2. Geotechnical Aspects

Local Site Effects

The seismic event produced strong ground motion throughout the region, but its effects were amplified primarily within the alluvium valley of the Ulua and Chamalecon Rivers. Damage was selective of those structures that were supported on soft foundation soils and/or supported on filled or reclaimed land. This was evident at sites located in San Pedro Sula and Puerto Cortés. The most obvious example of local site effects was at the Supreme Court Building located on the Segunda Circunvalación Road in San Pedro Sula. The Supreme Court building is a three story reinforced concrete frame which underwent structural damage (see Figure 11). The building is supported on about 3 m of fill underlain by soft and compressible organic soils. In contrast to this structure, a multi-story reinforced concrete stadium located less than half a mile away did not experience this level of damage.

Liquefaction

Liquefaction was widespread in areas underlined by granular saturated sediments. Sand boils, surface cracks, and lateral spreads were evident in many areas near Puerto Cortes and towards the town of Omoa on the Caribbean Sea coast. The structures impacted by the widespread liquefaction were petrochemical terminals, ports, wharfs, roadway embankments and other smaller buildings.

Of particular interest was the damage encountered at the Chevron Terminal in Puerto Cortés. This area was built on sandy fill. Liquefaction sand boils were wide spread throughout the terminal within tanks, pipe racks and small buildings (see Figure 3). Damage to tanks was not evident, except a pressurized vessel that settled more than 2 ft on one side tilting the entire tank, which was supported on shallow foundations (see Figure 4). Small structures supported on shallow foundations were damaged, such as the laboratory and office buildings (see Figure 5). Safety inspection requirements and repairs of tanks and pipeline systems will take more time.

Figure 3 – Chevron Terminal remains closed as of 06/28/2009.

(a) Note inundation due to wide spread liquefaction [05/28/2009 N15.848287, W87.958041],
(b) Same entrance location 3-weeks later [06/20/2009 12:40PM, N15.848287, W87.958041], and
(c) Multiple pipeline deformation and breaks [06/20/2009 1:24PM, N15.849177, W87.959274]

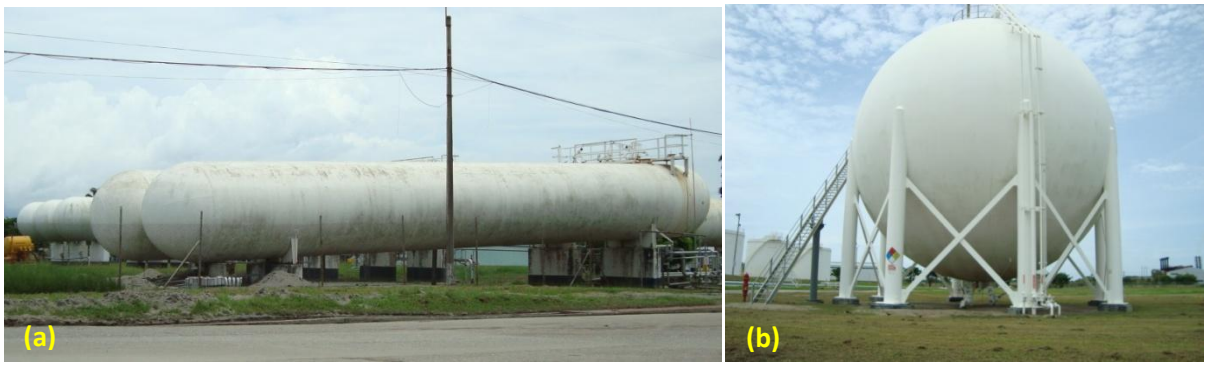


Figure 4 – (a) Tanks supported on shallow foundations sank and tilted, notice sand boil piled up next to foundation on left [6/20/2009, 1:12PM, 15.851061, -87.956882], and (b) those supported on piles performed well [06/20/2009, 1:16 PM, N15.851226, W87.958534].

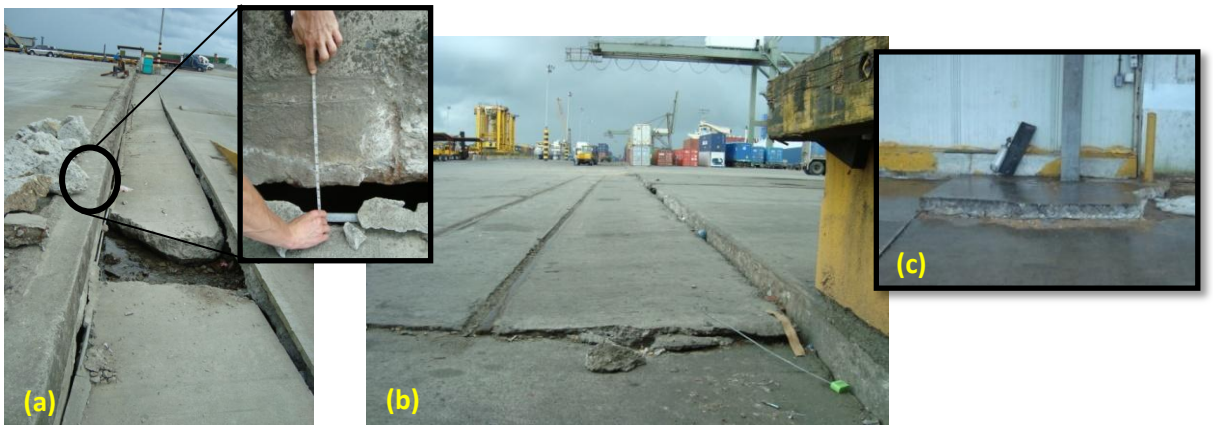
Figure 5 – (a) Buildings and small structures sank up to 3 ft and were flooded with liquefied sand [06/20/2009, 1:08 PM, N15.849851, W87.95793], and (b) vehicles sank into sand boils, see carport automobile was already extracted [06/20/2009, 1:25 PM, N15.848216, W87.958604].

