USE OF MARGINAL SOILS IN SOME SPANISH ROAD CONSTRUCTION, HIGHWAY A-44, SANTA FÉ-LAS GABIAS

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In Spain in the last 10 years exists a growing concern related to the environmental awareness, specifically in the transport's world. Too many road works have tried to reduce the impact of the new technologies on the environment with different strategies, such as the use of marginal soils excavated during the construction of the own road (forming part of the embankments).

In the Detailed Design Project of the A-44 Highway of Sierra Nevada, "The Granada Orbital", sections between Santa Fé and Las Gabias, the marginal soil composed by gypsum excavated from the axis of the road is used in the construction of the nucleus of the embankments always assuring the existence of a capsule composed by seleccionado soil in the upper part of it, laterals and foundations. In addition, a PEAD layer is placed between the upper part of seleccionado soil and the nucleus of marginal soil that contains gypsum between 5 and 20%. The purpose of it is to assure the water tightness to the humidity changes.

The works related to the Detailed Design previously indicated have started a couple of years ago. In this article the issues included in the Project about this form of proceeding and the reality and experiences occurred during the construction works will be deeply described, trying to show how in Spain "environmental works" are widely extended in the Roads World.

1. BRIEF DESCRIPTION OF THE SECTION COVERED IN THE PAPER

The section covered in the project begins in the municipality of Granada, very close to the current A-92G and south of it.

It starts at the intersection with the A-92G, at the 1 m section of the A-44 motorway exit (direction Bailén - Motril) that runs towards the slip roads in the direction of Santa Fé or Granada.

After about 100 m the motorway enters the municipality of Vegas del Genil where the above intersection is located. The crossing of the bi-directional road, which is achieved by means of an underpass, is carried out in the vicinity of the 0+250 progressive kilometre of the main road.

The route from its origin to the Cúllar - Vega intersection approximately runs through the so - called "Vega de Granada", where the terrain describes some gentle slopes. In this sub-section, almost 3,000 m long, all the crossing structures have been established with underpasses, except the one located at progressive kilometre 2 + 310, where an overpass has been chosen.

The Cullar - Vega intersection is located southwest of the municipal district of Vegas del Genil, 800 m south of the municipal district of Santa Fé.

The intersection is the diamond interchange type, and is defined by two roundabouts (one on each side of the main road) with 2 lanes and a radius (at the inner paint line) of 17 m.

Two direct roads give access to and come off the main motorway, a bi-directional road connected to the current road in the direction of Belicena, another bidirectional road connected to the current road in the direction of Arroyo Salado and another bi-directional road that crosses the route and connects the two circulatory carriageways.

After this intersection the terrain becomes steeper and the route passes from an embankment to a cutting and with steeper slopes.

Around progressive kilometre 4 + 120 the route passes from the municipality of Vegas del Genil to the municipality of Las Gabias, remaining here until the end of the route.

From the Cúllar - Vega intersection until practically the end of the section (progressive kilometre 7 + 200) the motorway runs through a terrain in which practically no types of buildings exist.

At the end the A-338 road is interrupted, around progressive kilometre 7+970, which is replaced by an underpass, after which is the intersection with the A-338 or Las Gabias intersection.

The type selected for this junction is the "four way" type with a roundabout at a different level and underpasses to negotiate the motorway.

This lower level roundabout has a radius of 60 m, direct slip roads exiting and accessing it from the future motorway, and two bi-directional roads that link up with two roundabouts, east and west, defined in the current corridor of the A-338 road and whose replacement was described in previous paragraphs.

At this point, the solution described in previous paragraphs has a total length of 8,713,923 m.
In general, and to finish the description of the work, it has been necessary to establish a supporting wall, between the acceleration lane in the direct direction of the intersection with the A-338 and the main road, as well as a total of 4 channels and 17 cross drainage installations, 4 of which are frames, the rest being 1,800 mm diameter pipes, to ensure the permeability of the installation with respect to the natural basins and channels the route crosses.

