can be assumed in the project.

A real case of a tunnel constructed in a karstified limestone ground is presented, the problems encountered are described and the proposed solutions are discussed. A systematic approach, as a knowledge tool for future work in similar situations, is presented.

2. Geological framework

From the geological point of view, the study area is located in the Les Gavarres region, which is included within the Catalan Transverse System, directly related with the Neogene depression of the Empordà (Agustí et al., 1994).

Les Gavarres region consists of a fringe of Palaeogene materials (mainly Eocene), arranged around a Hercynian rock massif, outcropping south of the study area. The age of these materials is prior to the Alpine Orogeny, as they have suffered deformation and fracturing during this tectonic phase. The series is dislocated in blocks, separated by fractures that lead to the uplifting of the massif. The general structure is a monocline arrangement, dipping mainly to Northeast (IGME, 1983, 1995). The geological formations affecting the tunnel are (Figure 1) the following:

- *Barcons Sandstone Formation* (E_A). It is composed by glauconitic sandstone, medium to coarse grained, locally conglomeratic. The predominant colour is grey-yellowish or ochre. The grains are mainly of quartz and feldspar with a scarce clay matrix. It has calcareous cement and abundant bioclasts. At the base and top of the series, the layers are decimetric to metric, presenting a more massive appearance in the middle of the formation. The average sedimentation corresponds to a deposit in the frontal area of the delta, which is rather thick, but of limited extent. The age of the series is Eocene.
- *Banyolas Limestone Formation* (E_M). This formation is composed of layers of limestone and marl, whose relative proportion varies throughout the series. They are of grey and bluish grey colours, and the layers have decimetric thickness. The carbonate content ranges from marly clay to limestone, affecting materials' strength, weatherability and the stability behaviour of the rockmass. Some spans of the series are mainly composed of hard clay and marls. The age of

* Corresponding author. Tel.: +34 963877582.
E-mail addresses: santiagoalija@gmail.com (S. Alija), fratorec@trr.upv.es (F.J. Torrijo), mqf@dct.uc.pt (M. Quinta-Ferreira).
[1] Tel.: +351 239860500.

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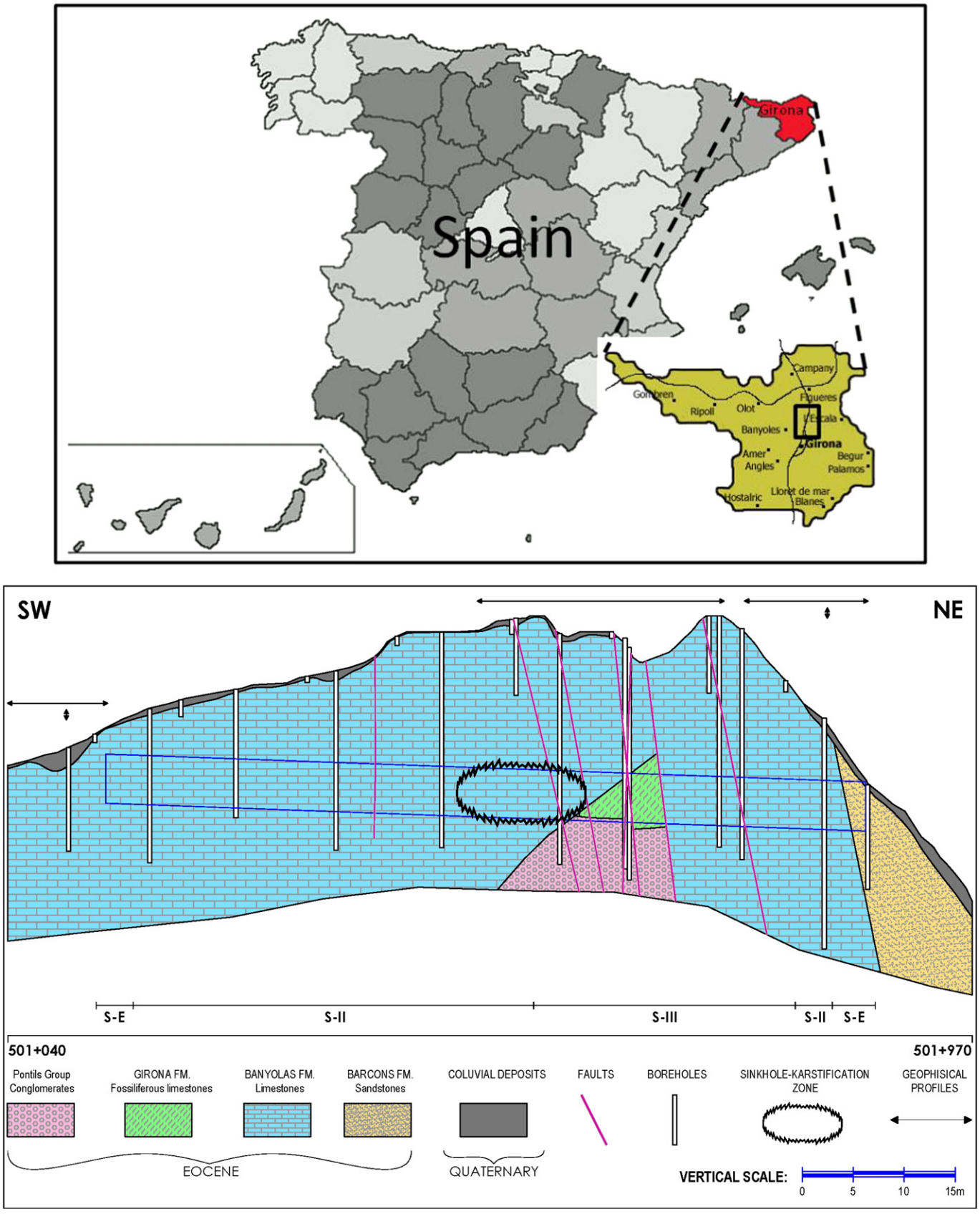

Fig. 1. Location map and geology profile along the Gavarres tunnel.

the series is Eocene. It is important to note that the Banyolas Limestone Formation is in concordance with the underlying Girona Fossiliferous Limestone Formation.

- *Girona Fossiliferous Limestone Formation* (E_C). It is a fossiliferous limestone, presenting oolitic terms at the base. The predominant colour is ochre. It is rather recrystallized and arranged in layers of a wide range