

4.3 WATER SUPPLY SYSTEM

Overview

The water supply system of the Northern Zone Project (Proyecto Zona Norte) that covers the San Salvador metropolitan area including Nueva San Salvador, Santa Tecla, suffered the most serious damage (**Tables 4.1-4.3**). Power outage stopped pumps for water conveyance, water purification and water distribution facilities. Water pipes were cut off by slope failures and rockslides in Cojutepeque and other cities of Cuscatlan. Wells providing water for these cities were also damaged seriously. In rural areas, water shortage caused latrines to be kept long out of use, increasing the worry of epidemics. Some water valves were shut off immediately after the earthquake to minimize the loss of water through leakage, though it was expected that the operation would stop water supply to some highly populated areas. As a whole, problems of soils and foundations more or less affected the water supply system.

Table 4.1 Damage to water treatment equipments

Damage types	Locations
Malfunctions of Electric devices	
*Batteries *High voltage systems *Short-circuits	Finca Montenegro (Nejapa) San Jose and Las Delicias (Santa Tecla) Jucuapa, Ozatlan and San Fco Javier (Usulután), Chinameca, Carolina and Lolotique (San Miguel)
*Damage to substation *Utility poles *Control box	FENADESAL Pump plant (Armenia) Col. La Chacr Quezaltepeque; “Finca Montenegro” (Nejapa), Hacienda San Jose (Santa Tecla), San Alejo (La Union).
*Turbines	Canton Jardines del refugio (Ahuachapan).
Water leakage in equipments	
*Turbines *Foundations *Others	Balneario El Trapiche Panchimalco; Canton Conception Ctgo. Policia de Hacienda
Damage to valves	
*8-inches iron valves	Apunian River (Ahuachapan)
Damage to chlorination equipments	
*Chlorination equipments *dispersers	San Fco. Javier (Usulután) and Pasaquina (La Union) San Agustin (Usulután)

Table 4.2 Damage to pipes

Damage types	Locations
Damage to cast-iron pipes	
* 4-in diameter pipes * 5-in diameter pipes * 6-in diameter pipes *14-in diameter pipes *Impelling pipes	Armenia-Sacacoyo, El Chorro-Los Chicos” Abduction Line San Jose La Majada (road to Santa Ana) Paraiso del Osorio, (El Balsamo) Talcomunca System” (Sonsonate) Jucuaran (Usulután) and “Canton El Barro” (Ahuachapan).
Damage to distribution pipes	
*Pipeline bridges	Rpto. Las Canas San Bartolo” and “Circulo Estudiantil”
Damage to intake cast-iron pipes	
*6-in diameter cast-iron pipes	Nahuizalco mountain area
Damage to cast-iron impelling pipes	
*pipe foundations *24-in and 48-in pipes	Jucuaran, (Usulután); Canton El Barro (Ahuachapan) and San Juan Talpa (near the road to Comalapa). Zona Norte System- Impelence Line (Nejapa)

Table 4.3 Damage to cisterns

Damage type	Locations
*Cracking of cisterns	Apopa (San Salvador); San Agustin (Usulután) and Santa Tecla.
*Cisterns got muddy.	“Ciudad Arce” (at the end of Fco. Gavidia street); El Tinteral; “Canton El Zacatal”; Suburbs of “Colonia San Juan; and “Canton El Botoncillal.

Damage to tanks

(1) Las Colinas del Norte Tanks

Water tanks are often constructed on hilltops and thin mountain ridges so that they can supply waters to widely spread areas. A typical wall of a water tank in El Salvador is a cylindrical shell of reinforced masonry or reinforced concrete. Two tanks of “Las Colinas del Norte” are located on a thin hilltop of Apopa Town (Figure 4.18). There appeared extensive 1m-deep cracks on the top terrace as illustrated in Figure 4.18. Paved walkways around the tanks were fissured. The cracks were certainly a serious threat for about 200 houses around the hill of a possible landslide that can carry off foot soils of the tanks. The tanks were thus abandoned and demolished (Figure 4.19).

