Contributions for standardisation of plate loading test

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INTRODUCTION

The static loading plate tests have been done in different engineering works and particularly in earthwork quality control. At Portugal AFNOR NF P94-117-1 and DIN 18134 standards are frequently used for this purpose. These standards differ on the test protocol and on test interpretation, which reflects on the final elastic modulus obtained. Attempting the importance that this parameter assumes on quality control of embankments layers, there is the need to clarify the interpretation of test results following each standard and to compare their results.

In the aim of a national research project POCI/ECM/61114/2004, entitled "Interaction soil-rail track for high speed trains", financed by the Portuguese Foundation for Science and Technology, it was established a protocol between the National Railway Network (REFER) and four national research institutions (University of Minho – UM, National Laboratory of Civil Engineering – LNEC, New University of Lisbon – FCT-UNL and Technical University of Lisbon – IST) to develop the knowledge concerning the methodology for the construction and control of the railway embankments and railtrack layers for high speed trains. One of the objectives of this protocol was the interpretation of results of plate loading tests following standards AFNOR NF P94-117-1 (plate of 600 mm) and DIN 18134 (plate of 300 mm) and the comparison between them, in order to develop a specification of this test to be used as a reference method in Portugal by REFER. To reach this goal it was constructed a trial embankment in the railway of the Évora railway line, about 2,5 km far from railway station of "Monte das Flores", and a test campaign was performed between October and November of 2006.

In the trial embankment materials similar to the ones used on the new Évora railway line were employed. Two types of materials were used: soil, for the embankment layers, and crushed aggregate for the sub-ballast layer (fig. 1). This embankment was constructed above a foundation layer with 0,60 m thickness, compacted in two layers of 0,30 m each. Different layer's thicknesses (30cm, 40cm, 50cm) and different moisture contents (w-2%, wopt, w+2%) were used for the embankment layers.

PLATE LOADING TEST (PLT) ACCORDING AFNOR NF P94-117-1 STANDARD

This standard specifies a method which permits the relationship between load and settlement (load-settlement curve) to be determined, the aim being to assess the deformation and strength characteristics of soil and to determine the deformability modulus (NF P 94-117-1 2000).

The test consists in the application, after a pre-load, of two successive loading cycles on a plate with stiffness and diameter normalized. For a 600mm diameter plate (fig. 3a), the first load cycle should correspond to a 0,25 MPa stress under the plate and this stress maintained till the plate's settlement stabilization. Following, the load is release at once. In the second load cycle it should be reach a stress under the plate of 0,20 MPa. The load release should be done only after the plate's settlement stabilization, as the first load cycle.

The deformability modulus, Ev2, is calculated to the second loading cycle using Boussinesq solution and secant method (fig. 1) as follows:

$$E_{V2} = \frac{\pi}{2} \cdot \left(1 - \nu^2\right) \frac{p \cdot r}{z_2} \tag{1}$$

where ν is the Poisson ratio, r is the radius, p is the normal stress below the plate and z2 is the settlement of the plate.

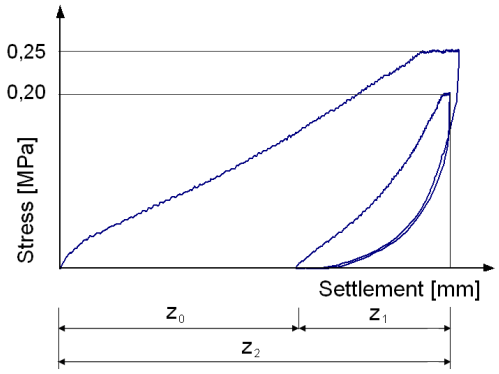


Figure 1. Interpretation of Static Plate Loading Test (*PLT*) following standard AFNOR NF P94-117-1)

PLATE LOADING TEST (SPLT) ACCORDING DIN 18134 STANDARD

As the AFNOR standard, the DIN 18134 standard specifies a method to determine the deformability modulus, EV, which is different of AFNOR.

To determine the deformability modulus, EV, the load should be applied in not less than six stages, in approximately equal increments, until the required maximum normal stress is reached. Each increase in load (from stage to stage) shall be completed within one minute. The load shall be released in stages, to 50 % and 25% of the maximum load and then to the load corresponding to the zero reading. Following that, a further (2nd) loading cycle shall be carried out, in which the load is to be increased only to the penultimate stage of the first cycle.

A 300, 600 or 762 mm loading plate can be used. To determine the deformability modulus for design calculations the load shall be increased until a settlement of 5, 8 or 13 mm, or a normal stress below the plate of 0,50, 0,25 or 0,20 MN/m2, respectively, is reached. If the required settlement is reached first, the normal stress measured at this stage shall be taken as maximum stress. A 300 mm diameter plate was used.

The strain modulus, Ev2, is calculated to the second loading cycle using the tangent method (fig. 2) as follows:

$$E_{V2} = \frac{1.5 \cdot r}{a_1 + a_2 \cdot \sigma_{0\max}} \tag{2}$$

where r is the radius, σ_{0max} is the maximum average normal stress below the plate and a_1 and a_2 are factors of the smooth load settlement curve.

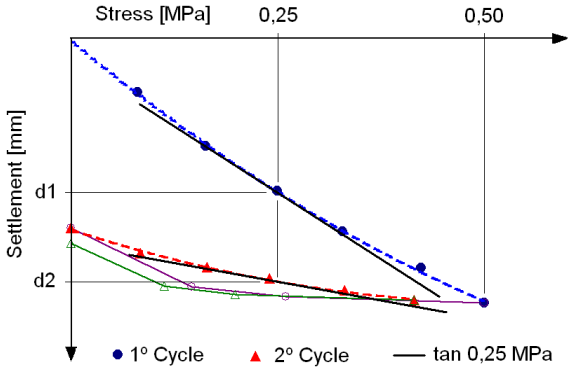


Figure 2. Interpretation of Static Plate Loading Test (*PLT*) following standard DIN 18134

COMPAIRISON OF STANDARDS RESULTS AND CONCLUSIONS

Examining each of the standards it was found some differences in interpretation of test results, two of which are highlighted: i) the stress value below the plate for which the Ev2 modulus is different; ii) the method used to determine the Ev2 modulus is different (DIN - tangent method; AFNOR - secant method). Therefore, to compare directly the values of the moduli Ev2 of materials that exhibit nonlinear behavior, it must be obtained for the same stress level below the plate and using the same method of analysis. Otherwise, advanced analysis is necessary using numerical inverse techniques.

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