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The Effect of the Produced Vibrations by the Urban Electric Train on the Fillings of Pumiceous Soils

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SYNOPSIS The paper presents the results of a study realized in Guadalajara, capital city of the -- State of Jalisco, in México, in which it proves that the vibrations produced by the operation of -- the urban electric train were one of the causes of settlements presented in a habitational zone. These settlements produced very several damages to more of 30 houses. To obtain this conclusion, - geotechnical studies, dynamic characterization of subsoil and laboratory tests that included the - use of a shake table were realized. With the information analysis, were obtained settlement predictions between 0.035 y 0.135 m.

INTRODUCTION

The valley where the city of Guadalajara, is situated, is formed by powerful deposits of pyro-- clastics materials, made on pre-existed basin; this pumiceous soils are presented in the form of gravels, sands or silts and their principal characteristics are: highly frictionals, lightweight, degradables and of high absortion.

The development of the city has made that the habitationals zones invade lands that for many -- years have been dedicated to other uses, that is why that the uncontrolled urban process has occuppied mountains and ravines, being these the -- most affected, because the unadequated construction practices have left many filled zones with soils in loose or semiloose conditions; these have caused many problems due that the pumiceous soils in these conditions are highly compressi-- bles i.e. erosionables as for vibrations of any source, as water and wind.

The above factors as rains, earthquakes and man made vibrations, had caused that frequently settlements ocurr in different points of the city, with the respectives consequences all of them - harmful.

This paper presents the results of a study realized to analyse if the produced vibrations by the urban traffic, including the urban electric - train, were one of the settlement causes that - appear in a habitational zone and provoked several damages to more of 30 houses of one or two levels and modest structure.

DESCRIPTION OF THE AFFECTED ZONE

The group of damaged houses, is located between the Calzada del Federalismo and Celedonio Padi-- lla street (Fig. 1), to a mid distance of 30.0 m from the train tunnel, which floor is 6.5 m under the street level, while the foundations of - the houses had a mid depth of 0.6 m in relation to the same level.

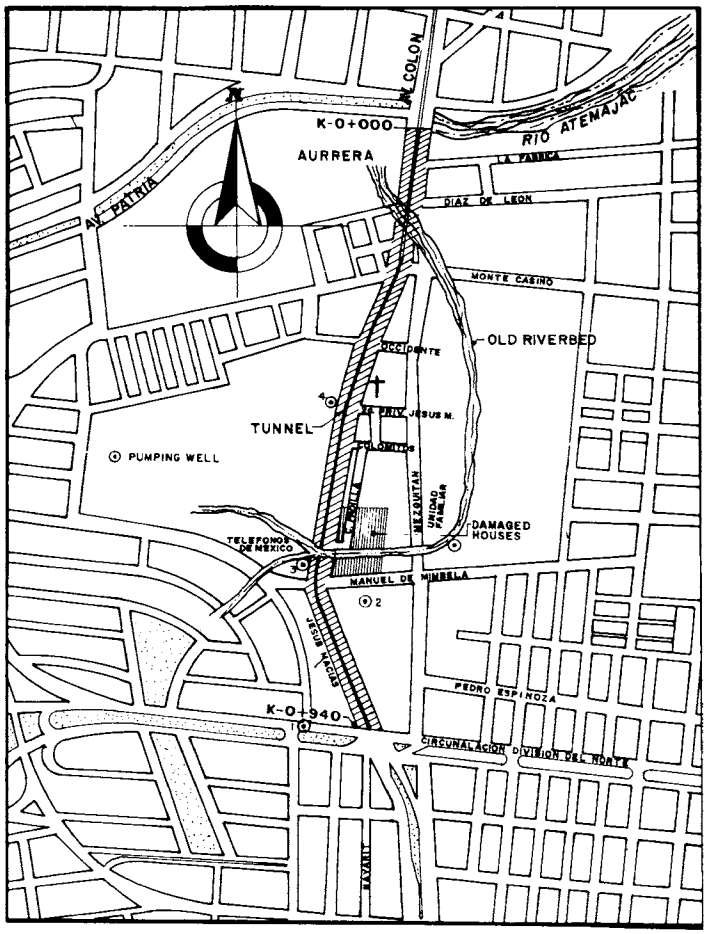

Fig. 1 Location of Damaged Houses

The damage in the constructions, started to - appear in cracking form, from december 1991 to may 1992, when some houses began to colapsed, - which deteriorations were due to settlements (Fig.2), in some cases were so severes, that it

was necessary to demolish 12 houses. The maximum settlement could be measured in the site, was of 0.16 m, this is not necessarily the real.

