A Liquefaction Case History, Chiapas, Mexico

Un Cas de Liquéfaction, Chiapas, Mexique

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SYNOPSIS A series of small magnitude(4.5 to 5.5 on the Richter scale), shallow foci earthquakes struck the area near the confluence of two rivers in the state of Chiapas, Mexico, during the latter part of 1975. They caused repeated widespread liquefaction in recent alluvial sands located adjacent to the river and within a distance of 6 km from the general epicentral area. Evidences of liquefaction consisted primarily of cracks oriented parallel to the alluvium-terrace contact from which sand and water flowed out in a liquid condition. It is believed that this kind of liquefaction manifestation is typical when the topography of the recent alluvium is relatively flat and a surface cohesive layer is present. In addition, a number of other phenomena such as bank failures are described.

INTRODUCTION

During the last fifteen years many geotechnical engineers have been involved with the situation in which structures are founded on loose to medium dense cohesionless soils which may be subjected to strong earthquake shaking.

This paper describes the results of a preliminary analysis of a particular case history of sand liquefaction which occurred in the epicentral area of a series of small magnitude earthquakes. The evidences of liquefaction consisted primarily of cracks in the recent alluvial deposits from which small to moderate quantities of liquefied sand and water flowed. Preliminary data indicate that the alluvium generally consists of medium dense, medium sand with few fines. The cracks with liquefied sand were typically many meters long, were encountered at many places in the fields on both sides of the river, and appeared repeatedly as a result of the seismic shocks which are reported here.

Field observations made in this study indicate that when recent alluvium is covered by a cohesive surface layer and the ground surface is relatively flat, the manifestations of liquefaction typically consist of longitudinal cracks with expelled sand rather than sand boils.

SEISMIC ASPECTS

The zone where the widespread manifestations of liquefaction were observed is located near the confluence of the Santo Domingo and Grijalva Rivers in the State of Chiapas (fig 1). The seismicity of the region is quite high and the study area has been subjected to Modified Mercalli intensities between VI and VIII several times during this century. The liquefaction reported in this paper was caused by two small earthquakes of magnitude 5.0 and 5.5 on October 6, 1975, and by another one of magnitude 5.6 on November 5, 1975. The approximate location of the epicenters with respect to the study area indicates that the most intense manifestations of liquefaction occurred within a distance of 6 km from the zone of energy release. The focal depth of the earthquake on November 5 was measured locally to be between 2.5 and 5.0 km

