Analysis of constructive pathologies of a building constructed on expansive ground and repair proposal

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1. Introduction –

The present paper provides firstly, an analysis of constructive pathologies of a building constructed on expansive ground; secondly, a study of the differential movements caused by the foundation, the angular distortions of the structure and masonry as a consequence of the stress increase, and thirdly, a general behaviour of the structures and foundation towards the deformation. We have used as a reference the studies from Sowers, G.B. and Sowers G.F. 1993, Skempton, A.W. and MacDonald, 1956 Burland, J. B., and C. P. Wroth 1974, and Building Code CTE-DB-SE-C.

For this analysis, we provide as a case study the repair proposal project on the housing development located on block 4 PP G-4 UE-1, Guillena, Seville, by assignment of the owners association.

1.1. Constructive characteristic of the building.

The building designed consists in a construction of 27 attached housing placed in a plot with an area of 3.216,71 m2. The plan is composed of six types of housing, being the type analysed on this paper a building with two floors with an interior and exterior courtyard, and a built area of 119.38m2.

The structure is designed through concrete reinforced porticos fixed in two directions, forming a hyperestatique structure. The timbers floors are built with unidirectional planes of semiresistant joists and concrete filler blocks of 25+5cm deep.

The foundation is executed by a structural concrete slab of 40cm deep and upper and lower reinforcement of Ø12mm every 20cm. The foundation is built over a compact ground layer of pipeclay of 50cm deep, and 50cm of gravel layer.

From the geotechnical study carried out in the plot, we detect an expansive ground formed by clays and slime, whose active layer is 4 metres deep, and a swelling pressure of 1.5Kp/cm², which corresponds to a high expansivity level.

1.2. Damage analysis

We confirm that the buildings show a generalize damage by fissures in the interior masonry wall, and cracks in the outward facing facades with values between 1 to 8mm, whose inclination indicates a differential settlement in the perimeter of the building with the courtyard.

We also perceive damage caused by the increase of the thickness joints flooring on the area affected by the foundation deflection, as well as the racking of the carpentry, windows and doors.

The following schematic pictures, Figures 1 and 2, show the location of the damage, and the thickness, direction, and inclination of the cracks.

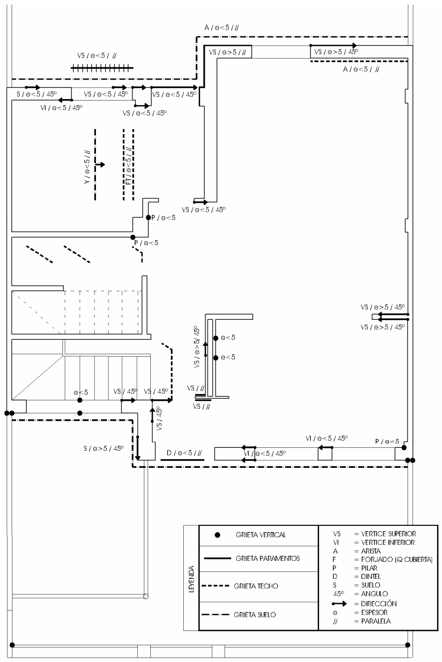

Figure 1. Graphic representation of the damage on the ground floor

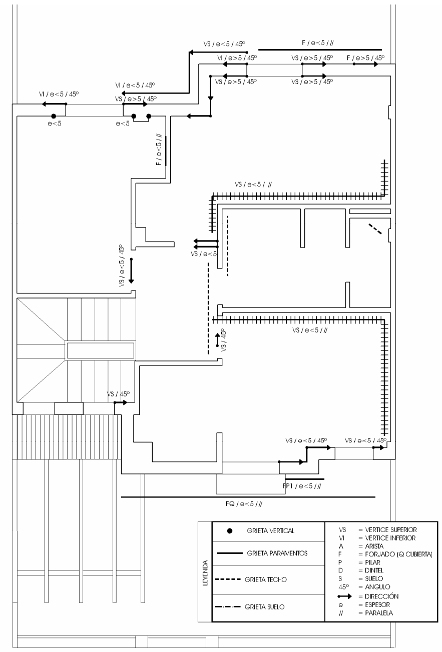

Figure 2. Graphic representation of the damage on the first floor

2. Experimental –Building Code CTE-DB-SE-C establishes the maximum admissible values of angular distortion for the Serviceability Limit State, S.L.T, L/300, where "L"is defined as the distance between pillars, and S.L.T. as the *"excessive foundation movement that can induce abnormal stress and deformations in the rest of the structure that rests on them. Although they do not break it, this affects the building appearance, the users comfort, or the equipment and facilities operation"*.

