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Underground works in Spain

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Spain is a very mountainous country with important ranges generally orientated from east to west, with an average height of some 660m. This rugged terrain has made it necessary to include tunnels in the network of trunk communications, both railways and roads.

The varied geological composition of the Iberian Peninsula often causes serious difficulties in the construction phase of these projects. These stem both from its tectonic characteristics and from its diverse lithology, encompassing as it does the whole range of rock from the hardest, most compact and most abrasive to loose sedimentary material.

The state of Spanish underground works at present is excellent, with an increasing number of projects being carried out, mainly related to the high-speed railway network. (Fig 1).

Tunnelling and underground work in Spain is currently looking very healthy: upgrading the communications network in line with the rest of Europe and planning for a link between Europe and Africa make for an even brighter future.

Main projects under construction

The Vallvidrera Tunnel

This is a road tunnel with three lanes (two up-lanes with a slow lane and one down-lane) which will link the centre of Barcelona with El Vallés, passing through Mount Tibidabo. Its approximate length is 2200m and its cross-section measures between 95 and 112m^2. The tunnel crosses metamorphic formations of slate, filite and anfibolite, with the occasional intrusion of porphyry. The maximum coverage is 160m.

Excavation will be carried out by drill +blast in the hard rock stretches and by roadheader in the sections of softer ground. Construction will be carried out using the NATM combined with the Bernold method in some sections. A second tunnel will be driven at a later date for the Vallés-Barcelona link, leaving the present tunnel for the Barcelona-Vallés link.

Madrid-Brazatertas-Córdoba tunnels

One of the most important public works to be undertaken in Spain is the modernisation of the National Railway Network (RENFE), which necessarily implies the construction of many tunnels. The Spanish government has estimated 2 billion pesetas (£10 000 million) worth of investment for this modernisation plan. The bulk of this sum will pay for the construction of new lines and the modification of some existing lines, equipping them for speeds of 200 and 250km/h in the short term, and 300km/h in the long term.

As part of this plan, work began in Aug '87 on the new Madrid-Brazatortas – Córdoba line, suitable for speeds of up to 250km/h for mixed passenger/goods trains. The new line will be 341km long from Madrid, which represents a saving of 100km on the present line. In future journeys from Madrid to Córdoba and to Seville in 1992, the year of Seville's Universal Exhibition, will take two and three hours respectively.

The new line will have 14 tunnels, with lengths varying between 0.3km and 2.5km, and a total length of 14.9km. Tunnels will have a cross-section of 75m^2, allowing for the aerodynamic effects which occur in tunnels supporting very high speeds, (Fig 2). The tunnels will run through very ancient Precambrian rocks of varying lithology in which quartzstones, sandstones and slates are predominant. One of the tunnels will cross a batolite of granite which serves as a dividing line between the Guadalquivir Valley, in which Córdoba and Seville lie, with a coverage of 100 to 200m, and the Pedroches and Alcudia valleys, where the tunnel coverages exceed 600m.

Some of these tunnels can be visited on the field-trips organised after the Tunnels and Water Congress which is to be held in Madrid from June 12 to 15 1988.

Within the context of the studies for the extension of this line to the north of Spain, one project which is being considered is the construction of tunnels with lengths varying between 5km and 20km, situated on the mountainous dividing line of the Sierra de Guadarrama which separates the Comunidad Autónoma de Madrid from that of Castilla-León. In these mountains, granite and gneiss predominate and several important tunnels have already been driven: a railway tunnel 2.4km long and two road tunnels have already been driven: a 2.4km long railway tunnel and two road tunnels.

The Gibraltar Straits tunnel

The Straits of Gibraltar, 13.8km wide at their narrowest point, have for many years aroused the imagination of engineers and politicians interested in the

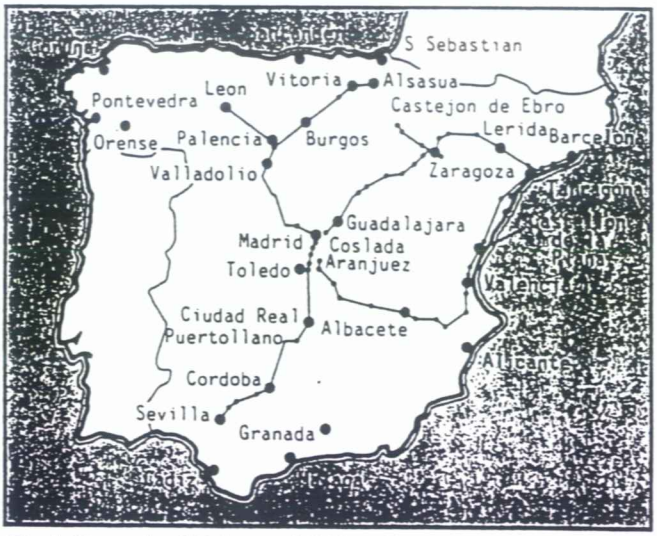

Fig 1. Network of high-speed (200-250km/h) Spanish railways.

