Learning From Earthquakes

Geological Aspects of the October 9, 1995, Manzanillo, Mexico, Earthquake

This article is excerpted from a comprehensive report on the earthquake which was sponsored by Grupo Interuniversitario de Ingeniería Sísmica (GIIS). The GIIS reconnaissance team included Hugón Juárez and José J. Guerrero of Universidad Autónoma Metropolitana (UAM), Andrés Gama and Robert A. Whitney of Universidad Autónoma de Guerrero (UAG); Raúl Vera of Universidad Autónoma del Estado de México (UAEM), and Francisco Hurtado of Universidad Michoacana de San Nicolás de Hidalgo (UMSNH). To receive a copy of the full report, contact Jesus Iglesias, University Autonoma Metropolitana, Av. San Pablo #180, Col. Reynosa Tamaulipas, Azcapotzalco, Mexico DF 02200, Mexico; tel (525) 724-4285; fax (525) 382-3998. Also see the December 1995 issue of the EERI Newsletter for a previous reconnaissance report on this earthquake.

Introduction

On Monday, October 9, 1995 at 9:36 A.M. local time (3:36 PM GMT), an earthquake with an epicenter located at 19.25°N and 104.19°W with a surface wave magnitude Ms=7.3 (USGS) and with moment magnitude Mw=7.6 (GS) and 7.9 (HRV) struck the area near the town of Cihuatlán in the southeastern part of Jalisco State, México. Over 8,600 structures either collapsed or were heavily damaged, affecting nearly 45,000 people. In the state of Colima 48 people were reportedly killed, all of them at the city of Manzanillo. In Jalisco at least 10 people died when their houses collapsed.

Seismic history

The seismic history of the Mexican trench in the area of the Jalisco block is known for about the last 100 years. Other events questionably attributed to this zone occurred up to 190 years ago. A magnitude Ms=7.5 event in 1806 and a Ms=7.7 in 1818 are assigned to this zone by Nishenko and Singh (1987). They also list an Ms=7.6 and an Ms=7.1 (possibly an aftershock) in 1900 and an event of Ms=8.2 ($Mo=1.0x10^{28}$ dynes) with an aftershock of Ms=7.8 in 1932. There has been no appreciable seismicity along this portion of the subduction zone since the 1932 event.

Plate tectonics

The epicentral region lies within the Jalisco block of southwestern México. This block is defined by a developing triple point in the vicinity of Guadalajara which is the location of the intersection of three systems of grabens and normal faulting, as noted by Luhr and others, 1985. They propose the graben structures mark the three arms of a triple point in the initial stage of an eastward spreading-ridge jump beneath the continental crust of the southern part of the North American plate. The two active arms of the triple point trend about north-south and northwest-southeast, bounding the Jalisco block, while the third, the failed arm, is presently undergoing extension with the resultant alocogen filling with continental sediments and volcanics related to the Trans-Mexican Volcanic Belt.

Collisional rates between the Jalisco block of North America and the Rivera plate are thought to be about 2 cm/yr by Nixon (1982), who believes the Jalisco block is becoming accreted to the North American plate. These rates are low compared with rates of collision of 6 to 9 cm/yr for subduction of the adjacent Cocos plate in the Mexican trench to the southeast (Drummond, 1986). The seismic event of October 9, 1995, is believed to have occurred in the subduction zone and is thus the result of this 2 cm/yr collision.

Ground motion

It is believed that one strong motion accelerometer was located at Manzanillo; however records of the earthquake have not been released to date. In spite of the lack of recorded data, the observation of damage distributions on structures enables us to conclude that maximum peak ground accelerations in the city must have ranged from 0.2 to 0.4 g. As in previous large Mexican earthquakes, an amplification effect was observed in México City and Chilpancingo, Guerrero.

The maximum Modified Mercalli intensities reported were in Cihuatlán, with high accelerations in other villages and cities. Intensities between VIII to IX were reported in a section of of the Jalisco and Colima coastal areas about 80 km long, where primary and secondary effects of the earthquake provoked severe damage to several structures, including the container port facilities of Manzanillo, and the large tourist hotels in the region. MM intensities decreased more rapidly with distance northeast across the Mexican Volcanic Belt than southeast and northwest along the southwestern Mexican Pacific Coast. In Tecolotlán, a town located 150 km northeast of the epicentral area, the reported modified Mercalli intensity ranges from V to VI.

