Geotechnical and hydrogeological analysis of land subsidence in Murcia (Spain)

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Abstract: The aim of this paper is to present the geotechnical and hydrogeological analysis of the subsidence by consolidation of the soil caused by drawing down the water level, of moderate intensity, which occured in Murcia city and its surrounding area.

Keywords: geotechnical, hydrogeological, subsidence, withdrawal, Murcia.

Introduction

The subsidence in cohesional soils due to groundwater decrement is a broadly well-known phenomenon. Cases like Mexico City, Bangkok, San Joaquín's Valley & California, among others, are habitual references in the geotechnical and hydrogeological bibliography [3 & 4].
Different land subsidence of moderate character, occured in the city of Murcia (SE of Spain) as a consequence of a athypical drawing down the water table, (hitherto not well-known, which was the result of a drought period) between 1992 and 1996 as well as the approval and realization of supplementary wells of the irrigated farming area ("La Huerta") in which the city of Murcia is located. The proximity and amount of affected buildings located in different parts of the urban center had been appear in a period of time less than two years caused a strong social alarm. The estimated losses were calculated in a range of 50 million euros according to different sources [3]
The model´s parameters of the phenomenon were obtained through the geotechnical and hydrogeological characterization of the geologic environment. The area is located over quaternary alluvial deposits of the Segura River in its middle course (flood plain, abandonned meanders and low terrace) belonging to the Vega Media Segura River. The subsoil is formed by deposits originated in a complex environment of alluvial sedimentation which is controlled by the recent tectonic subsidence. The representative subsoil column (Fig 2.) is com-

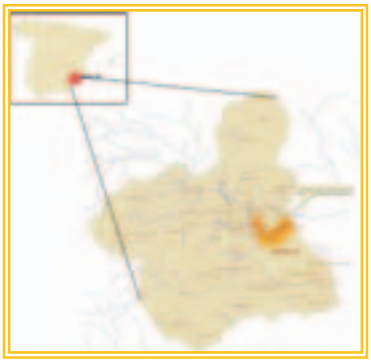

Figure 1. Localization of the research area

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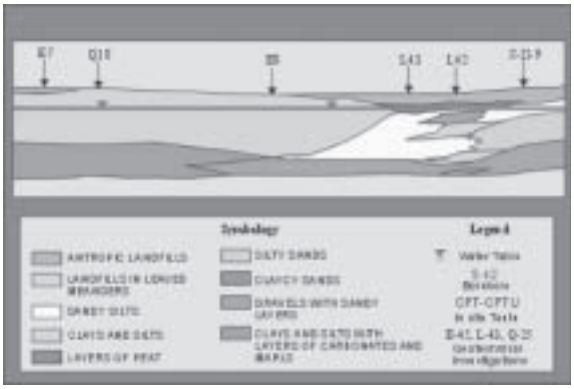

Figure 2. Geological and geotechnical profile of Murcia city

posed by 10 - 25 m of cohesional soft sediments (clays and silts) of medium-low plasticity, soft consistency and half-high water contents with interlayers of silts and sands which rest on a consolidated layer formed by gravels and sands and in some cases hard clays that points out the beginning of an alternation of levels of thick and fine grain inserted in a basically clayey matrix.

The geological materials that constitute the aquifer system of the Vega Media (Fig. 5.), belong to a detritus packet that can reach a thickness of 250 m and whose age ranges from the Pliocen to the present time. The aquifer has been represented in two main sections [2]: a) one superficial, of free character, of scarce interest as an aquifer due to low productivity (clays, fine sands and not consolidated silts), but of great importance in the hydrodynamic feature because most of the water exchanges between the aquifer and the its outside area, take place through this section, and b) a wide packet, semiconfined and multilayer, underlaying the above section compose by a first level of gravels of from 10 to 30 m of thickness. This packet´s thickness increases towards the central axis of the basin ,which coincides approximately with the bed of the Segura River, being the average thickness approximately of 150 m, being able to exceed 200 meters.

The subsidence could be attributed to two related hydrological situations; which are the drought and the extraction of water from the gravels layer produce a lowering of the water table in the upper clayey levels and a depression of the piezometric height in deep gravels.

The decrease of land volume due to consolidation of the top soft layers, with the subsequent reduction of the pore presure (Fig. 3) and the increase of the effective stress in the soil, has resulted in a vertical deformation (settlement).