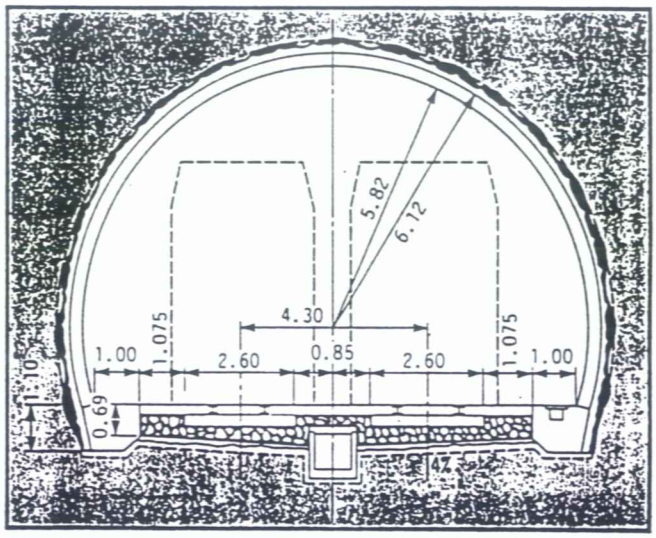

Fig 2. Cross-section of tunnels on the Madrid-Cordoba line.

possibility of constructing a stable, permanent link between Europe and Africa. Several different solutions have been put forward this century and some investigation work has been carried out which culminated in 1979 in the signing of a scientific technical study between Spain and Morocco, thereby laying the foundations for the development of a joint feasibility study for a permanent link. This work is being carried out by two companies created specially for this purpose: SECEG in Spain and SNED in Morocco.

The topography of the seabed greatly conditions the configuration of the various possibilities. In the narrowest part of the Straits the maximum depth reaches 800m, while at the western point there are two exceptionally fine sills with maximum depths of some 300m. The corridor combining the two most important parameters (distance and depth) in the most favourable way is situated between Paloma Point in Spain and Malabata Point in Morocco, with a distance of 27km between the two coasts.

Geologically, the project is situated in an extremely complex zone made up of 'flyschs units' consisting of a rhythmical pattern of packets of hard metric rocks (sandstone or limestone) alternating with softer ones (marls or clays) and there are some formations (Tangiers or Almarchal) consisting almost solely of clays and marls several hundred metres thick.

Two preliminary studies have been carried out on the technical feasibility of a railway tunnel beneath the seabed. Both studies are agreed on the same 'S'-shape longitudinal plan of about 50km, of which 27km would be below sea level, with stretches above ground linking the mouth of the tunnel with Cádiz or Algeciras in the north and Tangiers in the south (Fig 3).

Various solutions have been studied for the longitudinal profile, with gradients ranging between 12 and 20‰. The minimum thickness of rock cover which defines the point of maximum depth of the course has been fixed provisionally at 100m to accord with technical criteria and until more accurate geological information is available.

Two types of solution are contemplated for the cross-section profile:
A main double-track tunnel with a service gallery.
Two single-track tunnels with a service gallery (Fig 4).

The future for tunnels and underground works in Spain seems hopeful, mainly due to the positive effect of the success with which a number of projects have been completed in recent years. The fact that they were finished very nearly on schedule, within budget, has helped considerably to allay the fear of 'tunnel solutions'.

Moreover, awareness of ecology and the importance of the environment makes the tunnel solution more and more attractive to planners. Even so, if confidence in tunnels and underground structures is to be maintained, the design projections that are drawn up must accord as closely as possible to reality, and construction costs must continue to fall if they are to compete with alternative solutions.