Fig. 2 Typical Cracking Due to Settlement

On the other hand, the electric train had almost three years of operation at beginning of the - appearance of severe damages in the edifications (Fig. 3).

Fig. 3 Electric Train in Operation

GEOTECHNICAL STUDY OF THE ZONE

The exploration consisted in eight standard penetration tests with extraction of samples for field classifications and laboratory index tests. The depth varied from 6.0 to 11.0 m in addition in every perforation a piezometer was installed, to be used as part of the hydrological study, - realized in that time.

In Fig. 4, a typical stratigraphy of the zone is presented, in which the superficial layer of the subsoil, with thickness of 3.0 to 5.0 m, is formed by pumiceous soils fillings in practically loose conditions with resistance of 1 to 4 blows in the standard penetration test (relative density of 0.09 to 0.17); following a stratum of aproximately 3.0 m of thickness formed - by silty sands of medium density (12 to 30 - - blows) and from that level to the end of the borings a sandy silt formation very compacted (more of 40 blows). The groundwater level was located in an average depth of 4.8 m.

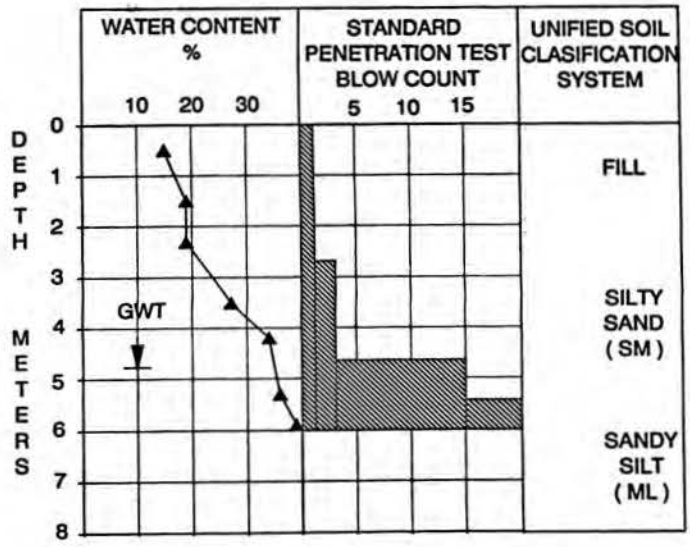

Fig. 4 Typical Soil Profile

In the index tests realizes in the soils samples obtained of the borings and open cuts, were - found the following results.

Natural water content	14-36%
Void ratio	1.31
Specific gravity	2.30
Bulk unit weight	10 kN/m3

The above results showed that fillings were almost loose which made them sensitive to suffer rearrangements as much for vibrations of any -- kind, as well as for humidifications or hydric erosion.

Due to geohydrological and seismic analysis, did not explain satisfactorily the ocurred fenome- - nous, a field studies were made to determine the effect of urban traffic in the performance of - the fills.

DYNAMIC CHARACTERIZATION OF SUBSOIL OF THE DAMAGED ZONE

Due that the electric train, as well as, the superficial traffic are vibration sources, a field study was made to determine the vibration grade that provokes in the subsoil. The study covered 12 points of the area, using sensors of intermediate period, obtaining 12 seismograms, 10 taken in superficial points and two in the bottom of excavations realized for foundations piers, with a depth near to 5.0 m. In the seismograms, three spacials components of the movement, north south, east - west, and vertical were graphed.

The results showed than in the ground surface, the vibration velocity is very slow (0.01 mm/sec) and its value very inferior to the limits marked as dangerous by some organizations specialize and corresponding to vibrations unperceptibles by the people.

