Results from the construction of a road embankment with tire derived aggregate

T. Mateos
Iberinsa, UPM

O. García
Iberinsa

ABSTRACT

This paper shows the results obtained from the construction of a road embankment employing tire derived aggregates (TDA) close to Madrid. The embankment is about 100m long and between 2 to 10m high. It was built over fluvial sediment from Jarama river. In this case soil foundation deformation was considered negligible. The embankment was instrumented with two principal purposes: to measure the deformability of the TDA layers and their temperature.

Data obtained from the embankment auscultation were analyzed with a finite element model in order to obtain realistic values of the deformation modulus of TDA layers. This analysis shows that the settlement recorded in TDA layers of this embankment is similar to data published in previous works about this topic and also they agree with laboratory test results performed with the same material, simultaneously to this project, by the Geotechnical Laboratory of CEDEX (Ministerio de Fomento).

This project is partially granted by the Environmental Ministery of Spain.

Keywords: Tires, embankment, deformability, lightweight fill.

1 INTRODUCTION

The increase of used tire waste generation -about one tire per person and year- and the implementation of new regulations which forbide the disposal of tires either in municipal solid waste landfills or in debris landfills are the main causes of the rise in nowadays shredded tires management problems. Therefore, it seems important to develop environmentally safe applications in order to improve tire derive aggregate (TDA) management according to actual needs.

In that sense, geotechnical applications such TDA filled embankments and TDA backfilled walls seems to be reliable, due to two main advantages: they use a large amount of the waste –thousands of tons of residue may be employed in a single project- and, since they are lighter than traditional construction soils, they can substitute alternative and more expensive lightweight fill materials (expanded clay, polystyrene).

The TDA filled embankment construction have been extensively developed and applied in the State of New York (U.S.A.), meanwhile in other states such California, the initiative have been applied in a more restrictive way, focusing on solving embankments foundation problems in soft soils areas. These applications are based on a ASTM standard (D-6270), which includes recommendations on building methods, geometrical considerations of TDA layers and granulometry of TDA shredded tires. The resultant embankment is a kind of layered body filled with TDA and soil. The natural soils employed in this type of fill must also fulfill the requirements of this standard.

This paper shows some of the main results obtained from the construction of a TDA embankment in a road close to Madrid. This work belongs to a broad project granted by the Environmental Ministery of Spain which also includes laboratory testing and theoretical approaches. This project have been developed by the Polytechnic University of Catalonia (UPC), Acciona i+D and Iberinsa.

2 MECHANICAL CHARACTERISTICS OF TDA

The first mechanical property of TDA to be remarked is its specific weight, which is usually between 1 to 1.27 (Humphrey, 2003), about half the specific weight of normal soils.

Compaction studies have shown that, with energies similar to the Proctor test, the final apparent density remains almost constant in a range between 6 to 7 kN/m^3. If TDA are just poured, apparent density is lower, between 3,5 to 5 kN/m^3. This is the reason for its employment as light fill both in embankment or as backfill in walls.

Compressibility has been mainly studied in oedometric conditions. Tests from Ahmed (1993) results in values for the compressibility index (C_c) between 0,11 to 0,22 if the material has been previously compacted. If the TDA has been just poured the value for C_c is about to 0,25. These values are similar to those of soils of medium to high compressibility. In the case of unloading (C_s) – reloading (C_r) indexes, values are higher than usual for soils, being more similar to values in loading (C_s = 0,11; C_r = 0,19). Consequently, a great part of deformation will be recovered in unloading this type of material.

Moreover, there are evidences of rigidization or strain hardening as have been shown for example by the oedometric tests done by the Geotechnical Laboratory of CEDEX (2007, internal report).

Shear strength have been studied in laboratory by direct shear tests and triaxial tests. Results have been very scattered due to the size of TDA pieces related to the size of the tests equipment, problems with the membrane of the cell in triaxial test, etc. However. at UPC laboratory it has been possible to take out reliable tests with a material similar to that used in the embankment construction (Munuera et al, 2008).