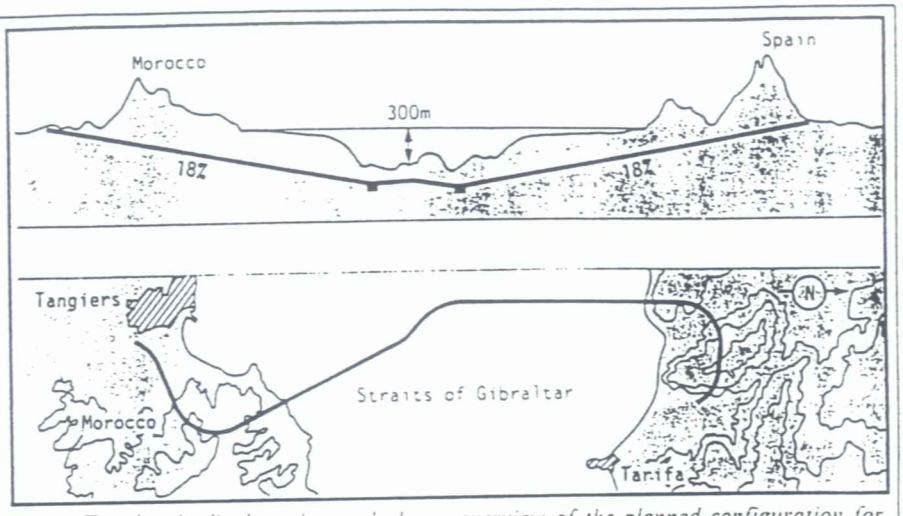

Fig 3. Top: longitudinal section and above: overview of the planned configuration for crossing the Straits of Gibraltar.

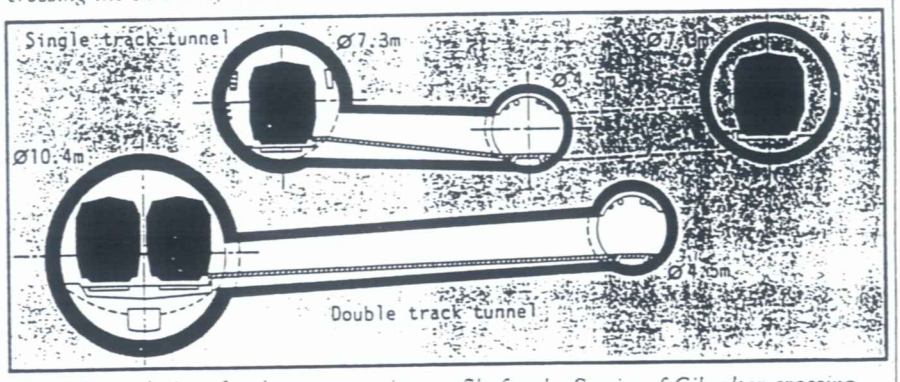

Fig 4. Two solutions for the cross-section profile for the Straits of Gibraltar crossing.

To secure the first of these objectives, it is necessary to undertake more research into the geology and soil mechanics of the area in question before starting work on any structure.

There are a number of research projects currently being carried out in this field: one of the most important is a project to perfect a machine able to carry out horizontal exploratory deep probes. This technique was successfully developed in Japan for the work on the Seikan Tunnel and will doubtless prove extremely useful in the construction of the Gibraltar Straits tunnel and other underground works.

As regards reducing construction costs, there are two main fields in which great effort is being made:

(a) Construction methods

The NATM has been widely employed in Spain since it was first used in 1974 on the Turo de la Rubira Tunnel in Barcelona. Its great flexibility lends itself to the type of ground encountered in Spain, where heterogeneity is the outstanding feature. Spain now possesses the high degree of technical expertise which this method requires of those responsible for its application. Adapting NATM technology to the specific conditions found in Spain should be continued, and this could result in considerable economies in tunnelling works.

(b) Machinery

Although Spain itself does not manufacture tunnelling machines, it has a lot to offer in the form of experience to research projects that Europe ought to promote if it is to compete successfully on the international market. Research ought to provide the impetus for great technological strides in tunnel construction.

Spain's entry into the EEC must surely be a hopeful sign for the further development of underground works inside the country, as it will be necessary to expand and modernise the existing communications network. This will mean general and underground works in greater investment in public works in particular.

The Asociación Española de Túneles y Obras Subterráneas (AETOS, the Spanish Tunnelling Association) has been gathering strength in the last two years and can now claim 300 members which include private individuals and institutions. AETOS will help in meeting the technological challenge which will confront engineers and private enterprise alike over the next few years. □