2. GEOLOGY OF THE SECTION

Morphologically the study area is characterized by a fairly flat topography over the first half of the route, while in the second half the topography is predominantly undulating.

The materials presented along the route correspond to a small range of geological eras that, from oldest to most recent, are as follows:

Miocene.

- *Sandy, loam soils with gypsum*: more clayey intercalated levels also appear. The gypsum forms centimetre-sized layers, although the normal ones are millimetre levels. The proportion of gypsum, as well as the thickness of its levels, grows increasingly over the kilometres. In fact, towards the end of the section, there are old gypsum quarries. This unit surfaces from the progressive kilometre 5 + 250 approximately and until the end.

- *Loam soils with gypsum and lacustrine limestones*: this unit is mainly composed of white limy soils with centimetre-thick layers of lacustrine limestones and gypsum. The limestones are characterized by abundant fenestral voids and a fine centimetre-thick stratification. This unit appears from the progressive kilometre 4 + 880 to 5+250 approximately.

- *Grey, sandy, loam soils*: these show some levels with slight centimetre-thick cementation. The thickness of this unit is about 10-15 m, although the way it appears on the surface it seems that this value is variable. This unit appears from the progressive kilometre 4 + 850 to 4 + 880 approximately.

Pliocene.

- *Loamy fine sands with stones*: this unit is characterized by loamy fine sands, with scattered centimetre-thick angular stones of a calcareous nature. It is located to the south of Santa Fé. These soils are recognized mainly by covering the smooth relief. This unit appears from progressive kilometre 2 + 700 to 4+850 approximately.

- *Loamy fine red sands with stones*: this is similar to the previous unit, but it is distinguished by its reddish colour and the greater proportion of stones that it contains. In addition, these stones, although they are carbonated, are a different type: these are paleosol (calcrete) and rhizocretion remains. This level is several metres thick (10-15 m). This unit appears from the progressive kilometre 4+140 to the 4+170 approximately.

Quaternary.

- *Mixed floodplain-alluvial fan facies deposits*: this geological unit is characterized by the presence of loamy sands with scattered stones. These stones are polygenic, similar to those contained in the alluvial deposits unit, but there are also lacustrine limestone stones. It is a transition area where both the floodplain facies materials and the pliocene materials from distal alluvial fan facies (outer fan) are mixed. This gives a mixed genetic character to this unit, and does therefore impact on its nature. This unit appears from the progressive kilometre 1+820 to 4+850 approximately.

- *Alluvial deposits*: this is a unit formed by clays, loams, sand and gravel. It occupies much of the beginning of this route. When it has been possible to observe directly, the sequence is sandy gravel at the base and 2-3 m of fine loamy sands on top, the latter being the flood plain and overflow deposits, while the former correspond to channel fillings. The thickness of this geological unit might be around 100 metres at the vertical part of Santa Fé, decreasing progressively at every progressive kilometre studied in the corridor. This unit appears from the beginning to the progressive kilometre 1+900 approximately.

- *Colluvial-alluvial deposits*: these are deposits of little thickness (1-2 m), formed generally by sandy loams and clays, of medium-soft consistency and that are produced by the alteration and redeposit of the underlying material, but with very little or zero transport. These are levels of little importance, and appear intermittently around the progressive kilometres 4+800, 5+800 and 6+300, but without being affected by the route.

- *Heterogeneous anthropic filling*: heterogeneous deposits of anthropic origin. In some places it has been observed that these fillings are recent alluvial sediments which have been placed on materials with high gypsum content to improve the crops.

3. SOURCE OF MATERIALS WITH RESPECT TO THE EMBANKMENT CORE

The materials to be used at the core of the embankments will be the soils of the Pliocene units, and partially the Miocene units, which are classified as tolerable and marginal. Given the imbalance in the filling and clearing materials existing in this section, the use of marginal materials (with gypsum) has been considered at the embankment, taking the necessary waterproofing measures.