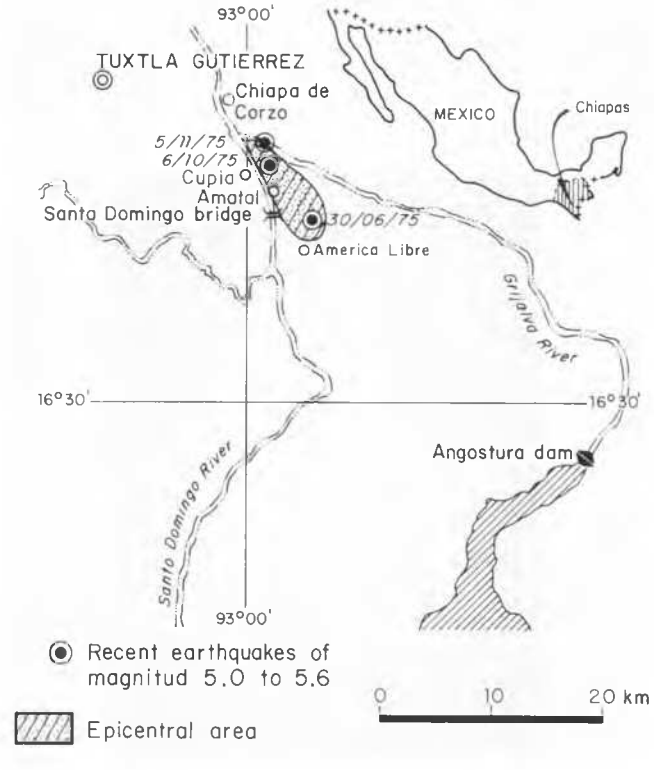

Fig 1. Epicentral area

The earthquakes caused serious damage to more than 50% of the houses in the villages of Cupía, El Amatal and América Libre; and to about 30% of the houses in Chiapa de Corzo. The damaged structures were constructed mainly with adobe walls and clay tile roofs. Well constructed residences of brick walls and reinforced concrete beams and columns, were not damaged. The Modified Mercalli intensity was VI to VII and the maximum firm ground accelerations in the study areas are estimated to have been on the order of 0.30 g.

FIELD OBSERVATIONS AND DISCUSSION

The main evidence of liquefaction consisted of long cracks in the ground from which sand and water flowed out in a liquid condition (figs 2 and 3). The cracks were only found in the nearly horizontal fields of recent alluvium adjacent to the river and ran parallel to the river and/or contact with compact terrace deposits which stratigraphically underlie the alluvium. No transverse cracks and only a few sand volcanoes or boils were observed. The longitudinal cracks which expelled sand and water in a liquid condition varied from only a few meters to more than fifty meters in length; these cracks were observed by the authors in numerous areas of the recent alluvium along the Santo Domingo River, and farmers in the zone reported similar descriptions in many other analogous areas. Locating the cracks was very difficult in fields which were not recently plowed because of the thick vegetative cover in the area. The cracks were typically only a few centimeters wide and large lateral displacements of the fields did not occur; this was probably due partly to the flat topography of the recent alluvium and partly to the short duration of shaking. The earthquakes occurred during the dry season when the river itself was only 50 cm deep and the ground water table in the adjacent fields varied between 1 and 2 meters in depth.

Fig 2. A crack from which sand and water flowed out

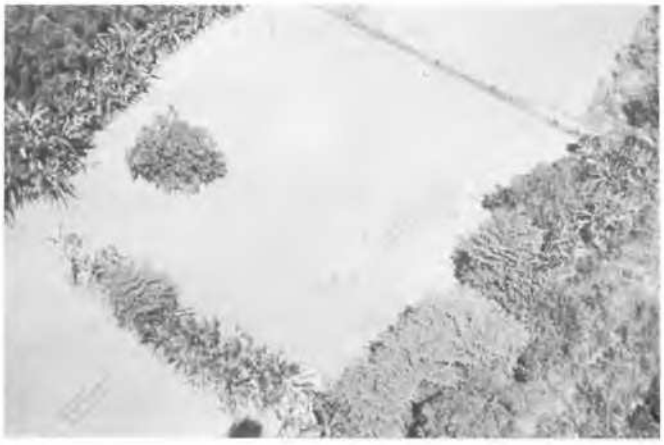

Fig 3. Aerial view of some cracks with liquefied sand

An open pit was excavated around a crack with expelled sand in the field adjacent to the Santo Domingo Bridge in order to get a better view of the phenomenon (fig 4). The ground water table was found at a depth of 1.3 m. Fig 4 shows a pair of cracks in the cohesive surface layer which filled and trapped the liquefied sand when the pore pressure dropped and the crack closed somewhat. The crack was generally narrower near the ground surface than at the ground water table where it was often empty. It typically was composed of only one branch up to 4 cm wide. The grain size curves of the liquefied sand found at the crack at the test pit and from other areas are shown in fig 5. The sand which liquefied appears to be mostly a uniform medium to fine granular material with little or no fines. The individual grains are generally subangular to subrounded in shape.