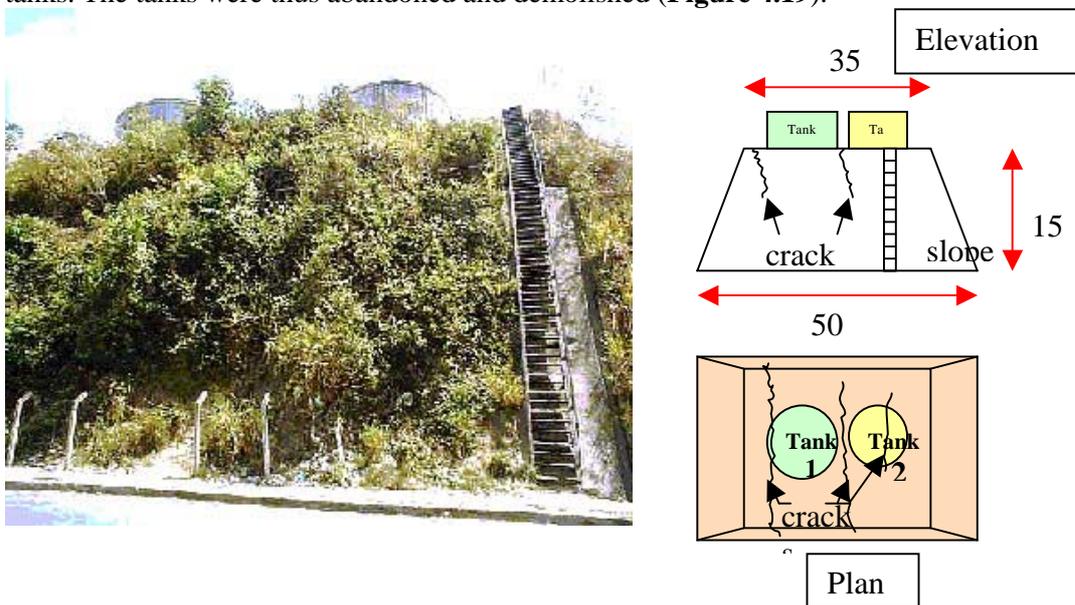


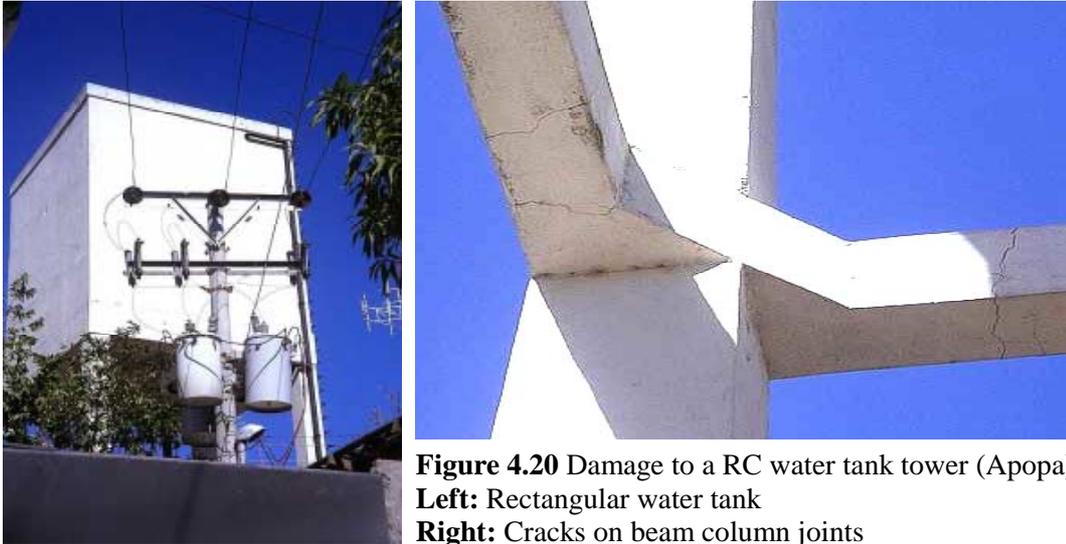
Figure 4.18. Tanks on a thin hilltop, “Las Colinas del Norte”, Apopa



Figure 4.19. Reinforced Masonry wal of “Las Colinas del Norte” tank

(2) Elevated water tank at San Luis Talpa

RC towers for some elevated water tanks were cracked. Beam-column joints of these towers carrying heavy tanks are the most susceptible to intense shakes (See **Figures 4.20 left and right**). Intense ground motions, however, were not the sole cause of the damage to the towers. At San Luis Talpa, Comalapa, RC columns were arranged in octagon and joined together slightly above their bottom ends with an octagonal RC frame. Cracks were mostly found on the mid-span of each side of the horizontal RC frame. The cause of this cracking may be attributed to unequal settlement of the column foundations (**Figure 4.21**), which settlement could induce some unexpected torque within the beams.



