# LIQUEFACTION IN THE MEXICALI VALLEY DURING THE EARTHQUAKE OF JUNE 9, 1980

J. Abraham Díaz-Rodríguez *

## SUMMARY

Fine sands liquefaction was observed during the Mexicali Valley, 1980 earthquake with magnitude $M_L$=6.7. Field investigations were performed using the standard penetration test (SPT), the cone penetration test (CPT) and the piezometer probe test (PPT), also "indisturbed" samples were obtained. A simple quantitative analysis is presented and a field laboratory is proposed.

## INTRODUCTION

An earthquake ocurred on June 9, 1980, of magnitude 6.7 in the Mexicali Valley Northern Baja California, Mexico. The epicenter was located at a distance of 11 km South East of the town Guadalupe Victoria, with coordinates 32.213°N and 115.028°W. The earthquake produced damage in a zone of approximate 7 km wide and 25 km long across the Cerro Prieto Fault, Fig. 1. During the seismic event cracking of the ground was observed. A great number of sand boils formed at the ground surface in the form of small craters. Also vertical and horizontal earth displacements were observed in the zone of the farming land, which is crisscrossed by irrigation canals and other installations.

## GEOLOGY

The Mexicali Valley is located into the area of the delta of the Colorado River, which has four phisiographic units:plains, tablelands, terraces and clifs of the Mountain Range of Cucapás. The affected farming land (number 14) is located in the plains with mild slopes toward the Gulf of California and the City of Mexicali. The flat land contains series of deposits of silt, sand, and clay. All this are sediments of the Marine Quaternary, continental, and lacustrine. Plain is cutted series of geological faults, Fig. 1, that follow NW-SE direction. They are parallel with the San Andrés Fault. The Cucapás, San Jacinto, Cerro Prieto and Imperial may be mentioned between the most important faults.

## SISMICITY

Baja California, as described in Ref. 1, may be divided in five zones with different sismicity, of which the Mexicaly Valley has the highest sismicity. The principal features of the earthquakes taking place there are:

- Superficial focus at a depth less than 30 km.
- Strong accelerations near the epicenter.

* Professor of Civil Engineering, Universidad Nacional Autónoma de México. MEXICO.

- Numerous after shocks

## DAMAGES

The principal effects of the earthquake may be resumed as follows:

a) Cracking of the ground near the towns of Delta, Pescadores and Murguía.

   The cracks observed do not present a definitive direction. Some of them follow the Cerro Prieto Fault and others follow a normal direction to the fault of to the North-South.

   The longest ground crack, approximately 10 km, was located 200 m South-East of the crossing at the Colorado River by the railway and the road leading by Murguía.

b) The ground displacements most representative are the vertical and horizontal displacements observed in some sections of the railroad tracks.

c) Liquefaction observed by sand boils in the form of craters were observed at several places. The sand boils showed very fine sand and silts. The zone with the largest number of sand boils was close of the town Delta. According to local information, the sand boils gave water for one week following the earthquake at the town Chimi.

d) Irrigation canals and drains were damage. The damage observed was the following:

   i) Widening of several centimeters up to 20 cm, between the embankments.

   ii) Rotation of the concrete slope slab about its botton edge.

   iii) Cracking of bottom concrete slabs at some sections of the canals with change of direction.

According to a report of SARH (Ref. 2), the damages caused by the earthquake are:

i) 27 555 hectares affected.

ii) Total longitude of canals affected 159 km.

iii) Total cost of reparing about 226 million pesos, (1980).

## FIELD INVESTIGATION

According with the zonification damage, it was decided to investigate the subsoil conditions at the neighborhood the Town Delta. Four sites were selected covering a zone of approximate by 1.5 km wide and 3 km long. The first phase of the exploration sites included standard penetration tests

(SPT) and cone penetration tests (CPT). The results permited to learn on the stratigraphy that may be generalized as follows:

i) A 2.5 to 4 m superificial layer of sandy silt or fine silty sand, more than 90% of material was found finer than 0.074 mm. The SPT N-values found less than 8. In some sites a 20 cm clay layer intercepted the sand deposit.

ii) Following the sand a clay stratum (CH) was found with average thickness of 1.5 m with a point resistance of 4 kg/cm$^2$ to 8 kg/cm$^2$ by the CPT test.

iii) Underlaying is a 1.0 m stratum of fine silty sand ($D_{50} \approx 0.2$ mm), with a point resistance of 4 kg/cm$^2$ to 45 kg/cm$^2$ by the CPT test and with N-values of 3 to 7.

iv) Following the silty sand a clay stratum was encountered with an average thickness of 1.5 m, and point resistance less than 5 kg/cm$^2$ and N-values of 4 to 6.

v) Finally at a depth of a fine sand stratum was found (SM), with point resistance of 5 kg/cm$^2$ to 75 kg/cm$^2$, and N-values of 4 to 18.