Also, as a part of this research project, direct shear tests have been performed. Some results have been included in Arroyo et al (2007).

Another important property of TDA is its permeability, which is about 1 cm/s, and makes this material useful as drainage layers. The influence of loading in this parameter is discussed elsewhere (Garcia & Mateos, 2008).

Finally, it is worth to remember that the use of TDA in civil engineering has been sometimes related to development of internal heating reactions. After three fire failure experiences, the FHWA constituted a study group directed by Professor D.Humphrey of Maine University. The principal conclusions of these works were included in ASTM D-6270. Since the approval of this standard more than 70 embankments have been constructed in USA without any problem related to internal heating reactions.

3 EMBANKMENT DESCRIPTION

The TDA were employed in an approach embankment to a bridge crossing a new road built over the Jarama terraces, north to Madrid Airport.

It has a maximum height close to 9 m and is about 140 m length. It has been built over a soil formed by terrace sediments constituted by sands and gravels. These materials lay over terciary sediments. Those soils are though to be rigid enough to be considered almost incompressible in relation to TDA. This makes easier to relate the settlements measured to the TDA deformability.

The building process and final geometry of the embankment was defined according to ASTM D-6270. Depending upon the height of the embankment two sections were defined:

Section I.- the maximum height of the TDA layer is 2 m.

Section II.- in the higher section of the embankment it has two TDA layer. The bottom layer is about 2 m thick while the upper layer is about 1 m high.

TDA layers must be always wrapped by a soil layer at least 1 m thick and a geotextil to separate soil particle from tires. In Figure 1 both sections are showed.

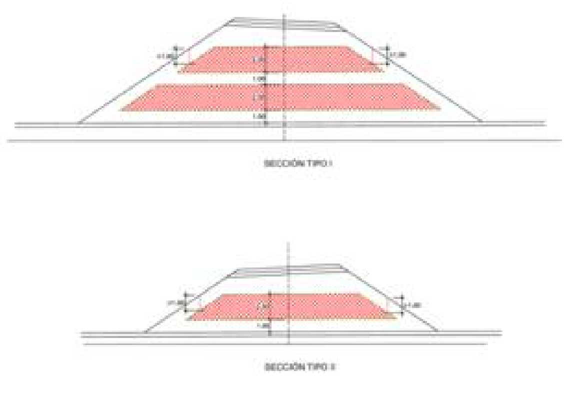

Figure 1Embankment section.

The granulometry of the soil employed in the construction has been similar to the required one in ASTM D-6270, but with a smaller fine content. This requirement is related to the capacity of the soil to be enough impervious to avoid water to reach the TDA layer. In order to be safe in this aspect the TDA layers were enclosed by an impervious geotextil. Usually, if the soil granulometry fulfill the standard, it is enough to wrap the TDA layer with a separation geotextil to avoid mixing between the soil and TDA.

Previously to the constructions it was defined a procedure to check the quality and characteristics of tires. This procedure was applied to the tires employed in the embankment construction and it was also a test of the procedure to be accomplish in other similar works.

In Figure 2 it can be seen how the TDA layer was compacted.