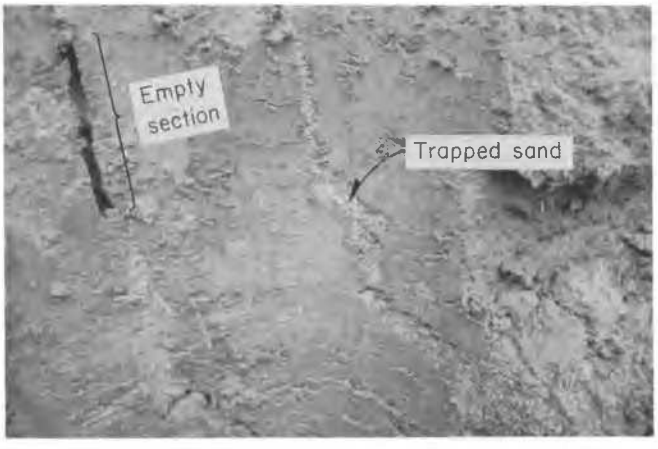

Fig 4. A front view of the cracks at the open pit

The soil profile along the axis of the bridge is shown in fig 6. The results of the test boring standard penetration resistance for that project (ref 3) were redrawn using the Gibbs and Holtz (ref 2) correlation for average conditions. It was found that Boring N°7

was located in dense formational terrace deposits of medium to coarse sand with few fines. This material was observed not to liquefy or show any other sign of distress. Borings made in the recent alluvium show considerable scatter in the penetration resistance but generally indicate correlated relative densities above 55% and may be classified as being medium dense. The penetration resistance of borings located in the river indicate significantly lower relative densities in the zone of frequent erosion and redeposition. Although these data were obtained in 1962, they appear to be reasonably consistent and tend to indicate that the sands which liquefied were generally located within a medium to dense alluvial deposit

The manifestations of liquefaction may be roughly grouped into three categories:

a) Cracks with liquefied sand in the middle of the fields overlying recent alluvium

b) Cracks with liquefied sand in the alluvium adjacent to the contact with dense terrace materials