Other buildings and residences were damaged in the central zone of Puerto Cortés due to the wide spread liquefaction and ejected sand. Buildings tilted and became inundated, leaving much sand behind. The surface storm sewer system was clogged for weeks until the municipality and neighbors were able to excavate the drains. A recently build roadway embankment that contains a major utility on the south side of the city was seriously affected by lateral spreading. (Figure6)

Figure 6 – Temporary repair of roadway embankment, due to lateral spreading [06/20/2009, 1:25 PM, N15.848216, W87.958604].

Port Facilities

Earthquake damage at the most important port in Honduras was localized even though it remains in operation. Most of the damage was concerning movement of slabs and wharfs causing joints to move in the vertical and horizontal directions. In some cases the slabs collapsed due to the loss of subgrade support (Fig 7a and 7b). It was reported that some of the pile supported wharfs moved upwards by several inches. Some foundations appeared to have moved upward, but this differential movement is all relative to the surrounding ground subsidence, which needs to be confirmed by precision survey (Fig. 7c). Fuel tanks supported on concrete mats experienced large deformations due to widespread liquefaction and surface rupture of fill materials, see Figure 7(d).



(a) Up to 0.46m at the main dock [06/20/2009, 3:37PM, N15.843718, W87.951739],
(b) 0.2m near port warehouses [06/20/2009, 3:49PM, N15.8424, W87.94941], and
(c) Relative foundation displacement up to 0.15m [06/20/2009, 4:00PM, N15.841912, W87.941644].

(d) Three view of fuel tanks and multiple ground fissures due to wide spread liquefaction [06/20/2009, 3:12PM, N15.846936, W87.963225]

Figure 7 – Liquefaction induced deformations at Puerto Cortés – Slabs on grade and Tanks.

Levees

The valley of the Ulúa and Chamalecón rivers (Valle de Sula), runs north towards the Caribbean Sea. A system of levees protects the agricultural activities, urban and residential areas. A preliminary survey completed by the Comisión Ejecutiva Valle de Sula (CEVS) identified 58 km of levee damage due to the earthquake event. Lateral spreading was observed along the banks of the Ulúa River. On the edge of a sugar cane plantation, about 250 meters from the river edge, long fissures opened in the direction parallel to the river (Figure 8). The crack openings ranged from 10 to 50cm with a depth of about one meter. *Allochthonous sand ejecta* ware present along the length of the fissures, and sand boils were scattered amongst the sugar cane plantations.

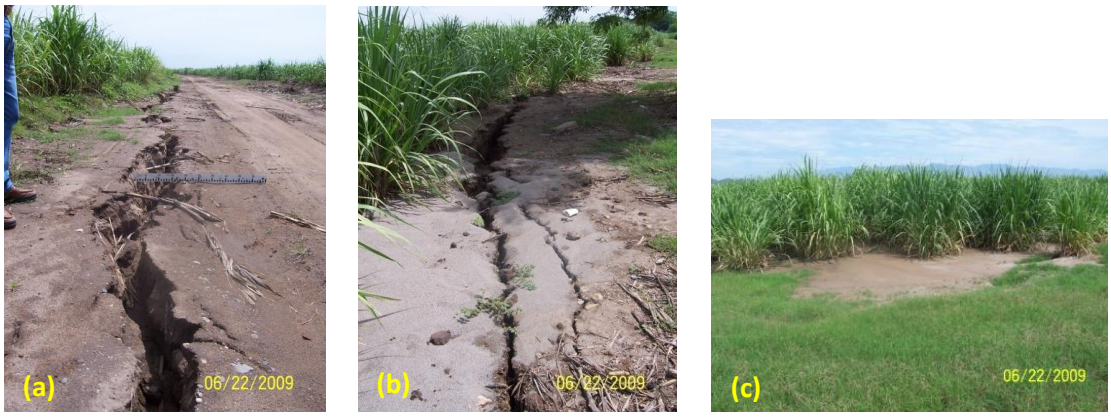


Figure 8 – (a) Longitudinal cracks along roadways [06/22/2009, 10:03AM, N15.368726, W87.861301], (b) with sand at surface [06/22/2009, 10:10AM, N15.369316, W87.860965], (c) sandboils within plantations [06/22/2009, 10:06AM, N15.368988, W87.861209].

Near the edge of the Ulua River, on the unprotected zone of the levee system, extreme lateral spreading was evident. Gaping fissures up to 5 meters wide and two meters deep have indelibly altered the landscape (Figure 9). This will have serious consequences as the rainy season approaches and the levee system is not able to keep the flood water out of the protected zones (plantations and rural residences).

Figure 9 – Multiple views of severe lateral spreading between levees and river [06/22/2009, 10:25AM, N15.391266, W87.845191].

Along the crest of the levee system, a network of smaller cracks (about 5-10cm wide and several meters deep) has rendered nearly 60 km of the levee system ineffective (Figure 10). CEVS is currently undergoing an emergency earthwork operation to reinstate levee geometries to its pre-earthquake conditions.

Figure 10 – Cracks at the crest of levees exceeding 1.5m deep [06/22/2009, 11:57AM, N15.344505, W87.868515].