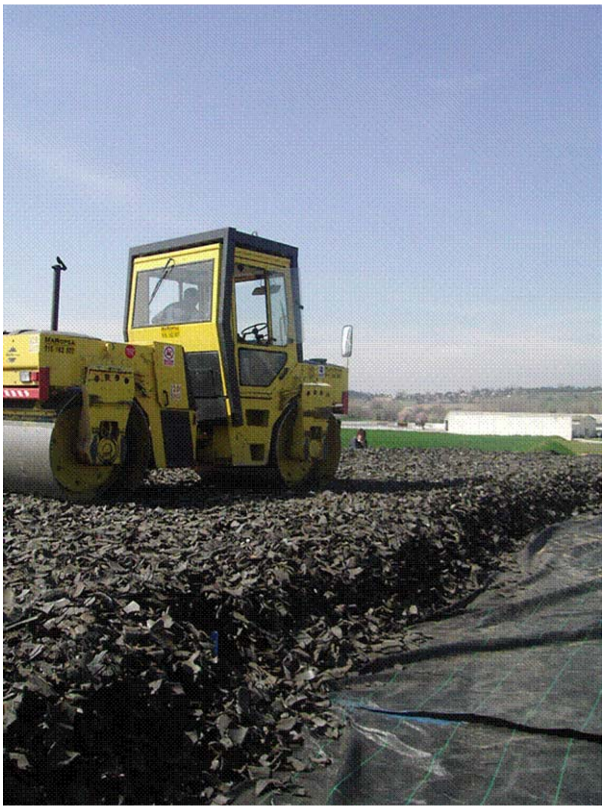

Figure 2. TDA layer construction.

Due to the development of the construction of this road the total building of this embankment delays for almost six months. During this time, settlements and temperature were measured.

4 RESULTS

The embankment was instrumented in order to record settlement and temperature in the TDA layers. The main results obtained are shown below.

4.1 *Settlements*

Settlements were recorded for almost six months at the same time the embankment was built. Figure 3 shows data corresponding to an horizontal inclinometer situated in a two TDA layer section, immediately over the lower one. For this reason values of settlement measured only belong to the deformation of this layer of TDA, not to the upper one.

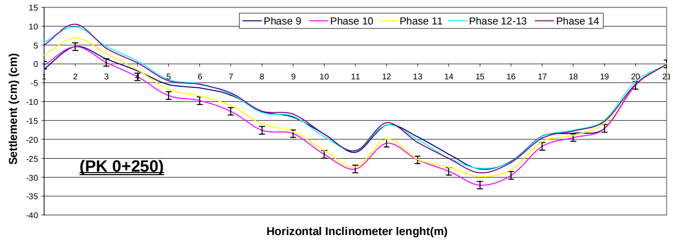

Figure 3. Embankment settlement recorded.

Maximum settlement value measured at the end of construction is between 20 to 30 cm. It has been no possible to establish the temporal development of settlement in relation to load increments. For this reason, we have had to relate the total vertical movements registered in this embankment section with total stress applied over this layer and to deduce the total deformation in the embankment from a finite element model.

4.2 *Temperature*

Temperature was recorded in several points in the inner of TDA layers for all the construction period and continues on. These data show that temperature remains almost constant all over the record in the lower layer. In the upper TDA layer temperature changes less than 4 degrees (ºC) meanwhile temperature in the soil changed from 13ºC to 21ºC, since the beginning of May to the end of June.

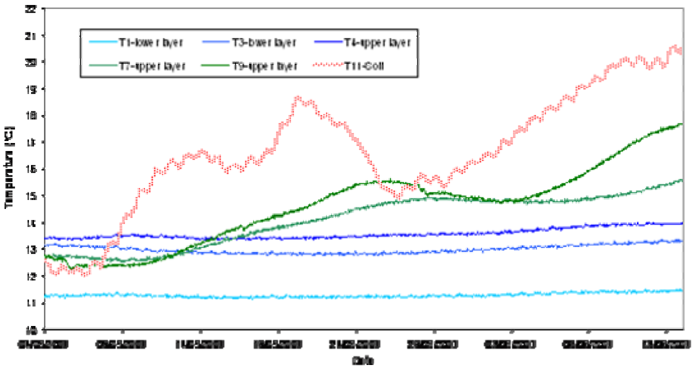

Figure 4. Temperature record.

5 SETTLEMENT MODELIZATION

Settlement modelization was performed by a finite element model employing PLAXIS. The aim of this model was to reproduce a settlement in the lower TDA layer similar to the measured magnitude.

Parameters for the soil placed around TDA layer were characteristic values for the soil employed (c' = 10kPa, ϕ' = 32º, E = 20MPa). In the case of TDA the constitutive model selected was lineal elastic and deformation modulus was obtained by a successive approximation method until getting the value of settlement measured. Although the model for TDA was lineal elastic, calculations were done by phases reproducing the sequences of construction.