Taking into account the geological characteristics of the materials and the possible geotechnical properties, in the absence of a full characterization of the different lithologies affected by the route, the expected use of the materials is as follows:

Summary table of materials possibly used on the route

Geological Unit	Type of soil	Use	Remarks
Sandy loams with gypsum	Marginal-Inadequate	Landfill/Core	High gypsum content.
Loams with gypsum and limestones	Marginal-Inadequate	Landfill /Core	High gypsum content.
Grey sandy loams	Marginal-Inadequate	Landfill /Core	High gypsum content.
Loamy fine sands with stones	Tolerable	Core, foundation and top	Top with prior treatment.
Loamy fine red sands with stones	Tolerable	Core, foundation and top	Top with prior treatment.
Alluvial deposits	Tolerable-Selected	Core, foundation and top	Top with prior treatment.
Mixed floodplain facies deposits	Tolerable	Core, foundation and top	Top with prior treatment.
Colluvial-alluvial deposits	Tolerable-Marginal	Landfill and core	Top with prior treatment.
Heterogeneous man-made filling	Marginal-Tolerable	Landfill and core	Top with prior treatment.

Given the geometric characteristics of the route, only the Pliocene and Miocene materials are usable, since they are the only ones that are affected by clearings. The pliocene unit of fine, loamy sands with stones is classified as Tolerable and Marginal (due to its gypsum content) according to PG3, making it a useful material for the construction of an embankment, and by taking certain precautions. Miocene materials have varying, but considerable amounts of gypsum. The gypsum content of these materials increases progressively at every progressive kilometre. These Miocene materials are classified as Tolerable and Marginal.

Given the needs for embankment material and the environmental restrictions for the location of borrow pits, the possibility of using Miocene materials of lower gypsum content (the initial part where they appear) has been considered. The use of these materials is possible for the embankment core by taking the necessary precautions, according to article 330.3.3. of the PG3, as they have less than 20% sulphates.

As for lime or cement stabilization of materials with sulphates, this will have to be ruled out. The effect of sulphates on concrete is well-known, being characterized by their reaction with soluble alumina and forming a compound (calcium aluminium hydroxide sulphate hydrate), known as ettringite and which, due to its significant increase in volume in its crystallization process, is the cause of major concrete deterioration. Since the lime stabilization process is characterized by the formation of cementitious materials similar to cement, one might consider the possible formation of ettringite in a soil with a high sulphate percentage.

However, studies on soils with lime-stabilized gypsum show how the formation of ettringite causes a decrease in resistance and swelling in the treated soil, with no more than 1% sulphates being recommended in soils treated with lime.

The high sulphate content of the soil and its expansive reactions is a factor inhibiting any improvement in characteristics of the mixtures and the implementation of stabilization processes. This is something to take into account when stabilizing the materials affected by the route, once the sections with a percentage of sulphates greater than 1% have been marked out.

The foundation will be made with fill material. Given the nature of the material that will form the core of the embankment construction, it is necessary that the upper level of the foundation fill material should always be at a height of at least 1.0 metre above the level of the previous natural terrain, to thereby prevent possible surface water flows that may occur reaching the core of the gypsiferous silts. In addition, it is also necessary to construct ditches at the tops of embankment construction slopes to prevent the surface water flow from penetrating through the embankment construction. Another measure that must be adopted is the insertion of a waterproofing sheet between the top fill material and the marginal material in the fills, while for the clearings this sheet must go under the fill materials that will form the subgrade and separate it from the natural gypsiferous terrain. The shoulders shall have a minimum width of 3 meters.

