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CONDITIONS OF STRUCTURAL STABILITY AND VIBRATION DAMAGE

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ABSTRACT

The paper presents the investigation conducted in a one-story-house and its rear annex which suffered severe damages due to a process of differential settlements of their foundations, flowing water in the subsoil and vibrations of the traffic of vehicles on the street nearby. The house is located in the city of Curitiba in the south of Brazil. The subsoil is composed of tropical clay and sand silty soils of Guabirotuba Formation. It is formed of pleistocene sediments in Curitiba area. The foundations of the house and the annex were in excavated small 8" diameter short concrete piles. Due to the differential settlements, a great number of cracks appeared in the house and in the annex walls. Many walls were distorted badly. Flowing water is presented in the subsoil. At the annex rear house the piles are embedded in a non-compacted fill. A concrete counterfort wall was constructed on the north border side of the site with a deficient drainage system. The damages which the house and the annex have been suffered due to the combination of geotechnical factors were such that the results were comparable of a earthquake with magnitudes M=5 to M=6^3/4, as the analysis showed. The studies showed valuable conclusions about the relationship between the differential settlements existing in the construction and the results of the seismic effects which are presented in the text. The house and the annex were underpinned, and their foundations were strengthened through the use of injected piles. The implications of the findings as far as the seismic aspects of the liquefaction phenomenon are concerned are discussed in the text.

INTRODUCTION

One of the main difficulties in analyzing the damages which have occurred in structures submitted to vibratory waves in the subsoil and their foundations are the contribution of the pre-geotechnical and pre-structural conditions before the vibratory wave impact.

Pre-geotechnical conditions are related to such factors as the subsoil conditions of the site, type of foundation, total and differential settlements of the foundation, drainage conditions of the area, static or flowing underground water, and position of the construction. Pre-structural conditions are related to the type of structure, its base dimensions and height.

A case history is described in the following paragraphs relating to the studies conducted on a one-story-house and its rear annex-house which have been suffered severe damages due to a process of differential settlements of their foundations. Flowing water in the subsoil and vibrations of the traffic of vehicles on the street nearby took place in the process. The foundations of the house and the annex were in excavated small 8" diameter short concrete piles. A great number of cracks appeared in the house and in the rear annex walls. Many walls were distorted badly. Also, to complicate the foundation problem, the location of the site, the declivity of the soil surface and the type of the soil were such that the flowing water is presented in the subsoil. The house and de annex achieved what could be considered as being in the verge of failure and the collapse of the house and the annex were imminent. A cross section of the site subsoil is shown in Fig. 1.

The house and its annex is located in the city of Curitiba in the south of Brazil. The subsoil is composed of sandy silt soils of Guabirotuba Formation.

The investigation had the aim to give a better understanding of the influence of the prevailing pre-geotechnical factors producing a condition of ultimate stability of the construction and the vibratory seismic effects.
It was conducted a seismic analysis of the problem and the results studied carefully.

GEOLOGY

The geology of the region is composed of a crystalline base formed by Pre-Cambrian metamorphic rocks. Disposing over the Pre-Cambrian rocks are the Pleistocene sediments of Guabirotuba Formation. It is composed of overconsolidated sediments and formed mainly by clays and silty sand clays containing sporadic thin layers of feldspatic sands. Overlaying the Guabirotuba Formation are the Holocene deposits of the rivers of the Curitiba region [Tavares 1990].

SITE SUBSOIL

Exploratory wash borings drilled in the area showed that the subsoil of the region is composed primarily by a very loose red fine sandy silt layer overlaying a dense residual soil of red clayey sandy silt. The subsoil in the annex is covered by a silty sand fill about nine feet thick.

The procedures to obtain the SPT N values were selected to give a energy efficiency transfer to the rods of 60%. The SPT values were obtained at each meter of depth during the drilling of the exploratory borings with the standard 2" diameter Raymond open sampler [Tavares, 1988a]. The soil profile of a exploratory boring drilled inside the site with the mean values of $(N_1)60$ normalized to an effective stress of 100 kPa and to a energy transfer of 60% [Jamiolkowski e al.] are shown in Fig. 2.