Figure 5 reproduces only the settlement value developed in the body of the embankment due to the construction of its upper part. The total vertical movement in the top of the embankment is about 35 cm.

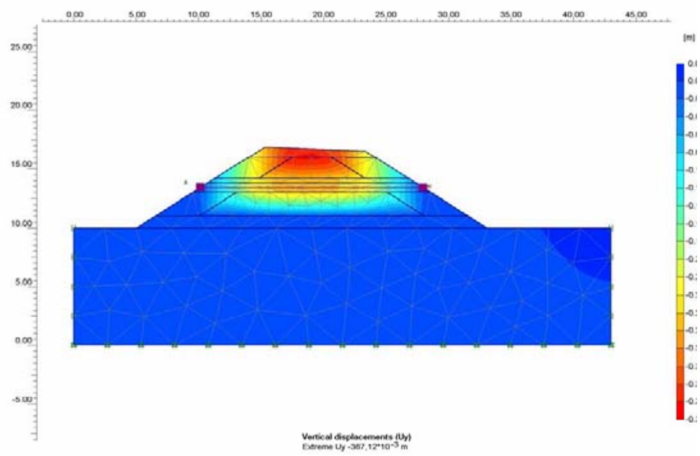

Figure 5. Settlement due to the construction of the upper part of the embankment.

In the next figure we have shown the settlement that would have been developed in the lower TDA layer due to the construction of the upper half part of the embankment. The value for this settlement obtained in the model is about 25 cm, which is very close to the measured value.

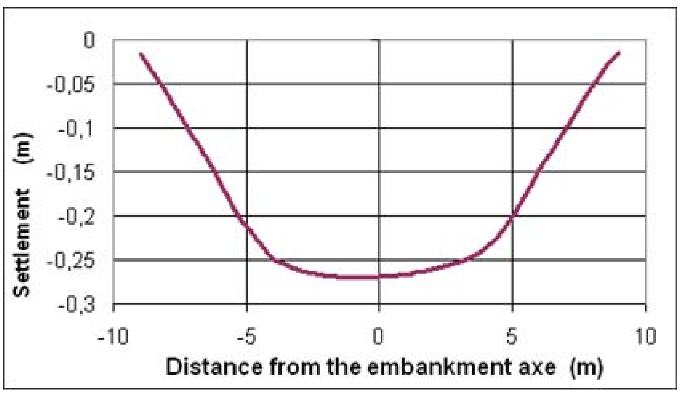

Figure 6. Settlement in the lower TDA layer.

Finally, in these conditions total settlements that the model predicted that must have developed in the embankment during its construction are about 47 cm (Figure 7).

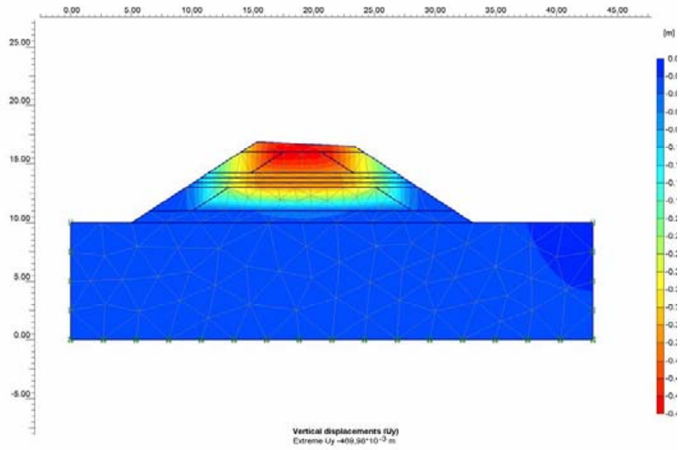

Figure 7. Total settlement in the embankment.

It has been impossible to confirm experimentally this last value due to the velocity of strain development in TDA layer, which has been quicker than the construction of the embankment. This means that as the same time the embankment was growing the TDA layers were deforming, so successive soil and TDA layers must have been constructed always thicker than they were designed.

