

3. Structural Aspects

Buildings

The Supreme Court building, located on the Segunda Circunvalación Road in San Pedro Sula, is a three story reinforced concrete frame which underwent structural damage. Each story is about 4 m high with columns and beams with the same (350 mm x 350 mm) cross-section. The building had frames with concrete beams running in orthogonal directions. The concrete frames were in-filled with brick masonry. Typical failures of these in-filled masonry walls are shown in Figure 11.

Inside the building and some locations, these frames were partially filled with masonry walls. This in turn causes the reduction in height of the column resulting in increased lateral shear during earthquakes. This is also called as short column effect. This failure mode, also called captive-column or captured-column, is very common in RC frames with infill walls. This failure happens when an infill wall is extended into a frame from the floor level up to another level to form a window, leaving a short free space in the top portion. The column in such a structure is partially restricted by the wall. This shortened column develops large shear force which may exceed the shear capacity of the column, resulting in failure. The problem is well known but is often ignored in practice. In some cases, the infill walls are separated from the column to allow flexure of columns. But insufficient gaps produced the same consequences. Figure 11b shows a reinforced column failed by shear. The column is constrained by masonry infill walls in perpendicular direction. Shear cracks were developed from masonry wall which led to shear failure of columns. Figure 11c shows the failure due to short column effect from a masonry infill wall. These columns had No. 3 ties spaced at 6 to 8 inches. This seems to be an inadequate detailing for seismic loading. The large spacing of lateral ties did not provide the required confinement to the core concrete.

Infill walls, usually located between RC columns and beams, can suffer out-of-plane overturn due to inertial forces during an earthquake. Because infill walls are non-load-bearing elements, they tend to be thin and cannot rely on the additional shear strength that accompanies vertical compressive loads. If infill walls are not properly restrained in out-of-plane direction, walls can collapse during strong ground shaking, producing damages to inhabitants and properties. If walls on the façade of a structure collapse, the consequences could be deadly to pedestrians. Figure 11a shows a typical in-fill wall failure.

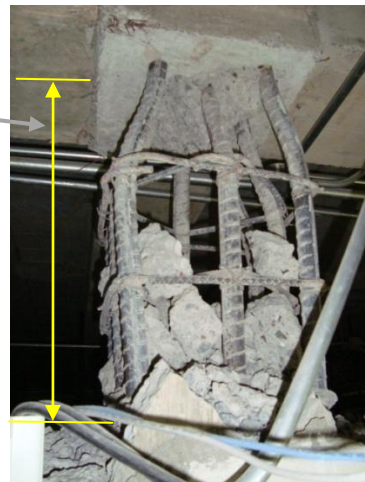


(a) Overall damage including out-of-plane failure of masonry infill wall [06/19/2009, 5:53PM, N15.472899, W88.018565].



(b) Column failure at the infill wall frame interface [06/19/2009, 5:08PM, N15.473038, W88.018103]

Unsupported height



(c) short column effect failure [06/19/2009, 5:31PM, N15.473346, W88.018592]

Figure 11 – Supreme Court Bldg. structural damage due to local site effects and aseismic design.

Bridges

Two bridges suffered serious consequences by the seismic events of May 28th, 2009. The reinforced concrete 3-arch bridge, entitled “La Democracia”, crosses the Ulua River near the town of El Progreso. The bridge connects this town to the major city of San Pedro Sula in northern Honduras. The bridge that experience collapse of the middle span was built in 1965 by a team of French engineers. The structure consists of two middle supports with nearly symmetric monolithic arches, with the middle span complemented by a straight beam span. The total length of the bridge was 258 m. The middle span was 36 m. These middle components consist of four simply supported T-beams. All supports, including abutments, consist of steel plate bearings. Figure 12 shows the collapsed middle span and in the background the newer 2005 twin bridge built by the Japanese, which still is in service taking the traffic towards el Progreso. The bearings on the abutments moved more than 250 mm in the horizontal direction. This bridge had shear key only in the longitudinal direction to support the T-beams. This simply supported girder Type Bridge had inadequate seating and no provisions like lateral restraint to prevent unseating. The lack of redundancy in the simply supported beam also prevented formation of alternate load path which resulted in the fall of the beams and consequently the middle span.