RESULTS AND DISCUSSION

The settlement estimates has been carried out using finite elements software program Zsoil v4(2D), which allow the tense-deformacional calculation with hydraulic coupling according to the water table evolution history that was considered. The initial data have been obtained through hydrogeological tests, in site geomechanical investigations [3](US, SPT ,CPT-CPTU), and laboratory test (edometric). The li-

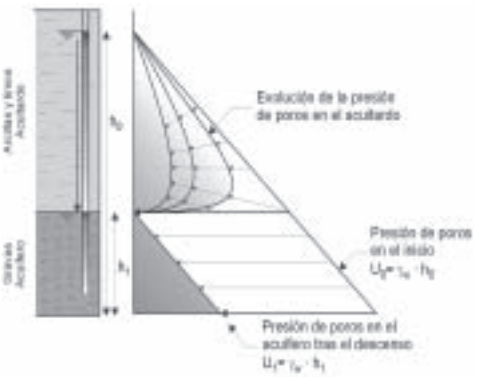

Figure 3. Pore pressure evolution in soil column.

thology, the thickness and the interlayers as well as of the time pattern generated pore pressures are those that control the historial develoment of the settlement. The settlement rates obtained for the different areas, give moderate values with theoretical maximum values that do not exceed 8 cms in the urban centre for the analysed conditions.
From the evaluation and Zsoil-modelization of the subsidence process, Susceptibility Maps based on the empiric index (ISS) and Settlement Maps (Fig 4) have been produced.

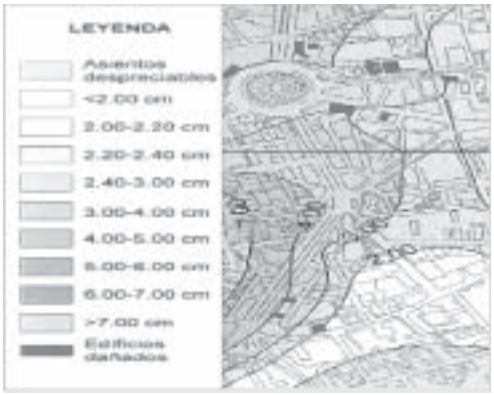

Figure 4. Detail obtained from the Settlements Map

Conclusions

The own structural problems or foundation of each building such as, "old rotten wooden piles, negative friction in concrete piles and break of cleaning" , seem to be up to this moment those that determine the affectation degree in the city buildings. Surely it is sure that land settlement rates have been higher than 25 cm. This factor would have had a bigges influence in the consequences that it has actually had in Murcia; with a moderate rate of the land settlement. The most important damages have been concentrated on old buildings, with superficial foundation. The affected buildings usually have an effect in their mediators. Different foundation types or sudden changes in the sustrate induce changes or strong slopes in the settlements column. The moderate subsidence can also have serious secondary effects due to the break of cleanings, waste pipes and nets of water supply.
The estimation of land settlements has been carried out through theoretical-mathematical modelization considering land caractheristics and the drawing down of the water level in a certain period of time. In turn, a numeric flow model has been elaborated in order to simulate the aquifer system feature in a wide period of time that includes the suffered drought. However, a limitation exists in the real quantification of the process, fact that is being investigated at the moment through the analysis of data provided by the control net installed a year and half ago in the southern area of the city inside the Metropolitan area. Nevertheless it is soon to obtain good series of data and derived tends. In a near future the data will be compared with those collected from the control piezometric net installed in the area in order to be used in this study to calibrate the proposed theoretical model.
The necessity to carry out precursor investigations of those geologic environments prone to suffer subsidence phenomena must be pointed out, even in area where no historical evidence of these kind of phenomena has been recorded and where such phenomena usually occur in a moderate magnitude in order to be prepared when another event of this kind appears.

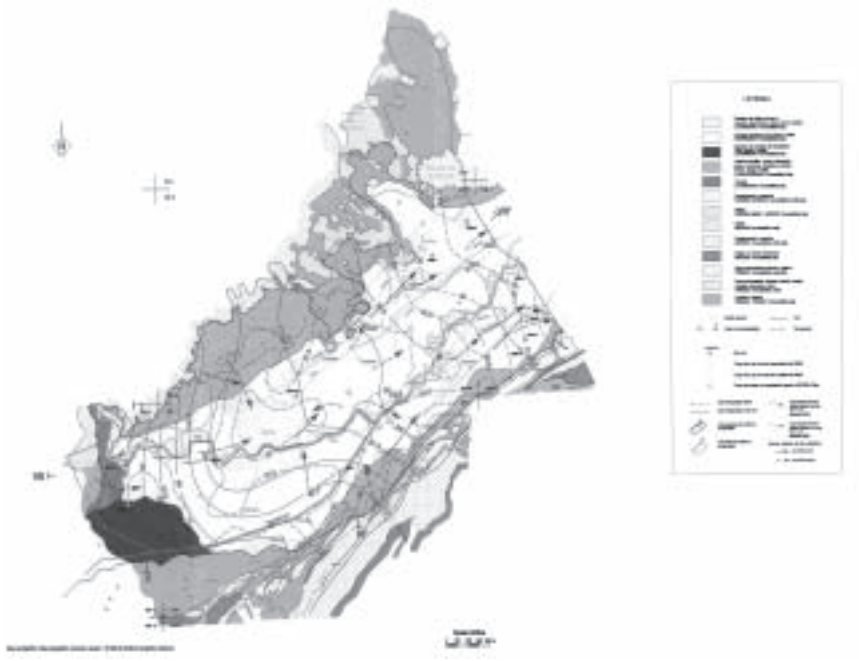

Figure 5. Hidrogeological Map of Vega Media. Segura River

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