A BRIDGE FOUNDATION ANALYSIS

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Abstract. *This document presents the analysis with CODE_BRIGHT finite element program of a geotechnical case. The problem analyzed is related to a mechanical analysis of soil-structure interaction considering different alternatives for the foundation of a bridge in El Prat de Llobregat (Highway A-2)[i]. The comparison of displacements shows that an alternative solution using shallow foundations can be considered in addition to the originally proposed, composed by sheet walls.*

1 INTRODUCTION

In order to validate an alternative design for the foundation of a bridge at the Highway A-2 (see general map in Figure 1.a) different solutions have been analyzed geotechnically developing appropriate numerical models with the finite element program CODE_BRIGHT[ii].

With the geotechnical analysis performed under different assumptions of calculation it is shown that the shallow foundation (concrete box and strip footing; see Figure 2.b), probably less complex and costly than the deeper one (sheet wall; see Figure 2.a), also satisfies the requirements of stability and strength needed while keeping displacements small.

Furthermore, is not unusual to find potholes near the bridge access, generated by the stiffness of the support structure against the settlements of the embankment on the access areas. The contact between the soil and the structure may develop shear stresses which limit the consolidation of the soil near the structure. This may produce an abrupt change on the pavement surface. The found behavior for shallow solution shows that the displacements can be in these zones smoother than in the case of deep foundation, thus reducing the bump effect of the potholes.

The cases have been calculated including plastic behavior (with Cam-Clay model in some materials) and elastic behavior for others. In addition, the presence of groundwater has also been considered in the analysis.

2.1 Model features: materials, properties and tension solicitations

Different laboratory tests carried out on samples taken from soil and characteristic properties have been selected for each material[iii]. The soil types that appear in the test area, according to information drawn from surveys (see geological section on Figure 1.b) can be classified into three types: anthropic fills (a way to describe recent filling materials of different origins), sand with a variable content of fines, and gravel with sand. Anthropogenic filling has a high dispersion of parameters; this dispersion on the values forces us to assume conservative values. The replacement of the bad quality filling material below the foundation by clean gravel (see Figure 2.b and Table 1 for the parameters) that contributes to a better behavior generating less and uniform settlement has also been considered. Furthermore,

another material for the leveling of the surface has been considered, adequately compacted and suitable for the layer required under the pavement. The properties and parameters that have been assumed for the materials that compose the different types of model materials are shown in Table 1.
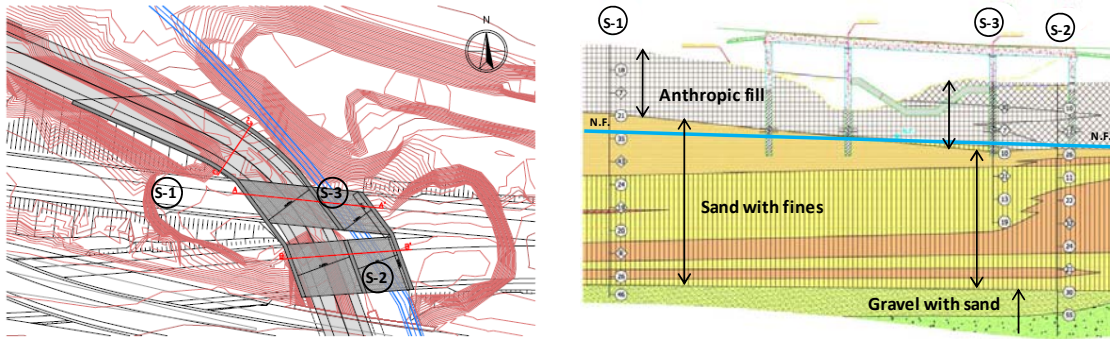

Figure 1: a) General location, **b**) Geologic section of the soil.
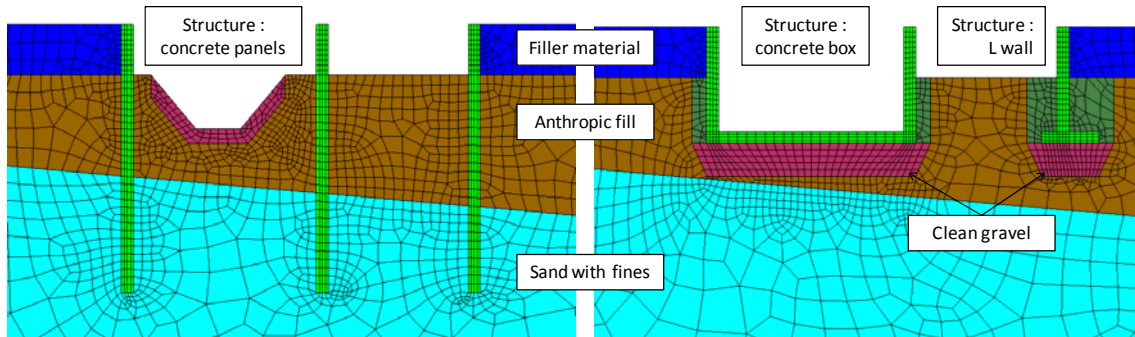