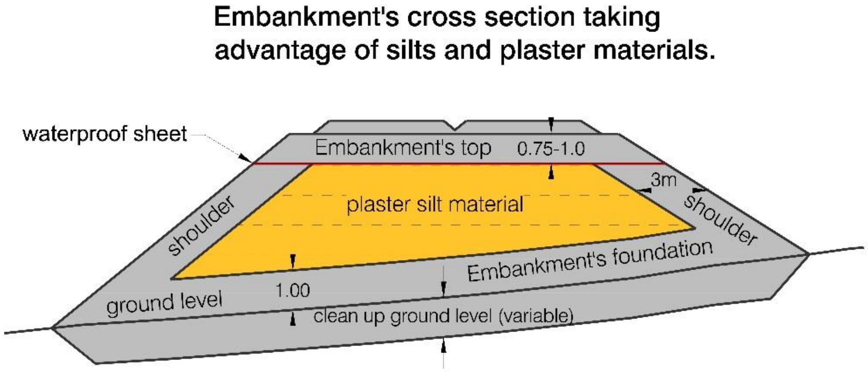

Figure 1 Embankment section with marginal materials at the core

The one metre thickness of foundation above the previous natural terrain level is justified by the height that capillary water could reach, should water appear at the base of the embankment (assumed at the height of the former topography). The following graph shows the height that capillary water can reach for different lithologies and the time necessary to reach this level.

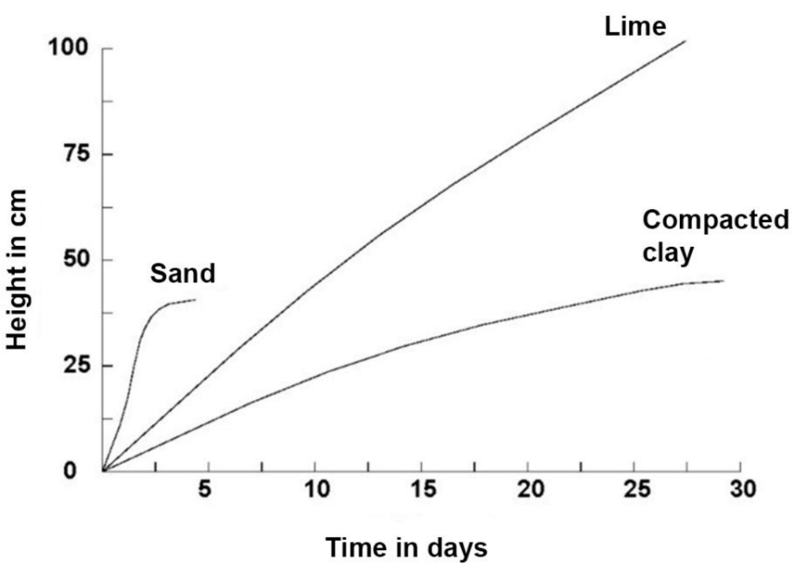

Figure 2 Capillary water height for different types

4. EARTH WORKS

Based on the characteristics of the materials to be excavated, and taking into account those required for the materials used in the construction of embankments, the excavation materials are classified according to their use or otherwise in the construction of embankments.

First of all, the vegetable soil layer must be stressed, which has a variable thickness which must be totally removed, both in embankment and clearing sections. This material cannot be used in any way for the formation of embankments.

It must be excavated and removed to a landfill or for the formation of excess excavation material prior to use, revegetation, etc. Its volume must be quantified therefore to be taken into account in the excavation unit, as well as its transport and its total quantification. But it should not be considered in the compensation process with the formation of embankments, or in the corresponding optimization.

The rest of the excavation materials have been classified in the geotechnical profile as largely INADEQUATE or MARGINAL, with small TOLERABLE percentages (according to classification O.C. 326/00).

The reason these units are classified as Marginal is basically due to the high gypsum/sulphate content of the samples tested, as well as not complying with the IP> 0.7 ratio.

The majority of the excavated materials correspond to the fine loamy sands with stones, displaying varying levels and high gypsum content, between the progressive kilometres 2+900 and 4+485, and sandy loams with gypsum, between the progressive kilometres 5+720 and 8+700.

Given the material needs for the embankment and the environmental restrictions due to the location of borrow pits close to the route, the possibility has been considered of using Miocene materials with lower gypsum content (5+720 to 6+120), and Pliocene materials between 2+900 and 4+485.