c) Cracks without liquefied sand along the river banks

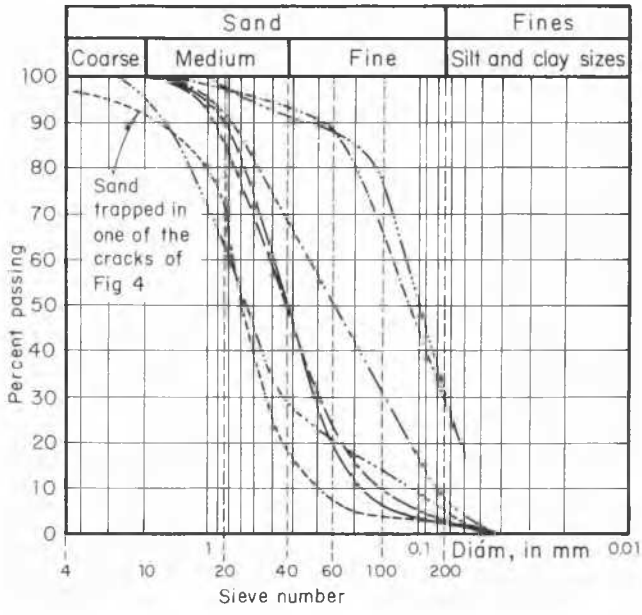

Fig 5. Grain size curves of the liquefied sand

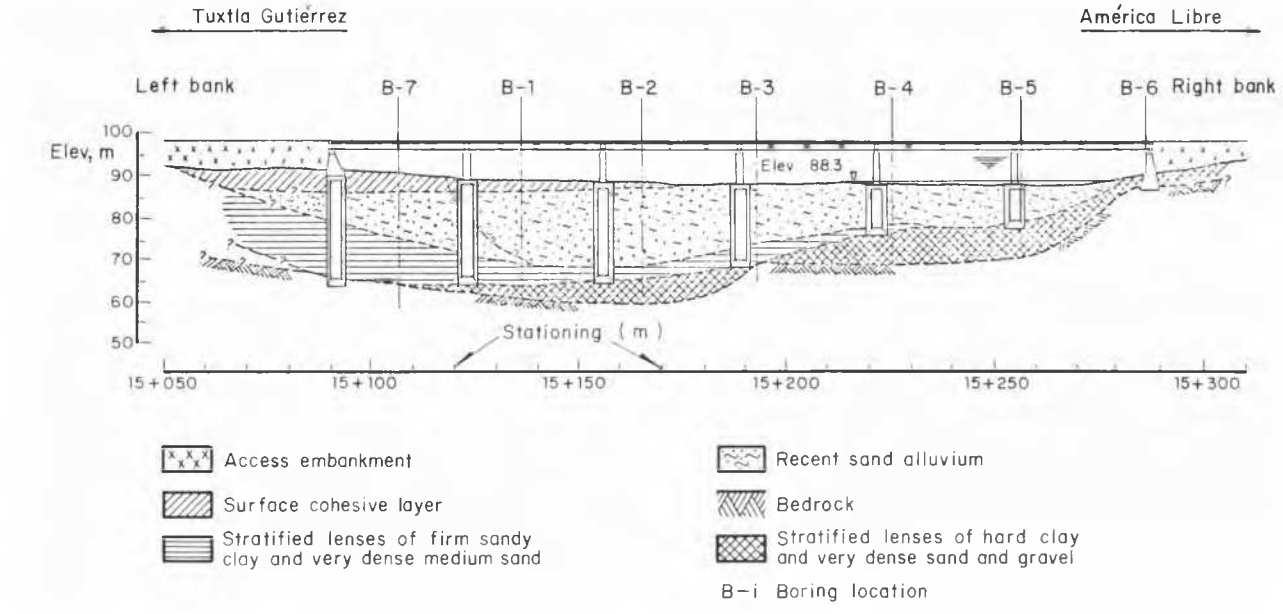

Fig 6. Santo Domingo bridge soil profile

The tendency for cracks to form at the contact between the recent alluvium and the very compact underlying formational materials was very pronounced in some areas. However until more specific data on the stratigraphy in these areas is obtained, it would be premature to speculate on the reason for the differences between groups a) and b). The cracks in group c) were as much as 50 m long and up to 40cm wide at the ground surface. They were generally located within 20 meters of the river bank and ran parallel to it. The cracks were found to be empty and only occasionally contained sand which had liquefied. The cracks were always widest at the ground surface and tended to close near the ground water table at a depth of 1 to 2 meters. The river bank appeared to form a block which had rotated downward about the base of the cracks and slid outward. The soil above the groundwater table is invariably cohesive, and below it consists of alluvial sands. Hence, it appears that the underwater toe of the bank lost its strength flowed into the river, and caused the observed bank movements

SUMMARY OF OBSERVATIONS

The region observed in this study has been subjected to Modified Mercalli intensities between VI and VIII several times in this century.

On at least two occasions, shallow focus earthquakes with magnitudes of about 5.5 caused widespread liquefaction in recent alluvium located at a distance of less than about 6 km from the zone of energy release.

Borings and standard penetration tests made in 1962, for the Santo Domingo Bridge, indicate that the recent alluvium is probably in a medium to dense state, and that it typically consists of uniform medium sand with few fines passing the N°200 sieve.

The principal manifestations of the liquefaction consisted of long cracks parallel to the river with expulsions of sand and water in a liquid state. The volume of expelled material was relatively small, and only spread some 50 cm on either side of the crack to a depth of several centimeters.

All of the cracks observed in the recent alluvium were parallel to the river and/or contact with underlying firm terrace deposits. No transverse cracks were observed and although lateral displacements of the fields were generally small, some of the fields appeared to have moved as a massive unit. It is believed that this kind of liquefaction manifestation is typical when the topography of the recent alluviums is relatively flat and a surface layer of cohesive material exists. In such cases it would be useful to dig shallow trenches and carefully try to locate such cracks as an auxiliary means of evaluating the liquefaction potential at future construction sites.

The river bank suffered movements of up to about 50 cm and moved both laterally and by rotation. The movement of the river bank was most probably due to a large loss of strength of the sand at the toe of the bank which then settled considerably.

The dense to very dense granular terrace deposits which stratigraphically underlie the alluvium showed no signs of liquefaction or any other kind of distress.

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