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Controlled Impact Technique for the Correction of the Verticality of Part-Collapsed Buildings with Semi-Compensated Foundations in the Lake Zone of Mexico City

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ABSTRACT

The article presents a new technique for the correction of the verticality of part collapsed buildings in the lake zone of Mexico City, the technique was conceived from the study of the deformation properties of the Mexico city subsoil and the behavior of the clays deposits of this city under cyclic loads, for buildings with similar foundations geometry that presents complex problems of differential settlements in this geotechnical zone. The problematic and properties of the subsoil where analyzed to design this technique that use mechanics procedures and geotechnical machines and conditions of load that are representable with laboratory. Also is presented a theoretical analysis of the condition of load for the process of this technique and the technical application procedure.

Keywords: Differential settlement Recovery, Settlements, Foundations.

INTRODUCTION

A high number of parts collapsed buildings in the lake zone of Mexico City has service failures (loss of the verticality). The deformation properties and resistance of the clay's deposits with 60m deep approx. in the downtown zone, the geohydrological and seismic activity of the zone are some of the main factors with influences in this matter. There are registered differential settlements in buildings over 1m, differential settlements about 30cm are commonly in the downtown zone. An original technique, focused in the exceptional water content property of the clays in this zone is presented to fix and treat this problematic within an geotechnical engineering scope.

BACKGROUND AND PROBLEMATIC

Several studies present the causes of part collapsed buildings in the lake zone of Mexico City. An a not correct determinación of the foundation dimentions (excentrics loads), a not correct determination of the high compressibility of the clay's deposits, but the presences of shallow water wells, and the constant seismic activity are the main factors. The combination of these factors increases the problematic. The figure 1 shows the problematic of water wells in the lake zone of Mexico City. The image shows a steel casing, that was used as a part of a water well on the deep sand layers of the city. The constant pumping causes a long term, by consolidation, what is known as regional settlement, visible in the image. The ground has settled around of the steel casing more than 5m. due to the high compressibility of the clays deposits, this in the zone of revolution monument plaza.

Figure 1: An old steel casing, part of a water well, exposed due to the consolidation of the subsoil

The water wells that pump water from the shallow sand layers have a radius of influence and it is caused a change in effective stress state, see figure 2. If the water well is located beside of a building or structure, would provoke differential settlements in the structure and in several cases the loss of the verticality.

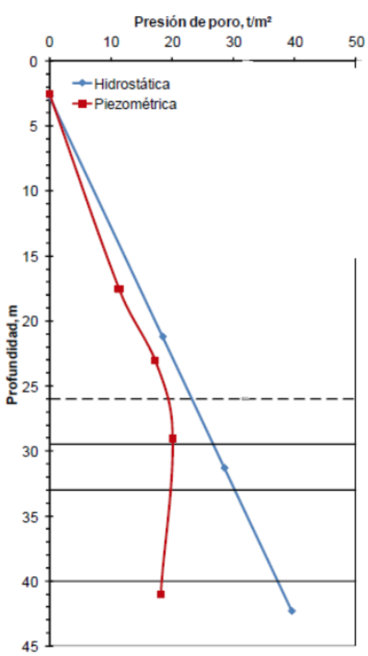

Figure 2: Piezometry, Doctores neighborhood, México city. Ingeniería Geotecnica y Construción 2010 [1]

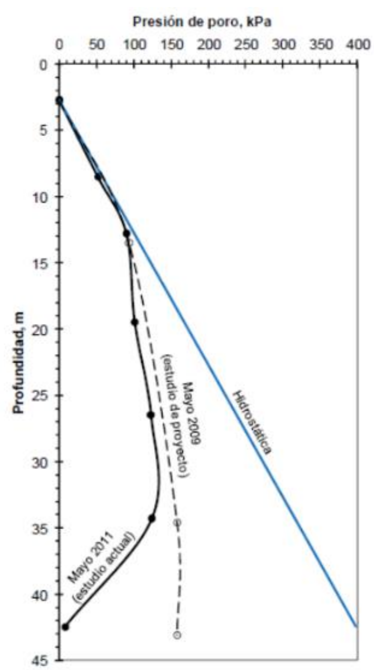

Figure 3: Piezometry, Tabacalera neighborhood, México city. Ingeniería Geotecnica y Construción 2011 [2]

The Figures 2 and 3 show the results of the instrumentation with a piezocone for geotechnical design in the lake zone of Mexico City. In the image it is shown that the water pressure at more of 30m deep is minor than the hydrostatic pressure, this change in the effective stress state is what it cause the regional settlement and the total and differential settlements.