The use of these materials is possible for the embankment core by taking the necessary precautions, according to article 330.3. of PG3, as they have less than 20% sulphates.

The basic outline of the section considered for the use of these materials is shown in Figure 1.

The foundation and overbreak filling (if this is necessary) will use material that will be extracted from quarries.

As with the foundation and overbreak, the shoulders will be constructed with fill material that must be extracted from quarries, having a minimum thickness of 3 metres.

The only longitudinal adjustment to be carried out on the route will as a result be the following:

Excavation from 2+900-4+885 + Excavation from 5+720-6+180 Vs. Embankment Core (for heights over 3 m) on motorway and slip roads.

Other units will have to be brought from quarries.

5. SOLUTION ACTUALLY IMPLEMENTED

As shown in Figure 1 above, the design of the project for the encapsulation provides for the provision of a waterproofing sheet, only between the core and the fill on the top.

However, the Management has considered it necessary to expand this sheet to fully surround the marginal material in the foundation and shoulders, to ensure a compact and impermeable mass, as shown in Figure 3.

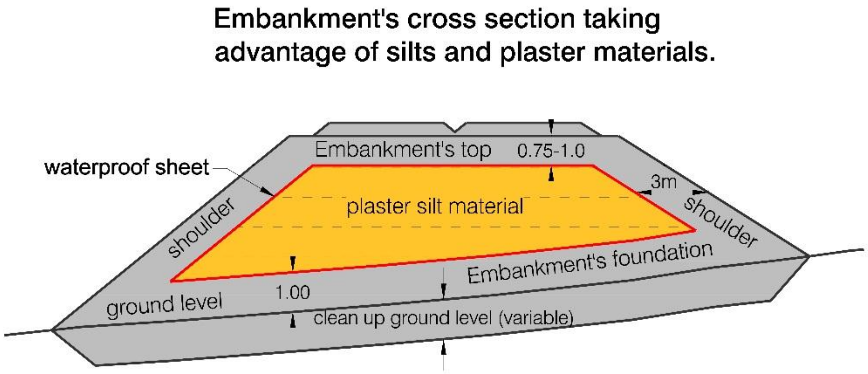

Figure 3 Embankment section actually constructed with marginal materials at the core. This is the main difference with the planned design. For everything else, the Design Project has been strictly followed

6. PECULIARITIES OF THE CONSTRUCTION

– Placement of the sheet.

Continuity between the different polyethylene sheets has been achieved by welded joints (hot air welding). These joints represent a critical point in waterproofing, and thorough checking is therefore necessary.

– Constructing the core with marginal material.

These types of materials are difficult to work with it, being necessary to apply a disintegration process beforehand to facilitate their compaction. Several test sections were required to determine the optimum wetting and the number of operations with the compactor.