For the measurements made at 5.0 m of depth, were obtained for the train pass, a vibration velocity of 1.0 to 1.5 mm/sec, with acceleration from 0.02 to 0.06 of the gravity, in that level an appreciable vibration was felt that caused fallings of particles from the excavation walls, it was verified that this phenomenon belonged to the passing of the train.

DYNAMIC ANALYSIS OF THE SUBSOIL

Use of models

After measuring the vibrations in the bottom of the excavations for the piers of the houses in process of reconstruction, it was decided to analyze this effect, for which, taking advantage of the boreholes, bulk unit weigths and water contents were calculated in the site; samples were obtained for laboratory tests, so to get the necessary parameters for calculation.

The critical vibration velocity of the fillings, were calculated with the criterion of Haussner and Formazin (1989), with this parameter, the measured vibration velocity, a fill thickness of 5.0 m and the proposed equation of Formazin and Haussner (1985), it reached to a settlement prediction between 0.035 and 0.078 m, that is, according to this procedure the vibrations produced by the electric train, could have caused rearrangements in the fillings.

Shake table tests

In Fig. 5, is shows a shake table that was adapted to produce accelerations between 0.02 and 0.25 g.

The experiment consisted in elaborate two specimens with soil of fills to field density and moisture of the site and submitted in the shake table to three different values of vibration, 0.02, 0.06 and 0.25 g, each one during 120 minutes; taking lectures of vertical desplacement, every two minutes. In average the relative density varied from 0.10 to 0.14 in the first lapse, went up to 0.21 the second and at the end of the test to 0.31, with vertical strains of 1.2, 2.7 and 5.4% respectively.

In Fig. 6, are presented the results of one of the tests and should be noticed that for graph 3, the one with the most value of vibration, is

Fig. 5 Shake Table

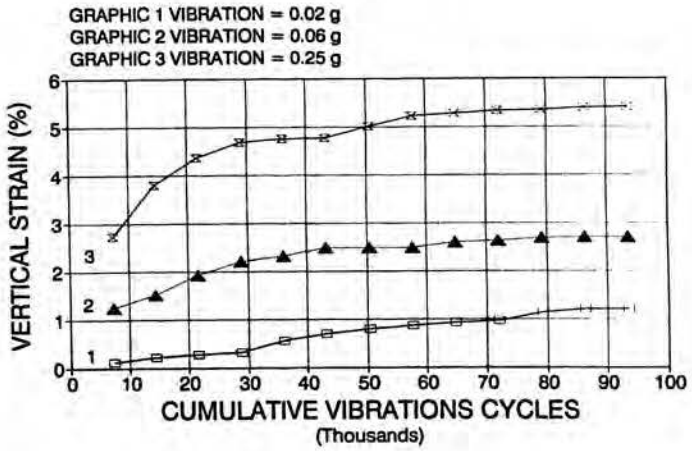

Fig. 6 Results of a Shake Table Test

clearly appreciate the effect of the fatigue in the pumiceous grains, due that at the beginning of the lapse, the vibration causes an initial rearrangement, after even if, slows the deformation velocity, the vibration starts to degrade the grains, which provokes a new rearrangement lapse and so on.

With the strains of 1.2 and 2.7% and a fill thickness of 5.0 m, the settlement predictions vary between 0.06 and 0.135 m.

CONCLUSIONS

The results showed that the vibration produced by the pass of the urban electric train, in the-

se fillings, could contribute to the presented - settlements, since the calculations give values of settlement between 0.035 and 0.135 m.

The failure apparently sudden of the houses, was presented when the settlement magnitude was so - big that the distorsion of the structures exceeded its limits of marginal stability.

Due to the above results, actually the study is continued to determine the minimum specifica- - tions that must fullfil the fillings, as well - as the elements of isolation of vibrations that should be put, to avoid problems as the one mentioned.

REFERENCES

Formazin, J. and Haussner, H. (1985) "Calcula-- ting Settlemens Caused by Dynamic Load", Pro-- ceedings, XI International Conference on Soil Mechanics and Foundation Engineering, San Francisco, California, U.S.A.

Haussner, H. and Formazin, J. (1989), "Crytical Dynamics Parameters of Non Cohesive Soils", - Proceedings XII International Conference on - Soil Mechanics and Foundation Engineering, Río de Janeiro, Brasil.