During the earthquakes of September 19th 1985 was possible to observe the response and behavior of different types of foundations in the whole city. In [3] is exposed a detailed resume of the foundations and it is behavior during this exceptional earthquake, the differential and total settlements of the part and total collapsed buildings. [4] and [5] are outstanding examples of laboratory apparatus and procedures, thinked for deformation and resistance properties of the Mexico City clay under cyclic loads. From these procedures was find that the resistance of the clays of Mexico City were abruptly affected from the 80% of the resistance established in the experiment, but the consolidation process was lightly affected by cyclic loads, the variable time was just lightly affected.

SOIL PROPERTIES AND TYPE OF DEPOSITS OF MEXICO CITY

The subsoil of Mexico City is conformed by a clay deposit of lake formation with volcanic origin, in the downtown the average deep is 60m with thin layers of sand and volcanic ashes, located at different deeps. [6] contains the most common wide studies of the Mexico City subsoil. In these sand layers are placed de piles of the deep foundations of the city. Figure 4 shows a stratigraphic cut based in the stratigraphic cut of Mooser. The clays deposits presents water contents higher of 300%, volumetric weights around $1.2t/m^3$ and compression index of 10. These clays are anisotropic with complex resistance and deformation properties [7]. In these clays with water contents over 300% is where the problematic is located, the expulsion of water in these layers is what cause the differential settlements, some of these registered of more than 1m.

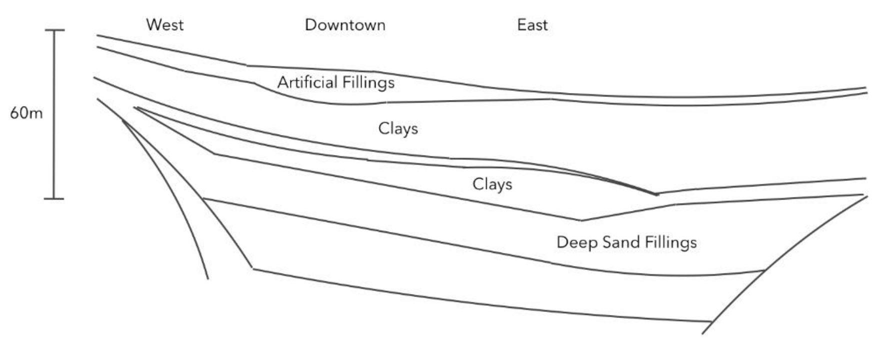

Figure 4: Stratigraphic cut of the México City subsoil, based in the stratigraphic cut of Mooser (SMMS, 1994) [8].

These conditions require a high quality in; sample extraction, test laboratory, design and very high supervision during the construction process and once the construction is finished.

OTHER METHODS

A lot of previous works have been done, trying to correct the loss of verticality of buildings, many of these methods consist on hand workers process or empirical techniques.

These methods are not discussed in this article, but it is necessary to mention for the importance of these buildings.

- Pissa Tower
  Process: subexcavation
  Type of structure: Romanesque
- Mexico City Metropolitan Cathedral
  Process: Subexcavation
  Type of structure: Colonial
- Mexico City Ex Foreign Relations Building
  Process: Varied
  Type of structure: Deep pile foundation

[9] presents infographics of the process for the correction of the verticality of the Pissa Tower and Mexico City Metropolitan Cathedral. [10] presents a resume of pile-control techniques used for the reinforcement and correction of the differential settlements of foundations in Mexico City.