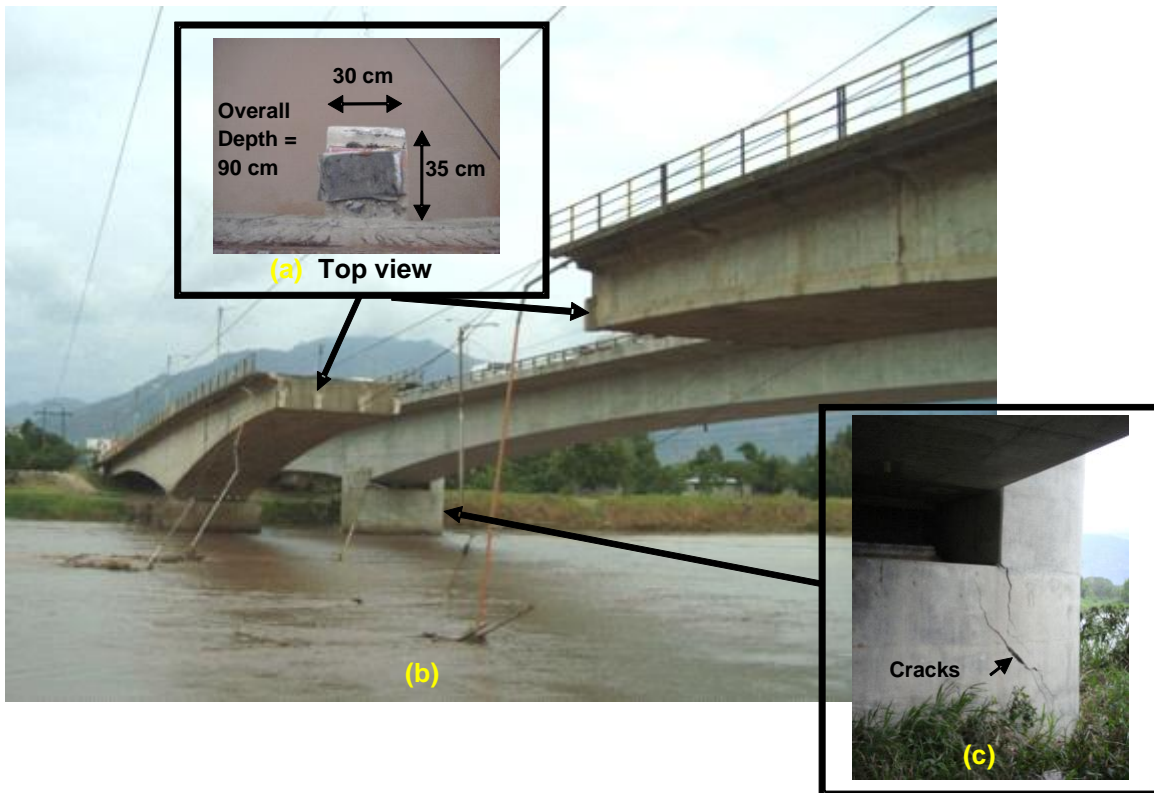


Figure 12 – La Democracia twin-bridge with middle span collapsed.

- (a) Top view of shear key [06/19/2009, 6:45PM, N15.404139, W87.820174].
- (b) Overall view of the twin bridge [06/19/2009, 6:45PM, N15.40478, W87.819967], and
- (c) cracking due to lateral restraint in the new bridge [06/19/2009, 6:58PM, N15.40408, W87.820615].

In contrast, the new bridge, which consists of a single monolithic concrete arched structure, has neoprene elastomeric bearings and shear keys at the supports. The shear keys suffered diagonal cracks, evidence that they engaged in keeping the bridge on its bearings during the seismic event. A transverse crack on the bridge (western bank) was identified. Liquefaction sand boils and significant settlement of the banks and possible lateral spreading was evident on the river banks. In some locations cracks and settlement exceeding 250 mm was observed (See Figure 13).



Figure 13 – Settlement of ground around abutments due to liquefaction
(a) Old bridge westbound [06/19/2009, 6:36PM, N15.404409, W87.821095], and
(b) New bridge, eastbound [06/19/2009, 6:52PM, N15.40422, W87.821021].