At the four sites there was liquefaction evidence. The water table was at a depth of about 2.05 m.

In one of the forementioned sites there was a second phase of exploration, adding 14 boreholes spread in two orthogonal axis, using the SPT, the CPT and the piezometer probe test (PPT) and securing continuous thin-wall tube samples.

The criterion followed for the design of the borehole distribution was:

1. To get at the same point information using two techniques, that is to say the SPT and the CPT tests, with a separation of 2 m, in order to complement and confirm both procedures.

2. To get information of several points along of X or Y axis that may allow us to know the stratigraphy in two and three dimensions.

RESULTS

a) The standard penetration test (SPT) was not very reliable for the identification of boundary layers. However, it is useful to obtain disturbed samples for clasification and laboratory grain-size and other index properties.

b) The cone penetration test (CPT) was found an efficient tool for the determination of the subsurface stratigraphy, it is less vulnerable to operator errors than the SPT and permits to obtain:

- A good identification of boundary layers.

- Soil clasification
- Indirect determination of relative density

From these experience one may recommend to study in a particular site the correlations obtained from the CPT results and the soil clasification, relative density and strength parameters. From this information one could construct maps of the sand liquefaction potential.

c) The piezometer probe test, permitting the pore pressure measurements during the static cone penetration test adds a new dimension to the interpretation of the liquefaction parameters.

   The excess pore pressure measured during penetration is a useful indication of the soil type and provides an excellent way for detecting details in stratigraphy. The dissipation of the generated pore pressure may be used as an indicator of the coefficient of permeability "in situ".

The results are shown in figure 2.

## BEHAVIOR ANALYSIS

The literature about this subject is quite abundant and there are several models or procedures for the evaluation of the liquefaction potential. Such models can be divided in "analitical" and "simplified". The first group includes numerical procedures and the second group field performance data. The literature inform us about the good correlation existing between the analytical and simplified methods, therefore, the following question arises; what is the reason to utilize more refined methods for prediction if the simplified methods are considerable more simple and economical?

A realistic answer to such question and other uncertainties may be obtained performing a planification and construction of a real field laboratory devoted to obtain "in situ" measurements on the real behavior of natural deposits such the one described in Ref. 3.

Taking into account the above mentioned statement, the case of the Mexicali Valley may be analized with use of field information and using simple considerations.

a) The collapse of the structure of the fine silty sand may occur to depth up to 10 m.

b) A good identification of boundary layers, in particular about to relative permeability, is indispensable.

c) Point resistances increase quasi-proportionally with depth only at relatively shallow depths (approx. 20 cone diameters) after that the point resistances may be a constant.

d) If the "in situ" effective vertical stress ($\sigma v'$) is divided by the point resistance ($q_c$) a useful ratio can be obtain in order to know the liquefaction potential.

e) In particular for the Mexicali Valley, apparently the critical boundarie separating liquefiable from non-liquefiable conditions, for fine silty sand materials is $\sigma v'/q_c = 1.5\%$.

## PROPOSAL

In accordance with the instrumenting above mentioned research, this paper proposes the research of seismic behavior of fine granular soil deposits to obtain "facts" recording the field behavior under the real environmental conditions, during the earthquakes. To accomplish this purpose the "Estación Experimental Mexicali" (Mexicali Experimental Station) was planed with most precision permiting to obtain:

- The history of ground displacements.
- The history of the accelerations at several points.
- The history of pore pressure generation at several points.
- The soil dynamic properties before and after the earthquake

Fig. 3 shows the initial tridimensional configuration of "Estación Experimental Mexicali.

We notice that the criterion followed in the design was to obtain a real pilot field laboratory. The design in such a to permit great flexibility to modify any initial configuration of the proper operation and of the interpretation of data by means of proper adjustments that may be taken into account.

## REFERENCES

1. Figueroa, J.A. (1973).
"Sismicidad en Baja California". Instituto de Ingeniería, Universidad Nacional Autónoma de México, No. 321, México.

2. Secretaría de Agricultura y Recursos Hidraúlicos (SARH). Representación General, BCN (1980).
"Efectos del sismo que se registró el día 8 de junio en la noche de 1980", 33 fotos, Mexicali, BCN, México.

3. Díaz-Rodríguez, J.A. (1983).
"Investigación del comportamiento sísmico de suelos granulares finos", División de Estudios de Posgrado, Facultad de Ingeniería, Universidad Nacional Autónoma de México, México.