CONTROLLED IMPACT TECHNIQUE FOR THE CORRECTION OF THE VERTICALITY OF PART COLLAPSED BUILDINGS WITH SEMICOMPENSED FOUNDATIONS IN THE LAKE ZONE OF MEXICO CITY

This technique is conceived from the study of the deformation properties of the subsoil observed in laboratory and specifically in the ground, with a new and novel load condition, designed for this specific purpose.

This technique consists of 3 main steps:

- Localization of the base of the layer with more water content, using water content laboratory tests. These layer are where the differential settlements can be fixed.
- Precise positioning of the “MJB steel casing" at the base of the layer with more water content on the side of the building where the correction of the verticality is going to take place.
- Controlled seismic load to induce the movement of the soil in the direction of the MJB steel casing and extract material with a thin wall pipe at any rate. The extraction of water would be 3 by 1 of solids, fixing the differential settlements of years, in a short period of time. Figure 5 shows the physics of this procedure.

Two important points of this technique are; 1. The consideration of the building as a rigid body. 2. The need for a characterization of very high precision of the layers under the foundation of the building. The technical position of the MJB steel casing must be like is what shown in figure 6 for an uniformed and faster correction of the verticality in the side of the building where the correction is going to take place. The number of MJB steel casing would depend on the width of the building.

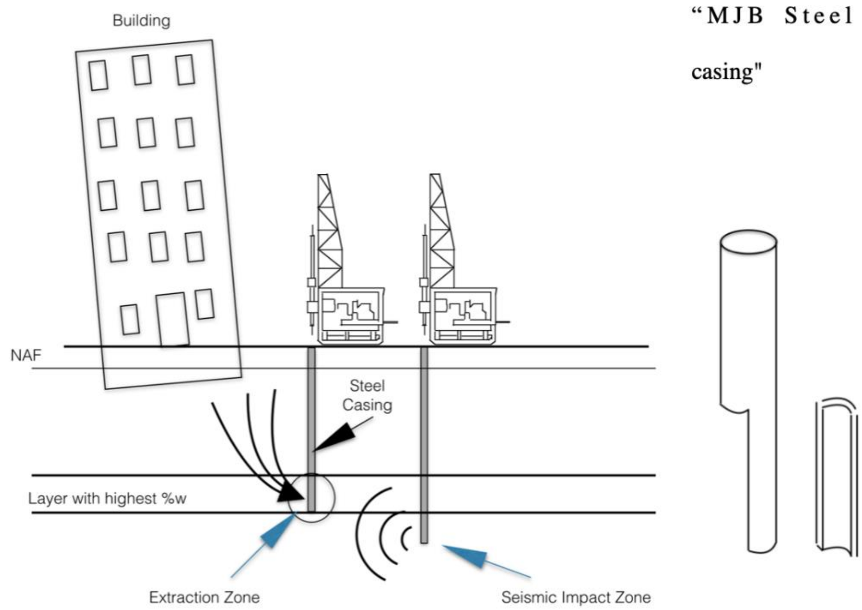

Figure 5: MJB Steel casing positioned at the base of the layer with more water content

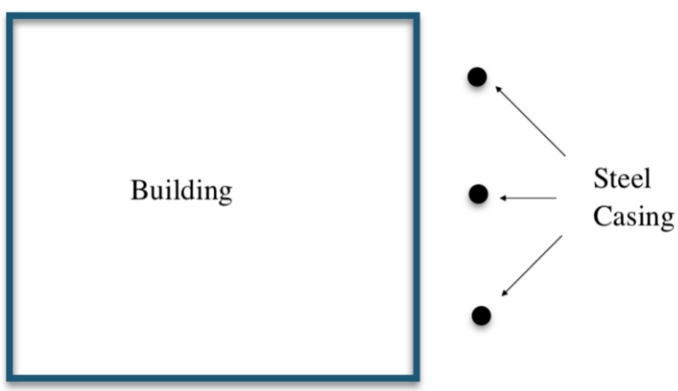

Figure 6: Steel casing locations.

TECHNICAL ANALYSIS

- Now, the frequency of the seismic loads must be controlled to be different from the vibration period of the deposit. For example, in the downtown zone of Mexico City the vibration period is around 2s. It is important that the seismic loads have a frequency that reduce the effect of resonance and not affect buildings with foundations near to the application of this technique.
- If the distance between the impact zone and extraction zone is reduced, the effect in other buildings will be decreased as well the magnitude of the mass of the impact instrument.