The distortion values between L/300 and L/150 would exceed the values established for the S.L.S. and therefore, it would cause damage that would affect the normal use and operation of the building.

Nevertheless, the coefficients of the material safety used for calculating the structure, the magnification loads coefficient and the high overload values established by the technical norms, allow an elastic behaviour of the materials, concrete and steel. Consequently, this distortion values do not involve a risk to the structural stability.

Finally, according to the bibliographic referencing shown in tables 1 and 2, the distortion values higher than L/150 would cause a greater strain than the characteristic resistance of the material. As a consequence, this would generate a plastic behaviour that could affect the structure stability contributing to total or partial collapse of the structure, behaviour defined as Ultimate Limit State, U.L.S.

The abacus in figure 3 relates the maximum angular distortion for the S.L.S. and the U.L.S. with the distance between pillars and the differential movement. The shaded area in the chart placed between the distortion values L/300 and L/150, represents the differential movement that, although it causes damage in the building, it doues not involve a risk to the structural stability.

bibliography reference	Angular distortion
CTE DB SE C [1]	L/300
Sowers 1993 [2]	L/250-L/400

Table 1. Admissible angular distortion in concrete structure

bibliography reference	Angular distortion
Skempton y Mcdonald 1956 [3]	L/150
Bjerrum 1963 [4]	L/100

Table 2. Excessive angular distortion in concrete structure

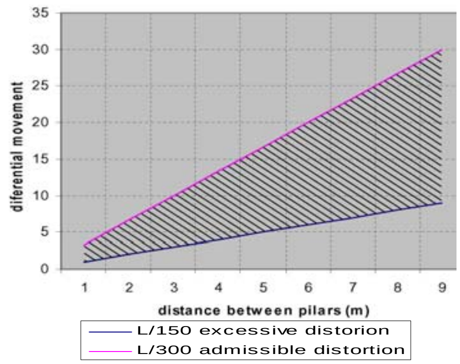

Figure 3. Abacus to relate the angular distortion L/150 y L/300 with the distance between pillars and the differential movement

In order to analyse the cause of the differential settlement of the foundation, and his possible effect on the structural stability, we carried out a topographic levelling of the ground and first floor, using a self leveling laser with millimetre precision and interpreting the values obtained from level curves, according to Figures 3 and 4.

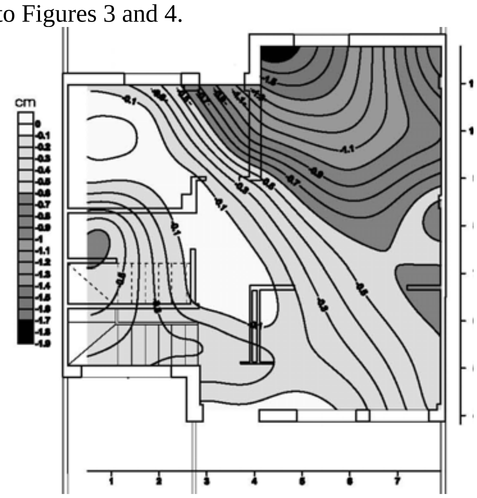

Figure 3. Topographic levelling of ground floor.

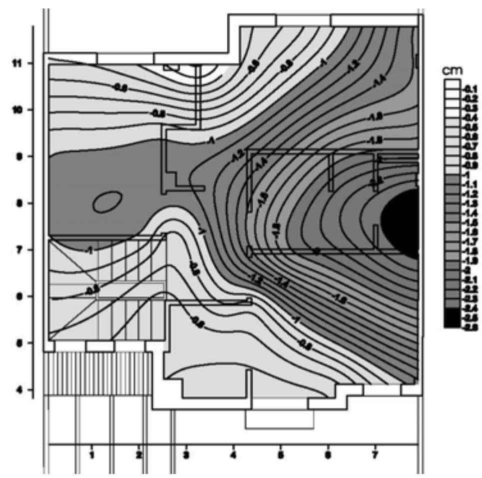

Figure 4. Topographic levelling of first floor

3. Results and Discussion. Through the topographic levelling we cand determine the location and the values of the differential movement, which will help us to deduce the cause of the damage. Therefore, we can establish the structural deformation to analyse the effect on the structure stability, comparing it with the reference values for S.L.S. and the U.L.S., as shown in Table 3.