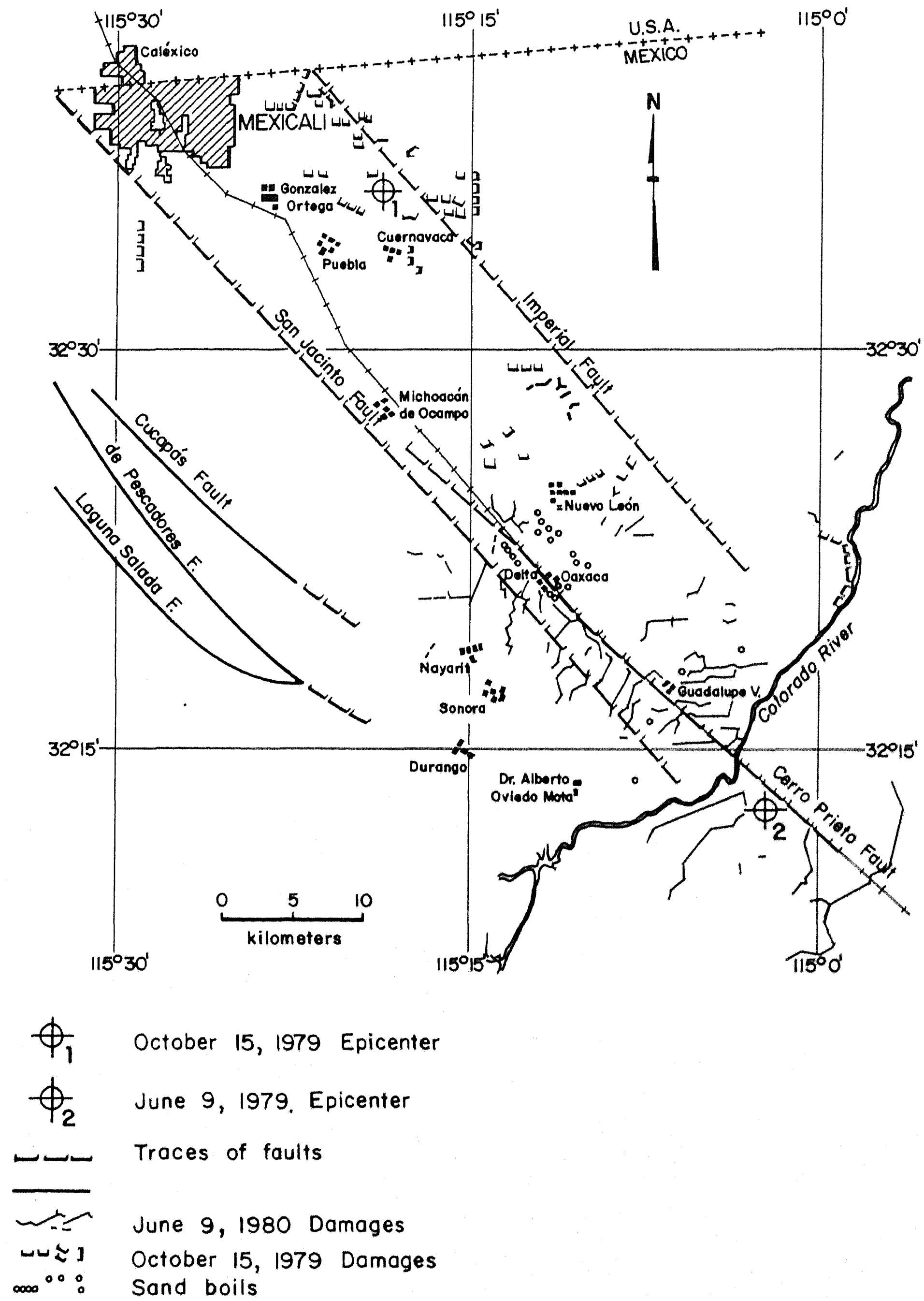



*FIG. 1 Regional map showing location of damages and epicenter of Mexicali Valley 1980 earthquake*

