The October 9, 1995 Magnitude 7.6 Manzanillo, Mexico Earthquake

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A magnitude M_S 7.6 earthquake struck Manzanillo, Mexico, a coastal town about 550 km west of Mexico City, on October 9, 1995 at 9:37 a.m. local time. Approximately 40 people were killed and another 100 injured. Two major buildings collapsed in the Manzanillo area, and lesser damage was widespread. The shaking was felt strongly in Mexico City and as far away as Dallas, Texas and Oklahoma City, Oklahoma.

The Servicio Sismologico National placed the epicenter at 18.7 degrees north and 104.3 degrees west, offshore about 20 km southeast of Manzanillo, at a depth of about 30 km. The earthquake occurred at the junction of three plates: the Cocos and Rivera subduction plates and the Mexican continental plate. Most of the damage was centered in and around the city of Manzanillo, in the state of Colima. The small town of Cihuatlan, about 12 km east of Manzanillo in the state of Jalisco, was also hard hit. Residents of Mexico City were shaken, as they had been during the September 14, 1995 earthquake in Guerrero, but no damage was reported there.

The Setting

The port of Manzanillo is a relatively small urban area with a population close to 100,000. The metropolitan area is about 18 km long and 1.5 km wide, bordered by the Pacific Ocean to the west and southwest and by a series of mountains to the east and northeast. The mountain slope is steep enough to have prevented urban development. The subsurface soil conditions change rapidly from the shore to the foot of the mountains.

Most of the engineered buildings were built along the beach-front in the 1970's and 1980's, to serve a growing tourism industry. Reinforced concrete frames with masonry infill is the typical structural system used for buildings four stories or more in height in this area. The old Manzanillo downtown area consists of low-rise commercial, administrative, and residential buildings, most of which are of non-engineered unreinforced masonry construction. Lightly reinforced concrete boundary elements (horizontal dalas and vertical castillos) of the same thickness as the single-wythe brick or block walls are used in many of these structures. A few one-story commercial buildings used light steel frames for the structural system.

The 1990 census showed that, of the approximately 20,000 residences, 15 percent are one-room houses, and 6 percent are built of cardboard or light gage metal sheets.

Liquefaction and Landslides

Houses constructed on landfill along the bank of the Laguna De Cuyutlan in Manzanillo suffered substantial damage due to liquefaction. In some cases buildings sank up to two feet in the loose soil, sometimes twisting and sliding several inches. Sidewalks were often highly distorted and uplifted. Sand boils, unable to rise through the paved street, were forced through the thin unreinforced concrete floors of the homes and literally filled them with sand or soil (Figure 1). The heavier two-story buildings were most susceptible to this problem. The houses did not collapse, but were a total loss. Damage associated with soil failure was also observed along the sea wall.

Two prestressed concrete continuous bridges with 25-30 meter spans suffered damage to the abutments due to soil failure. The bridges, on the Mexico 200 highway about 5-10 km outside the city of Manzanillo, remained open to traffic at reduced speed.

Landslides occurred along the four-lane toll road connecting the town of Manzanillo with the city of Guadalajara. Some occurred as far as 120 km east of the epicenter.

Coastal Flooding

La Manzanilla, a low lying coastal town north of the city of Manzanillo, experienced a tsunami. Residents reported that during the earthquake the sea retreated suddenly and then rose, flooding the town with two meters of water. Small boats were washed up into the streets several blocks from the ocean front. Buildings were flooded, but none collapsed.

Good Building Performance

The majority of the buildings in Manzanillo suffered very little damage

Figure 1 - Liquefaction caused a sand boil that forced its way through the weak concrete foundation of this home.

despite being very close to the epicenter. With very few exceptions, houses and buildings built on the hill side of the city, away from the shore, located in firm soil or on rock, showed no significant damage.

School buildings were damaged, but none collapsed. The schools, reportedly designed by a government agency, appeared to be of uniformly high quality construction. Most of the one-story buildings performed quite well with limited cracking in some brick infill walls. In some two-story structures, the damage to the infill was extensive. The concrete frames acted as successful back-up systems, preventing any collapses.

Most of the modern hotel and condominium concrete frame buildings performed satisfactorily, with damage limited to diagonal or horizontal cracking in the masonry infill. The nineteen-story Hotel Radisson Sierra is an example of a concrete shear wall building that performed well, suffering only nonstructural damage around the many seismic separation joints.

Among the non-engineered buildings of vernacular unreinforced masonry construction, those with short story heights (about 2.5 m) performed better than those with tall stories. The use of mid-story concrete beams (dalas) was associated with better performance, apparently limiting out-of-plane failures. Shear failures in concrete column boundary elements (castillos) were frequently observed, but buildings with these elements generally performed better than buildings without them.

Poor Building Performance

While most modern hotels and condominiums performed well, others were severely affected and in one case, collapsed. At the collapsed building, the Costa Real Hotel in Manzanillo, at least 12 people were killed. The building had very few walls, being open to the ocean on two sides. Inadequate splice lengths in the joint regions and only minimal transverse reinforcement in the columns were observed in the ruins of this eight-story concrete frame building with block infill. This hotel was closed due to damage after the 1985 Michoacan (Mexico City) earthquake, and subsequently reopened, reportedly without adequate repairs.