Undisturbed samples of the sandy silt layers were obtained through test pits. Shelby tube samples were obtained from the clayey residual soil layer.

Direct simple shearing tests and direct seismic tests were curried out on samples carved from test pits.

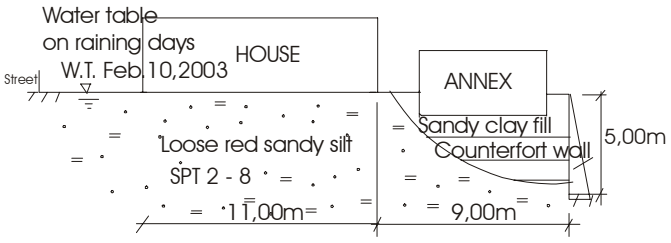

Fig. 1. Cross section of the site subsoil

TYPICAL BORING

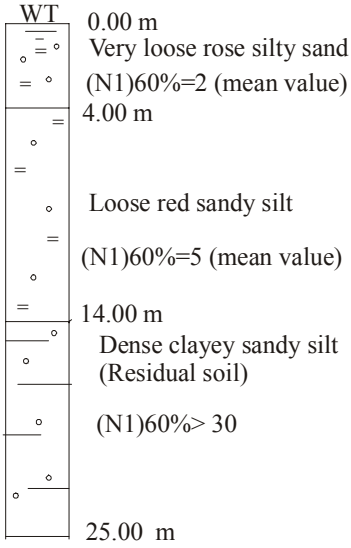

Fig. 2 Typical soil profile in the site area

STABILITY ANALISYS

In the present case history, many geotechnical factors take place in the progress of the geotechnical phenomenon at the construction. A total maximum settlement of about 20cm occurred in the houses, confirmed by "in situ" observations. The differential settlements attained 15cm. The unappropriated use of short bored small diameter uncased piles for the type of foundations in the house and the annex; the prevailing soil conditions of the site and the situation of a non-compacted fill under the central part of annex house where the bored piles were located; the occurrence of the fine sandy silt soil favorable to occur a liquefaction phenomenon; flowing water and vibration waves of the traffic of vehicles on the street nearby; large declivity of the surface soil where superficial raining water flows; a deficient drainage system in the site and through the counterfort wall.

The influence of the vibratory effects of the traffic near the constructions was evaluated through a dynamic analyzes which has showed that it causes small effects in the overall geotechnical phenomenon. This was due to the small vibrations waves developed by the traffic.

To interpret the problems that occurred in the constructions with so many variable causes, and attending to the fact that the subsoil of the site was formed by sandy silt soils with characteristics that could be occurred a liquefaction process, it

was evaluated the ground subsidence from the results of (N1)60% values of SPT and Seismic Energy Method of the European Commission [Azis C. Stamatopoulos et al 2001], and make a comparison to the maximum settlement of the constructions.
For the SPT (N1)60% = 5, for a epicentral distance d=20 km, and a earthquake magnitude of M= 6.2, the subsidence of the ground would be of 20.3cm. This is the value of the maximum total settlement achieved in the construction presented in this case history which could be considered for this case as a ultimate value. This finding is valuable because represents some measure of the influence of the pre-geotechnical factors prevailing when a structure and its foundations are submitted to vibratory waves of a earthquake or from any vibratory source.

FOUNDATION STRENGTHENING

The house and the annex were underpinned, and their foundations were strengthened through the use of 100mm diameter injected piles [Tavares 1997]. Also, the superstructures of the house and the annex were reinforced conveniently.

CONCLUSIONS

The paper presents a case of one-story-house and its one-story-annex whose stability almost reached the ultimate condition. Their structures were in the verge of failure due to many geotechnical factors.

It is shown in the text the very important influence of the pre-geotechnical factors prevailing in the subsoil and on the foundations of a structure, which should be take into account when a structure submitted to vibratory waves is analyzed.

In the present case, the constructions were underpinned and their foundations and structures were strengthened. They are safe now.

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