DECONFINEMENT ANALYSIS

The extractions of subsoil at the deep where the MJB Steel Casing is positioned will cause a deconfinement and a deformation. At first, due to the anisotropic conditions of the subsoil, the stress state will be σ1 y σ3 as is shown in the figure 7. After the extraction, the state will be σ1 and σ4=0.

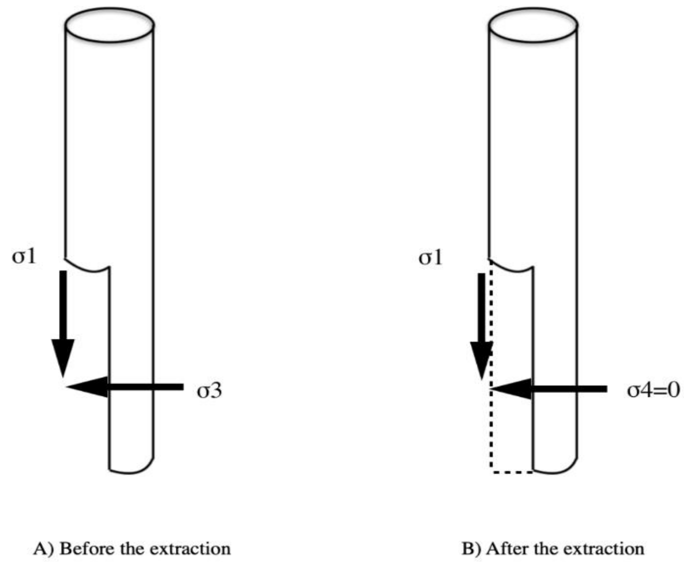

Figure 7: Stress state condition before and after extractions.

Deconfine like this would cause two types of deformations, including elastoplastic and failure by the seismic loads and secondly by the remolded material, cause the repeated extractions. The figure 8 shows the expected deformation in laboratory.

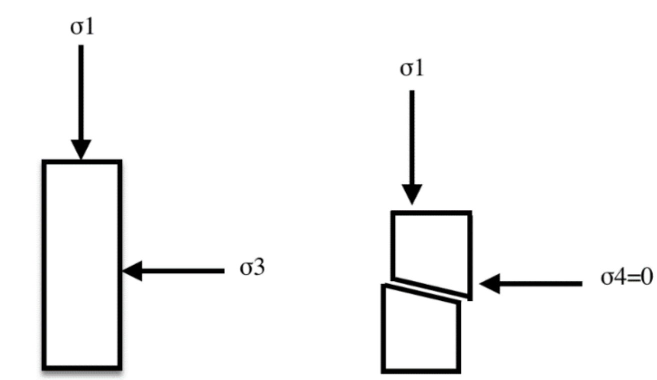

Figure 8: Laboratory representation of the behavior of the soil samples deconfined.

If the deformation is not suitable, the rith application of controlled seismic impact will create the willing deformation.

CONCLUSIONS

This technique is conceived for rigid foundations on a subsoil with the deformations characteristics of Mexico City subsoil, but is possible to adapt it to a different subsoils and for deep foundations. The core of this techniques considers the use of geotechnical machines and conditions that are representable in the laboratory. A laboratory apparatus for the determination of a deformation parameter (differential settlement) would be a enriching line of investigation. An elastic analysis would be important to compare with laboratory tests and in situ instrumentation. The rate of the correction of the verticality mainly would depend on the integrity of the structure and the number of extractions of material per unit of time. This technique represents an advance from the more common and news techniques in this area, which consist in excavation with people and hand tools at shallow depths with none possibility of presentation in laboratory and none possibility of theoretical analysis. This technique is for a virgin area, that is why the proposal of a laboratory apparatus is recommended. The standardization of the procedure is highly viable, considering that the number of buildings are profitable and is not needed expensive procedures with hydraulic jacks or over times with manual procedures.

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