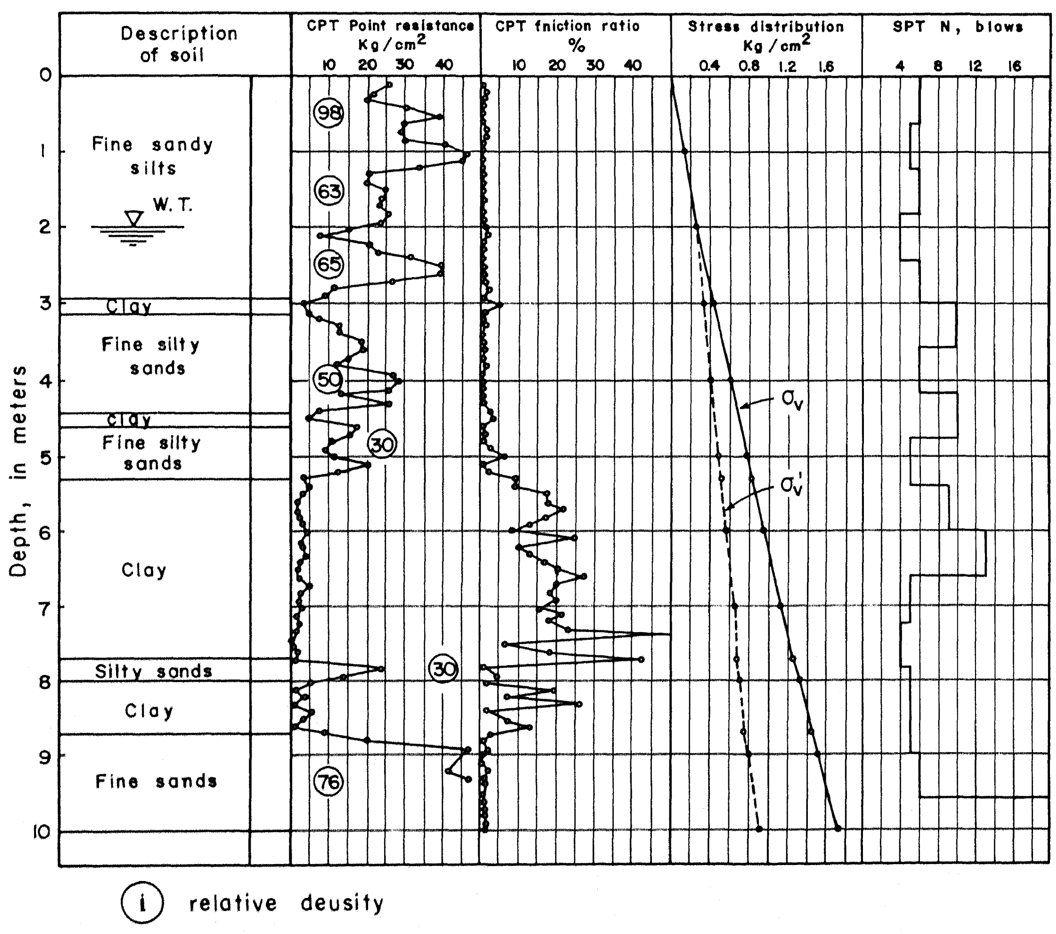
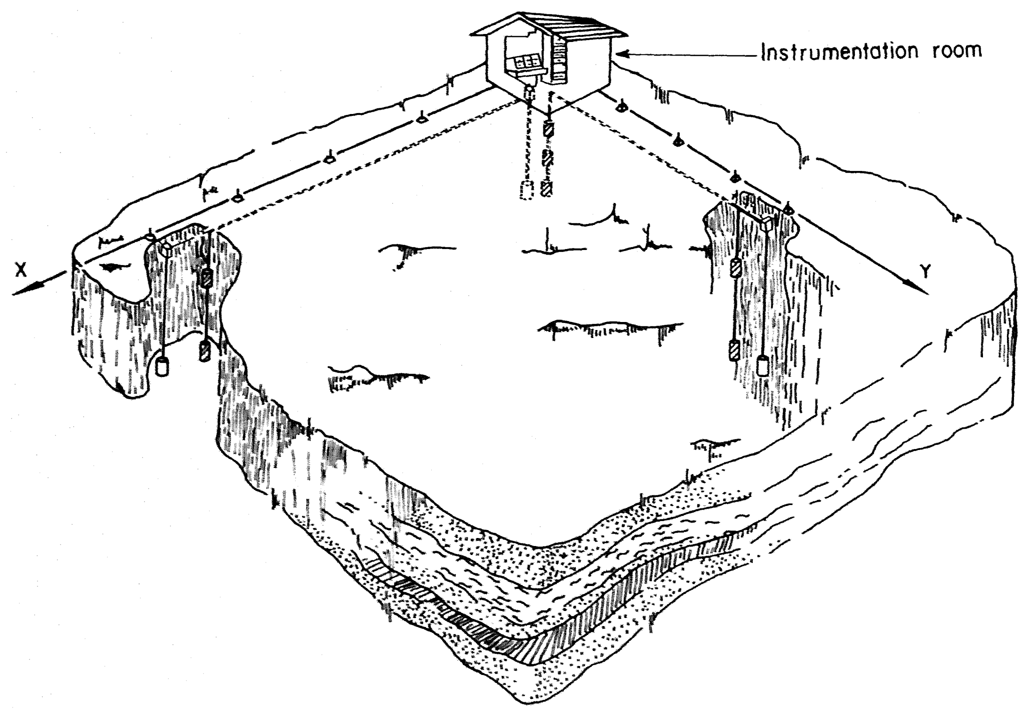



*FIG. 2 Logs of two borings showing electrical CPT and SPT records*




- Bench marks
- Surface strong motion instruments
- Deep strong motion instruments
- Electric piezometers

*FIG. 3 Field station Mexicali, México*