7. SOME PHOTOS TAKEN IN THE PROCESS OF PLACING THE SHEET

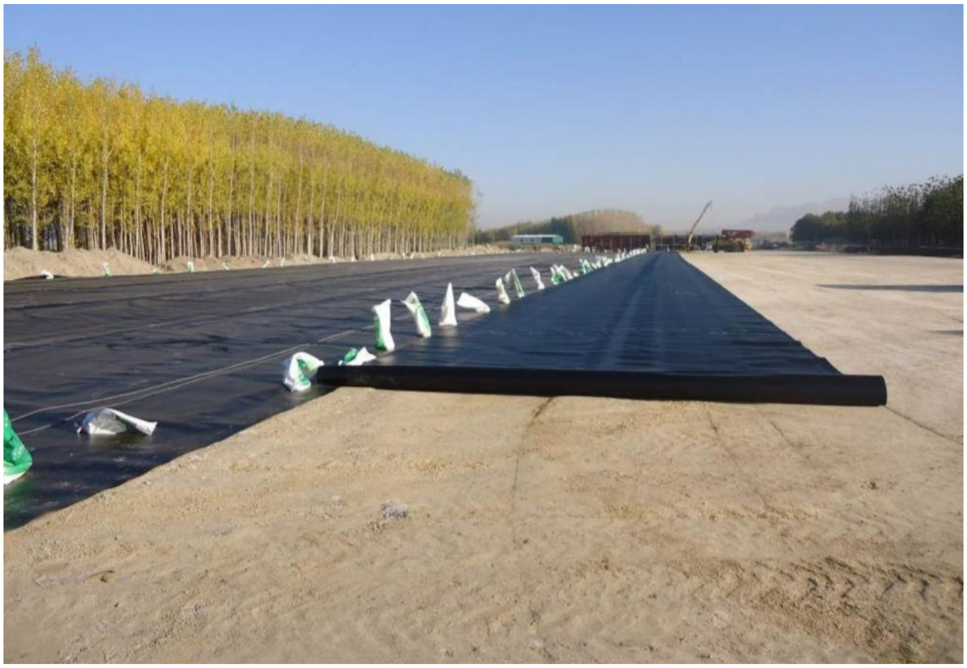

Figure 4 Sheet placed over the foundation

Figure 5 Placement of the sheet on the slope

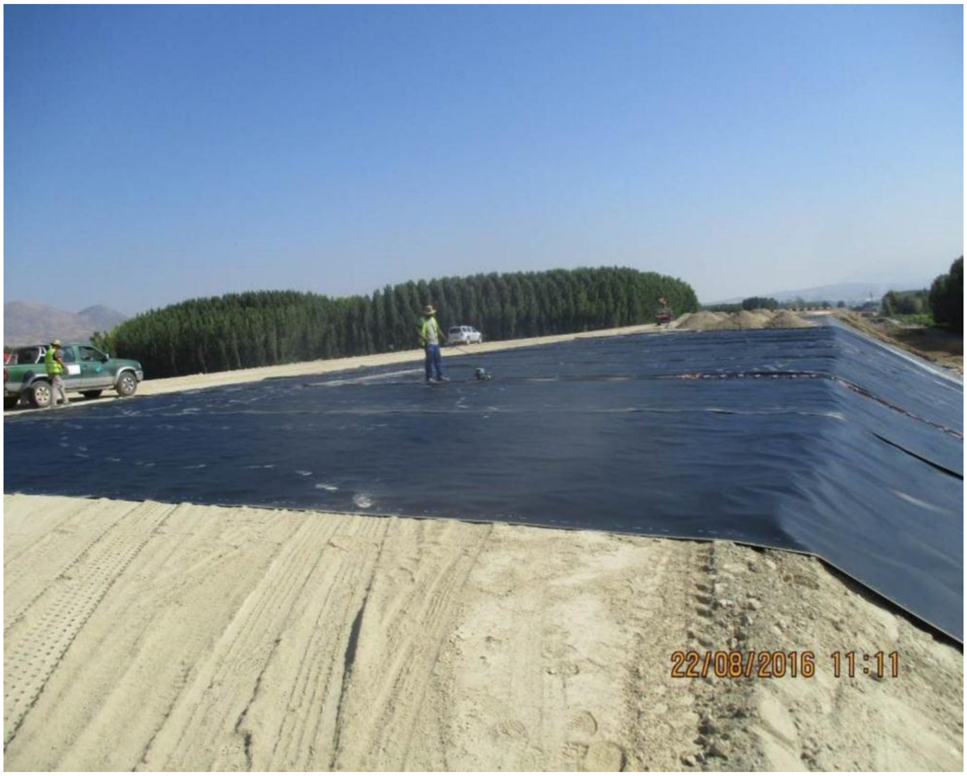

Figure 6 Execution the welded joints in horizontal

Figure 7 Execution the welded joints in the slope

Figure 8 Remodeling and clean-up of the sheet on the foot of the slope

Figure 9 General view of the execution of the shoulders