A 15-story beach-front condominium in the town of Santiago was severely damaged and closed. Damage was concentrated at the interface of the brick infill and the beams of the concrete frame and in interior brick partitions. In Melaque, the Casa Grande Resort consisted of multiple five-story buildings constructed within the last 20 years. All three stair towers on the oldest structure collapsed. Each stair tower supported a 45-ton water reservoir (Figure 2). These masses undoubtedly contributed to the collapses.

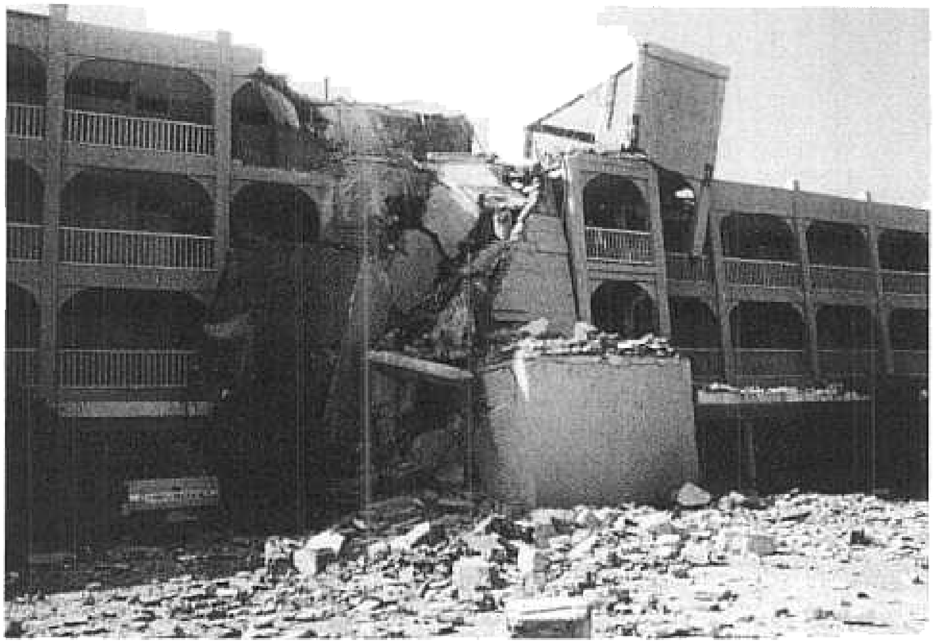

Figure 2 - A collapsed stair tower at the Casa Grande Resort in Melaque. A 45-ton water tank constructed on top of the stair tower probably contributed to its failure.

Figure 3 - The partial collapse of a two-story office building in a Santiago shopping center was due to inadequate exterior columns.

A four-story telephone company building suffered severe distress in the north-south infill masonry block walls. The column lines in this building were spaced at 5 m in the east-west direction, and approximately 20 meters in the north-south direction. The clear height of the first floor of the building was approximately 5 m to the bottom of the north-south girders, which were approximately a meter in depth to the bottom of the slab.

One of the most widely affected areas was a large shopping area in Santiago. The complex included a large open warehouse, three one-story shopping centers, a two-story federal office building (containing a jail), and a bank. The buildings used steel columns with masonry walls, an unusual form of construction for the area. Many of the shopping center buildings had very high (3 m) masonry parapets. One of these collapsed and fell into the building. Several other parapets were damaged. The exterior walls of the federal office collapsed on three sides (Figure 3). These brick walls had many openings and no exterior steel columns. The one-story bank building had a steel frame which was apparently undamaged, but the masonry infill was considerably distressed. Loose clay roof tiles littered the complex. The fact that other buildings around this particular shopping area were relatively undamaged casts suspicion on the construction methods used.

The main hospital in Manzanillo was evacuated after the quake. The fairly new building was constructed using a ductile concrete moment frame. Structural damage was limited to three areas. The frame in the mechanical room was severely damaged; some columns and construction joints suffered spalling; and several heavy concrete infill panels pulled away from the outside of the building and in one instance fell from the structure. The mechanical room problem may have placed critical hospital equipment in jeopardy. Non-structural damage in the form of broken water lines appeared to have substantially damaged the interior.

Figure 4 - This two-story home in Manzanillo collapsed due to a heavy roof and inadequate walls.

In the non-engineered low-rise masonry buildings, diagonal cracks between openings were common in both brick and block walls. Sheer failure of vertical lightly reinforced concrete members (castillos) was typical. In the collapse of a two-story police station, insufficient continuity appeared to have caused the damage.

Complete collapses occurred in many of the simple masonry buildings that did not make use of supplementary horizontal and vertical concrete elements (Figure 4). Much of this type of construction has clay tile roofs; the tiles were often shaken loose.

Conclusions

Most of the damage occurred in non-engineered masonry construction. The damage observed after the quake indicated that the use of concrete columns and beams can greatly enhance the performance of these buildings.

With a few notable exceptions, engineered buildings performed well. Structures with a significant amount of wall area seemed to perform better than those with less wall area.

Site and soil conditions greatly influenced the level of shaking apparently suffered by the buildings. Filled land was susceptible to liquefaction. These observations point to the need for intelligent land-use planning in earthquake-prone regions, and careful site selection by individual building owners.

The collapse of the previously damaged Costa Real Hotel underscores the need to adequately assess and repair earthquake damage.

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A second report on the Manzanillo earthquake will appear in next month's newsletter.