The other bridge that suffered damage during the seismic event was the bridge near Santa Rita over the Humuya River (Figure 14). The foundation support was already weakened due to scour, which historically has damaged the bridge and scour continues to aggravate the situation. The most common cause of bridge failure is structural instability and undermining caused by movement of column bent exaggerated by excessive scouring. Scour is the result of the erosive action of flowing water, excavating and carrying away material from the bed and banks of streams, and from around the piers and abutments of bridges.

This two-lane bridge consists of 8 spans of 5 simply supported reinforced concrete girders (1m x 0.6m x 30m) built in the 1970s. Two supports experienced significant movement and the third column bent was tilted and rotated causing settlement and a reduction in the bearing support of the girders. The fourth span had only about 5 to 6 cm of bearing on the third column bent as shown in Figure 14. The night of June 28th several spans collapsed as shown in Figure 15.



Figure 14 – Santa Rita Bridge over the Humuya River after the earthquake and before collapse

- (a) [06/21/2009, 6:08PM, N15.191548, W87.82559]
- (b) [06/21/2009, 5:43PM, N15.191017, W87.8922393]
- (c) [06/21/2009, 5:40PM, N15.190907, W87.892658]



Figure 15 – Collapse of the 2 to 3 spans of the Sta. Rita Bridge over the Humuya River post-earthquake [06/28/2009, N15.191019, W87.892095] (source: LaPrensa.hn).

El Cajon Dam

A visit by the recon team was made on June 21st consisting in meeting with the director of dam safety at the dam site and external and internal visit of this concrete arch dam. The dam is 227 m high arch dam and it forms a reservoir 94km². This dam is the most significant civil infrastructure in northern Honduras and continued normal operations during and after the event. However, the response of the dam to the earthquake was successfully recorded by the instrumentation monitoring system at the site, including one seismograph and three accelerographs. After the event a visual inspection was made by the safety inspection squad and was followed by a more detailed data collection survey of the installed instrumentation. The following is a summary of the measurements and observations made immediately after the earthquake event.

Accelerographs: Historic values were reached during the event. At the top of the dam (El. 291m) the Dam registered its maximum value of -0.081g was recorded. At the bottom of the dam (El. 78m) the maximum acceleration was recorded as 0.010g. The maximum value obtained before this event was of -0.045g on July 11, 1999.

Seismograph: During the following 13 hours after the main event, 23 events were registered in the seismograph, which is located on rock below the safety engineering station on the west abutment. The seismograph data was delivered to INETER in Nicaragua for interpretation.

Pendulums: There are 21 pendulums which measure the deformation of the dam. The readings of these instruments are not outside the normal parameters because there was not a deformation in the dam. Evidently, during the event the alarm went off because the dam moved.

Extensometers: These instruments measure the deformation of the rock in the base of the dam. The readings from these devices are between the same parameters as before the event, so there is no value outside the boundaries.

Filtration Flow and Drainage: The increments in the flow are not significant. The change in flow after the event was noteworthy, from about 138 lt./sec. to 167 lt./sec. Turbidity was detected in the downstream outflows shortly after the event (3 days), but none was observed during our visit. This is evidence of adjustments within the rock and soil that may promote continued filtration through the curtain.



Figure 16 – (a) Weir passing turbid water at base of dam [05/28/2009, N15.03096, W87.747885], and (b) reflected in downstream river [05/28/2009, N15.03096, W87.747885].

Pore pressures: In general the behavior of the impermeable curtain was not significantly impacted. However, four piezometric instruments in the G78 gallery present increments equivalent to about 16 to 19 m of pressure head. This coincides with the location of the “Fault III” within the dam site, suggesting movement during the event.



Figure 17 – (a) Turbid seepage at base of dam [05/28/2009, N15.03096, W87.747885], and (b) clear seepage at base of dam [06/21/2009, 11.55AM, 15.03096, -87.747885]

Powerhouse: There are no seepage increments in the filtration paths of the north well and GL11 spring (old access), but the water is showed high turbidity. At a joint of the access tunnel I17 similar situation was observed with higher temperatures reaching 34.6°C.

Even though the dam safety instrumentation measured the impact of the earthquake event on the dam, the structure is considered safe and continues to operate normally. The dam safety plan did not require any further action, as none of the thresholds were reached. However, a grouting plan programmed for the near future to seal the existing grout curtain is currently being re-assessed.