Geologic effects of the earthquake

The only primary effect of the event was the high accelerations felt over a large epicentral area. No surface rupture was encountered or reported, which is consistent with what is expected from subduction zone earthquakes. Secondary effects of this

earthquake included induced landsliding and rock falls, widespread liquefaction and subsidence, and a moderate tsunami.

Landslides and rock falls occured on many of the steeper inclines in the epicentral region. Most of these were rock and soil falls onto highway pavement from adjoining vertical or near vertical road cuts. Loss of engineered structures from mass wasting processes was not reported nor encountered.

Liquefaction and related subsidence was prevalent in some low lying areas of the epicentral region. Liquefaction occured in both artificial fill deposits and natural soil horizons. The area of liquefaction of natural deposits was concentrated in the Cihuatlán, Jaluco, Barra de Navidad and Bay of Tenacatita areas. Artificial fill failed when underlying saturated natural deposits liquefied, allowing large lateral displacements in the overlying fill. Most affected were the Cabo Blanco portion of the town Barra de Navidad, Jalisco, and the port facilities in the city of Manzanillo, Colima. A series of liquefaction cracks which destroyed a home in La Manzanilla, Jalisco, also intersected a reinforced concrete slab floor of the local school. Proper engineering and construction practices in the building of the school prevented all but very superficial damage.

A tsunami with a maximum amplitude of about 4.5 meters was reported from Tenacatita Bay south to Manzanillo. Evidence for high water was found up to 40 km south of Manzanillo. In the western section of the Bay of Tenacatita, a restaurant known as "El Puerco," the westward most building in the bay, was hit by the waters of the tsunami. The water receded to expose the sea floor to the most distant rock at the beach, about 200 m from the shore line; and rose to touch the overhead beams in the restaurant. It is estimated that water both rose and fell 4 meters from mean sea level at this location. The restaurant owner reported that water rose and receded three times, with the first time having the largest amplitude. He also reported that the ocean was exceptionally calm, with minor surface waves, and no large wave associated with the incoming high water. Chairs, tables and other miscellaneous articles from the restaurant were washed as much as 1 km inland in the low lying area behind the beach.

A trailer park at the beach, at Boca de Iguanas in the bay of Tenacatita, was destroyed by the tsunami. Trailers were floated to over 0.5 km from their parking places and automobiles and houses were inundated. Further south along this same beach, a decommissioned hotel which partially collapsed during the strong ground motion was additionally damaged by the high water.

The town of La Manzanilla was inundated by the tsunami, which rose and fell three times in this location as well with the maximum being the first wave. Witnesses reported that no wave was involved, only a gradual rise about 10 minutes after the earthquake, with associated strong currents as the water moved over the beach berm and inland. In La Manzanilla many beach front structures were affected, and trash was washed into the streets of the town. High water marks from the tsunami were observed about 4 meters above mean sea level.

The tsunami reached about 2 m above sea level in Melaque, Jalisco. Witnesses reported a recession of the water level followed by high water. The event began about 10 minutes after the earthquake and high water occured three times, in about 10-minute cycles.

High water from the tsunami entered the channels in the suburb of Cabo Blanco in Barra de Navidad, Jalisco. This high water apparently did little damage but probably added to the liquefaction which destroyed the suburb.

A condominium complex, on a beach known as La Boquita, about 10 km north of Manzanillo, Colima, was also affected by the tsunami. The beaches of the complex were inundated and eyewitnesses and high water marks indicate the tsunami rose about 4.5 meters in this location. The witnesses reported five high water waves, each preceded by a recession. The third was the largest. The recession bluffs above the beaches and the high water marks can be determined by the line of affected vegetation (Fig. 1). Again witnesses reported no large wave, just a gradual rise of the sea level to the high water mark.

***Figure 1** - The line of affected vegetation confirms eyewitness reports of a tsunami indundation of about 4.5 m at a site 10 km north of Manzanillo. No wave was reported, just a gradual rise of the water level.*

About 30 km south of Manzanillo the coastal highway follows the coastline in back of a large natural beach berm. At one cut in this berm which allows vehicle access to the beach from the highway, evidence of flooding from the tsunami could be seen, where the currents of the high water were funneled through the vehicle access cut.

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