All these results were achieved employing a deformation modulus for the TDA layers of 350 kPa. This value is similar to that obtained in "oedometric" tests carried out by the Geotechnical Laboratory of CEDEX (2007) for a similar vertical stress.

It was observed that settlement development was almost immediate, because of that it was not possible to record this movements due to the fact that the embankment was growing up as the same time that TDA layer settles. So, it must be recognized that in this type of fill it must be prevented an extra volume of soil to accomplish with the final height of the embankment according to the type section in the project, as it is sometimes done for embankments over soft soils. This extra volume of soil can be estimated from the expected deformation of TDA layer, so it is important to do a reliable prediction of its deformation modulus.

In the case studied a deformation of about 14 to 20% was modeled for the lower layer and between 4 to 8 % for the upper layer. These results were close to that recorded for another embankment with a very similar TDA layer geometry (Humphrey et al, 1998, 2000. Humphrey, 2004). In this last example an embankment about 10 m height with two TDA layer, each about 3 m thick was built. At the end of the construction the value of the strain measured was about 15.6% for the lower layer and 10% for the upper one. Building procedures in both cases were also similar. So the recorded settlement seems to be coherent with previous experiences.

6 CONCLUSIONS

This work includes the main results obtained from the construction and instrumentation of a road embankment with two TDA layers.

The embankment construction and TDA and soil selection were done according to ASTM D-6270. This standard were written in order to prevent fire risk and to get enough stable fills.

The maximum settlement value recorded by an horizontal inclinometer situated over the lower TDA layer was about 25 cm. From this value and with a finite element model it has been possible to obtain a value of the deformation modulus for TDA layers of about 350 kPa. This result is similar to others obtained from laboratory tests and from experimental embankment published by other authors.

Strain data obtained from the finite element model have been compared with results from another very similar embankment built in Maine (USA). It has been found that strain data from both cases are very similar.

Finally, just to say that one year after the embankment construction and about eight months after it was open to traffic no deformability problems have been generated.

ACKNOWLEDGEMENT

The experimental embankment described in this paper was partly supported by the research funds of the Spanish Ministry of the Environment through grant 197/2006 2.5-2. The authors are grateful ACCIONA Infraestructuras and the Soils Engineering Department of the Polytechnic University of Catalonia, partners in this project.

REFERENCES

ACCIONA Infraestructuras, Iberinsa & UPC. 2005-2007. Shredded scrap tires fills: mechanical properties and construction applications. R+D Project funded by the Spanish Ministry of Environment. Grant No. 197/2006 2.5-2.

Ahmed, I (1993) Laboratory study on the properties of rubber soils, PhD thesis, Purdue University.

Arroyo, M., Estaire, J., Sanmartin, I. & Lloret., A. 2007. Size effect on tire derived aggregate mechanical properties. International Workshop on Scrap Tire Derived Geomaterials (TDG) – Opportunities and Challenges. Yokosuka (Japón).

Estaire, J. 2007. NFU characterization. Internal report (CEDEX).

García. O. & Mateos, T. (2008) “Use og tire derived aggregate in landfill’s drainage systems”. Euroengeo 2008. Madrid (Spain).

Humphrey, D.N., Whetten, N., Weaver, J. & Recker, K.(2000) “Tire shreds as lightweight fill for construction on weak marine clay” Procc. of the Int. Symposium on coastal Geotechnical Engineering in Practice. Balkema, Rotterdam, pp. 611-616.

Humphrey, D.N. (2003) Civil engineering applications using tire derived aggregate (TDA), California Integrated Waste Management Board.

Humphrey, D.N. (2006) “Course on: Civil Engineering applications using tire derived aggregate (TDA)”. Sponsored by: California Integrated Waste Management Board.

Munuera, J., Lloret, A. & Arroyo, M. 2008. Caracterización del comportamiento mecánico de neumáticos troceados. UPC.