Figure 2: Geometry and finite element mesh of cases to analyze: **a**) Deep foundations with sheet wall, **b**) Shallow foundations with box and strip footing.

Table 1: Constitutive parameters of the materials

Parameters	Materials					
	Anthropic fill	Sand with fines	Gravel with sand	Concrete	Clean gravel	Filler material
E	(5.5 MPa)	-	150 MPa	25000 MPa	15 MPa	50 MPa
ϕ'	26°	28°	-	-	-	-
M	1.03	1.13	-	-	-	-
C_c	0.15	0.12	-	-	-	-
C_s		0.0135 (*oc*)	-	-	-	-

In Table 1, E is the Young Modulus: it has been obtained from a geotechnical report or suitable for the objective and conservative evaluation; ϕ' is the effective friction angle: the adopted values are the most conservative values from the different tests and has been considered that cohesion is negligible in all cases; C_c is the compression index; C_s is the swelling index: shows that the material for the sand with variable presence of fines has a bit of overconsolidation, M is the slope of the critical state line in the plane of invariants (this is, the relationship between isotropic and shear stresses). Poisson ratio value is considered 0.3 for the soil materials and 0.15 for the concrete.

Anthropic fill and sand with variable content of fines soils have been considered with plastic behavior. This means that shear strength (*M*) and plastic compressibility are required (C_c or λ).

Self-weight of the structure, a distributed load due to normal traffic and point loads due to the presence of a heavy vehicle have been considered in the analyses. The values to be applied on the vertical structures (Figure 2) derived from these three types of loads are shown also in Table 2. The final stage of calculation and the results obtained below correspond to the combination of all these three loading types, i.e. maximum loading conditions.

Table 2: Value of the applied loads

Load Type	Central Support	Central Support	Right Support	Units
Self-weight of bridge: 15 kPa	98	173	75	kN/m
Traffic loads (distributed): 8 kPa	52	92	40	kN/m
Heavy vehicle (point): 600 kN	86	86	86	kN/m

2.2 Results

Figure 3 shows a comparison of displacements obtained from the analyses, considering the self-weight, permanent loads over all surface and the point loads over the three supports. Displacements are somewhat larger for the case of shallow foundation that is in more solidarity with the ground settlements.
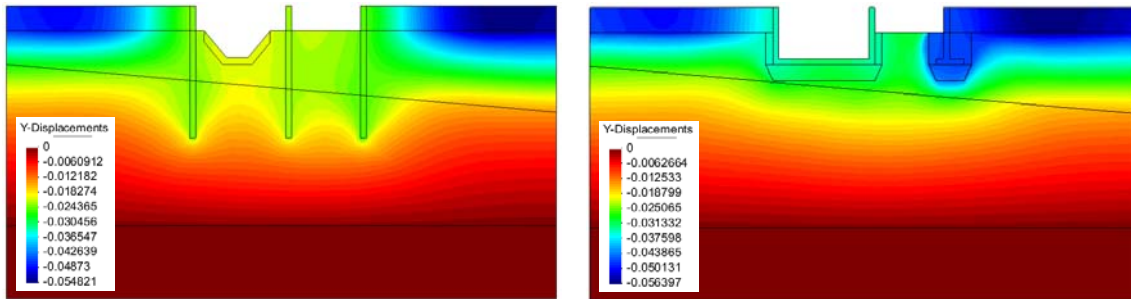

Figure 3: Vertical displacement for the plastic analysis.