Floor	Portico	Distance between pillars	Differential settlement	Angular distortion	S.L.S		U.L.S	
					value	TESTING	value	TESTING
Ground floor	P5 - P4	2,50m	1,1cm	L/227	L/300	fail	L/150	OK
	P1 - P4	5,30m	2,2cm	L/240	L/300	fail	L/150	OK
First floor	P5 - P4	2,50m	0,8cm	L/312	L/300	OK	L/150	OK
	P1 – P4	5,30m	2,0cm	L/265	L/300	fail	L/150	OK

Table 2. Maximum angular distortion calculated

According to the previous data, we deduce that the differential settlement is concentrated in the interior façade which adjoins with the garden courtyard, area which allows the filtration of the rain water and irrigation water to the ground.

The change of the ground humidity condition caused by the water filtration implies a change in its volume, due to the high expansive levels of the clays.

As a consequence, the low inertia of the surface foundation and the absence of the rigidity ground-structure, allows the deflection of the structure against the change of the ground volume.

4. Conclusions – Taking into account the previous results from Table 3, we conclude that all the angular distortions caused by the differential movement are lower than the limit values for the U.L.S. and therefore, they do not affect the structure stability.

For these reasons the repair proposal will be focused on the cause of the damage in order to reduce the humidity change and thus, the volume change. In order to do that, a drain trench is designed along the interior perimeter of the housing, according to Figure 6.

Moreover, in order to prevent the absent of the foundation support after the settlement of the foundation, we propose a repair by expansive mortar injection on the ground with three levels and at a depth of 1.5 m, as shown in Figure 7.

This intervention is designed along the interior perimeter of the concrete slab affected by deformations higher than 15mm.

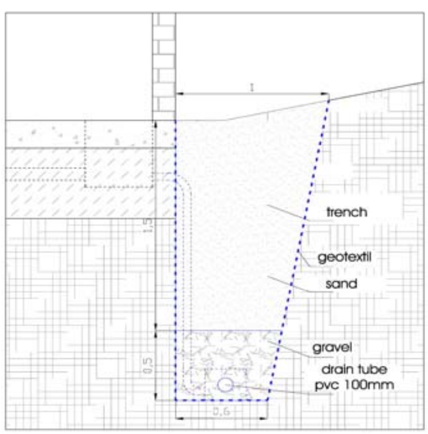

Fig. 6. Drain trench

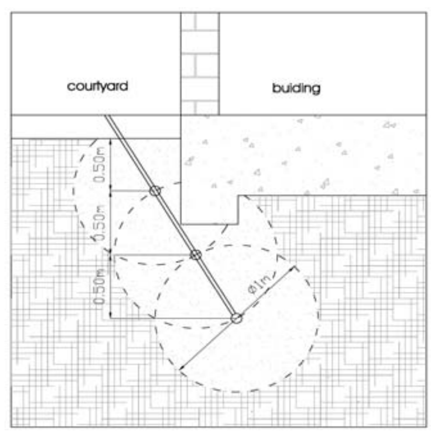

Fig. 7. expansive mortar injection

5. References

[1] Código Técnico de la Edificación, DB Seguridad Estructural Cimientos. CTE-DB-SE-C.
[2] Sowers, G.B. and Sowers G.F. "Introducción a la Mecánica de Suelos y Cimentaciones", (1993)
[3] Skempton, A.W. and MacDonald, D.H. (1956) "The Allowable Settlement of Buildings", Proc. Inst. of Civil Engineers, London, Vol. 5, Part. III, pp.727-784.
[4] Burland, J. B., and C. P. Wroth (1974), "Allowable and Differential Settlement of Structures, Including Damage and Soil-Structure Interaction," Proc., Conf. on Settlement of Structures, Cambridge Univ., Instn. of Civil Engrs., London, pp. 611-654.