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Liquefaction Studies on Guaratuba Bay Erosion

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ABSTRACT

The paper presents the studies conducted to explain the erosion process which occurred at the Guaratuba bay coast located in the South of Brazil [Tavares, 1989]. The subsoil in the area is composed mainly of fine clean sand. The erosion occurred as a result of the liquefaction of the sandy subsoil and is described in the text. Several buildings, including the City Hall, and some streets near the affected area were sunk into the subsoil. The phenomenon took place on the 23rd of September of 1968. In the years of 1998, 1999 to March, 2000, new studies were performed to evaluate the strength potential of the sand. The implications of the findings as far as the seismic aspects of the liquefaction phenomenon is concerned is discussed in the text.

INTRODUCTION

The flow slide which occurred in the coast of Guaratuba bay, in downtown Guaratuba, a city located in the south of Brazil, in September of the year 1968 was one the largest erosion processes which took place in the south of South America coast and produced injuries and failures of many properties, including private and public ones and, as a result, left a enormous cicatrix in the continent. Many streets were also damaged.

Just after the disaster had took place, our company, Consultécnica, has been contracted by the State of Paraná to study the slide phenomenon and to present a solution to defend and to recuperate the part of the coast which had been eroded. As a result of our duty, it was prepared a project to achieve these two goals.

In October, 1968, after a thorough analysis of the process, a designed was prepared to defend the coast and to recuperate the area. A brick stone marine wall was prescribed as a efficient defense structure for the affected coast. The eroded area should be subsequently completed with selected fill soil conveniently designed and constructed [Tavares, 1989].

In the years 1998, 1999, to March 2000, for scientific purposes, and to elucidate some doubts about the seismic aspects of the phenomenon, dynamic analyses of the process were conducted which were of great importance for the knowledge of the dynamic characteristics of the Guaratuba sand. In the following paragraphs, the results of the investigations are presented and discussed.

GEOLOGY

The geology of the region is very simple and includes the Crystalline base formed by Pre-Cambrian Gneiss-granite rocks. They form the hills nearby. Disposing over the Pre-Cambrian rocks are the Pleistocene marine sediments of sands and silty clays with shell detritus. Overlaying the Pleistocene sediments, are the Holocene organic marine clays sediments. Eolic deposits of sands are also presented in the region.

THE SANDY SUBSOIL

Exploratory wash borings drilled in the area showed that the subsoil of the region is composed primarily by a uniform very fine light gray sand with shell detritus of marine organisms. In some parts of the region, a blanket of a marine very soft organic silty clay covers the surface of the sand.

Through the values of Standard Penetration Tests – SPT, obtained at each meter of depth during the drilling of the exploratory borings with the standard 2" diameter Raymond open sampler, the sand was classified as very dense [Tavares, 1988]. The SPT N values have been checked by field loading tests. The soil profile of a exploratory boring drilled inside the affected area is Shown in Fig. 1. The average peak value of the angle of internal friction of the sand obtained through direct drained texts from block samples was $\phi' = 37^{\circ}$. Table 1 [Tavares, 1989] shows the main average index properties of Guaratuba sand.

Table 1. Index properties of Guaratuba sand. Average values

Property	Description/Value
Color	light gray
Percent finer 200 mesh	5%
Effective diameter mm	D_{10} = 0.08 mm/0.10
50% diameter	D_{50} = 0.200
Uniformity coefficient	C_U = 3
Specific gravity	s_s = 2.66
Saturated unit weight	γ_{sat} = 17.60 kN/m^3
Mineralogical composition	quartz with shell detritus
Grains	round and subrounded
Average peak friction angle	$\phi' = 37^{\circ}$

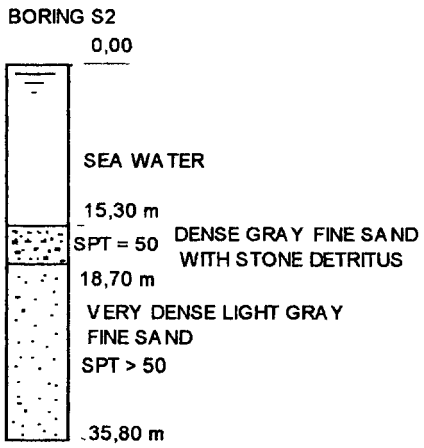

Figure 1. Soil profile in the erosion area

THE EROSION PROCESS

The erosion occurred at the night of the 23rd of September, 1968, in the coast of Guaratuba bay, downtown Guaratuba town.

The beginning of the phenomenon was observed by the sinking of lamp-posts located in the affected area on the Cel. Afonso Botelho Avenue in front of the old building of the City Hall. Subsequently, a gravity pier in the area was eroded. During about three hours all the erosion process had been finished. As a result many buildings were sunk into the subsoil and part of Botelho Avenue and some other streets nearby were eroded. In the continent a cicatrix of about 45m wide by 130m long and 12m deep was formed. Figure 2 shows a cross section of the erosion area.

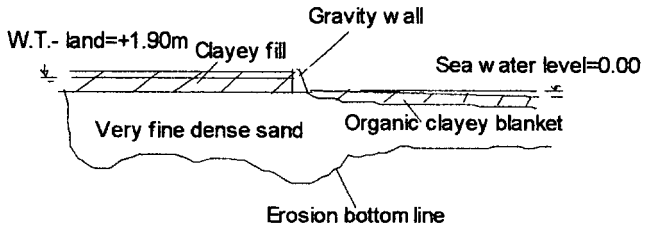

Fig. 2 Cross section of the erosion area

At Pinto Hill, not far from the affected area, a quarry was located. A dynamic analysis was conducted in 1988 in order to investigate if the flow slide could be due to a liquefaction process produced by the cyclic blasting loads developed at the quarry and for scientific purposes. Sand samples were tested undrained in cyclical direct text. The average strength potential obtained at that time normalized for a pressure of 1.0 kgf/cm^2 was $\tau_{max} / \sigma_{vo} = 0.71$. Using this finding to the present case applying the Seed's method [1966], it was carried out a thorough investigation of the liquefaction process developed in the area [Tavares, 1989]. The studies showed a reasonable agreement with the findings obtained by Jamiokowski and al. [1985]. Recently [1999 / 2000], new investigations were performed to check the strength potential of the sand, and showed average values for medium sand in the range 0.40 to 0.70. For dense and very dense sand with SPT N values higher than 40 and 50, the strength potential was in the range 0.60 to 0.82. Table 2. shows the average values of the strength potential obtained during theses investigations.

From the observation of the results of the strength potential of Guaratuba sand indicated on Table 2 , some discrepancies were observed as to the relationships SPT N values versus

Table 2. Average strength potential of Guaratuba sand

Density	Strength potential
Medium sand	0.40 to 0.70
Dense to very dense sand	0.60 to 0.82

strength potential of sandy soils in Japan obtained by Kokusho et al. [1985] for very dense sand. Considerable agreement is observed for medium sand.

The results of the dynamic analysis showed that the erosion which occurred in Guaratuba bay could have not been produced by the blasting effects in the quarry nearby and was a valuable tool to explain the sand flow slide that occurred in this case. The phenomenon was produced by a quick sand condition due to excess hydrostatic pressure developed in the sand by the differential free water level from the water table in the continent and the water sea level.

CONCLUSION

1. The dynamic analysis was of fundamental importance to explain the causes of the flow slide which occurred in Guaratuba sand.

2. There might be strong judgment in applying correlations of SPT N values versus strength potential to seismic liquefaction processes for very dense sand, as the present investigation has shown.

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