In order to illustrate the critical zones in this type of problems, Figure 4 and Figure 5 show the distribution of volumetric and shear plastic deformations generated by the overloading. In the case of sheet walls plastic deformations concentrate around the end of the sheet indicating the zone of support (local failure with a plasticized bulb). In the case of shallow foundation, the gravel fill transmits a stress that produces plasticization of the soil. This plasticization is local and does not show a global failure mechanism.
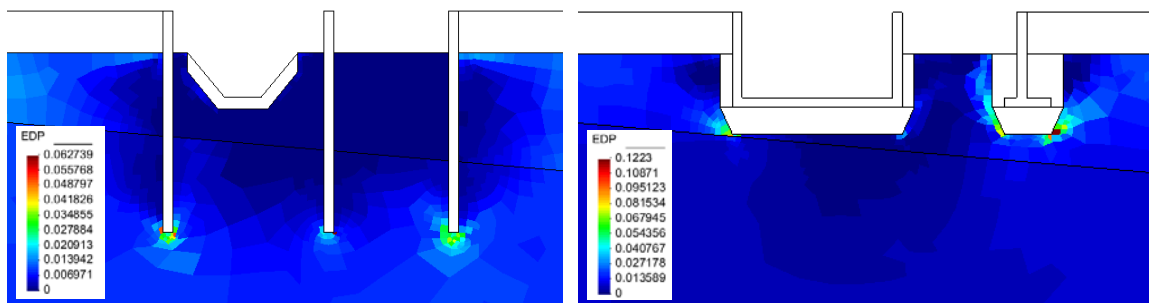

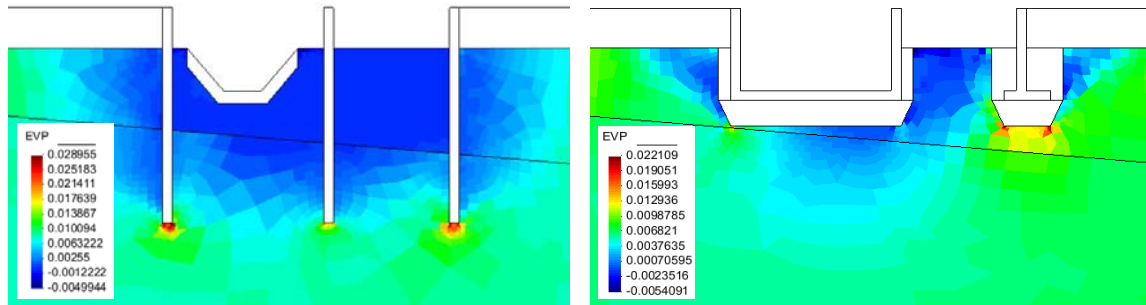**Figure 4**: Shear plastic deformation due to the overloading.

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Figure 5: Volumetric Plastic deformation due to the overloading.

The results of the vertical displacements calculated with a model that considers the presence of water in the ground according to the geological section shown in Figure 1, are presented in Figure 6. Displacements are similar than in the case of dry soil, but shear deformations show a somewhat different distribution.
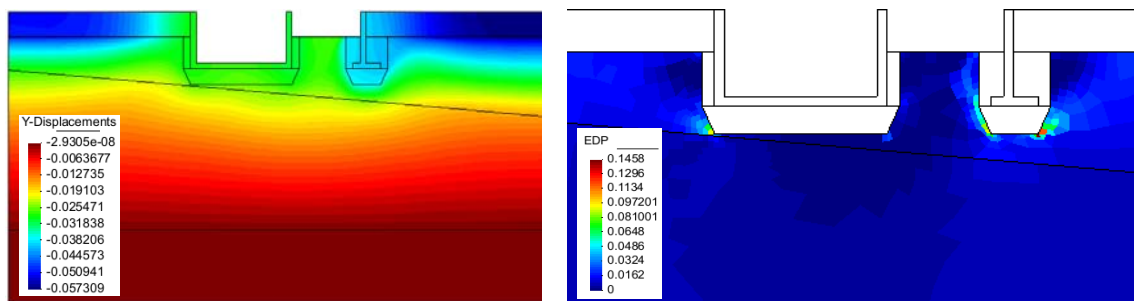

Figure 6: Vertical displacement and plastic strains for the case in which groundwater is considered.

2 CONCLUSIONS

CODE_BRIGHT has proved to be an appropriate tool for calculating the mechanical and comparative analysis of the proposed cases. From the results it seems that the solution by shallow foundations is as valid as the one composed by sheet walls to support the structure and to keep movements in normal range. The final results of the settlements show that the solution by shallow foundation produces movements of the ground surface more uniform than in the case of the sheet walls. This is expected to reduce the effect of potholes that eventually may appear near the entrances of bridges.

3 REFERENCES

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[ii] CODE_BRIGHT, Manual, User's Guide, accessible at:
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