Damage to water treatment plants

Facilities of some water treatment plants suffered some damages, which were not substantially large in terms of their effects on the essential functions of the plants. But full operations were curtailed at some plants including Guluchapa #1, 2 and 3 in Pozos (Ilopango) and Joya Grande (Guluchapa).

A 50m long sedimentation basin at Guluchapa Treatment Plant, Ilopango, takes 300 m³ water from Cuaya River and neighboring wells (**Figure 4.22**). The continuous concrete bottom slab of this basin was cracked, and the possibility of introducing watertight joints was discussed in its restoring work. Cracks were also found on construction joints on the walls surrounding a filtering facility (**Figure 4.23**).



Figure 4.22. A 300 m³ sedimentation basin at Guluchapa Treatment Plant, Ilopango. The bottom slab was cracked



Figure 4.23. Cracks on construction joints on RC walls surrounding filtering facility

Summary and recommendations

It turned out that ground subsidence and flows are the most responsible for the damage to various water treatment facilities. Landslides cut pipes, and carry foot soils of hilltop water tanks. Uneven subsidence of foot soils cause sedimentation basins, supports of pipes and water tank towers to be cracked. It is thus recommended to avoid constructions of these facilities on unstable soils. If unavoidable, ground should be stabilized, or flexible and watertight joints should be built in the facilities so that they could absorb soil displacements transmitted to the facilities. As for tanks taking much water, the effect of water sloshing should be taken into account, and to minimize cracking damage, reinforced masonry or RC structural members could be replaced with PC members.

4.4 TRANSPORTATION

The transportation network in El Salvador consists of approximately 10,000 kilometers of roads including the two major highways “Pan American” and “El Litoral” and some 600 km less used railway. One third of the roads are unpaved.

The January 13 quake triggered landslides blocking the Pan-American Highway and many rural roads. Most bridges sustained only minor damage. The total cost for repairing roads and bridges amounted to \$2.7 million and \$12.4 million dollars respectively.



Figure 4.24 Roads and Railway network of El Salvador

Damage to Main Routes

The most significant traffic disruption was due to the blocking of the Pan-American mountain highway by a large landslide (see Section 3.5) at the curve “Leona” to the East of San Vicente. The coastal highway “El Litoral” became an alternative traffic route for several weeks while the Pan-American highway was being cleared from the 100,000 m³ slide (Figure 4.25). Two of the four lanes of the highway were re-opened for restricted traffic following the earthquake.

Other damage to the main routes includes cracks crossing the “El Litoral” and the route to the International Airport (see Figures 4.26 and 4.27).



Figure 4.25. Landslide at “Leona” blocking the Pan-American Highway.



Figure 4.26. Horizontal Crack at Km 78 of El Litoral highway.



Figure 4.27. Cracks at Km 19 ½ of Comalapa Road.

Bridges

In general, bridges sustained no or very little damage. The most affected bridges were found in the central western part of El Salvador (Sonsonate, Comasagua Zacatecoluca, Comalapa, and Usulután departments) where minor damage such as settlements and cracks were commonly observed at the bridge approaches (see Figure below).



Figure 4.28. Settlement of a bridge approach

The recently constructed San Marcos Lempa bridge, spanning the River Lempa sustained only superficial concrete cracks and buckling of expansion joint covers and typically observed settlement and cracks at the west bridge abutment.



Figure 4.29. San Marcos Lempa Bridge.

Liquefaction was observed along the riversides, but it did not cause any damage to the San Marcos Lempa Bridge. Next to the San Marco Lempa Bridge stands a 65-year-old railway bridge, “El Puente de Oro” (The golden bridge, **Figure 4.30**). Liquefaction induced lateral spreading with up to 18 cm wide cracks topped one of its simple supported spans and cracked its concrete piers as shown in **Figure 4.31** below.

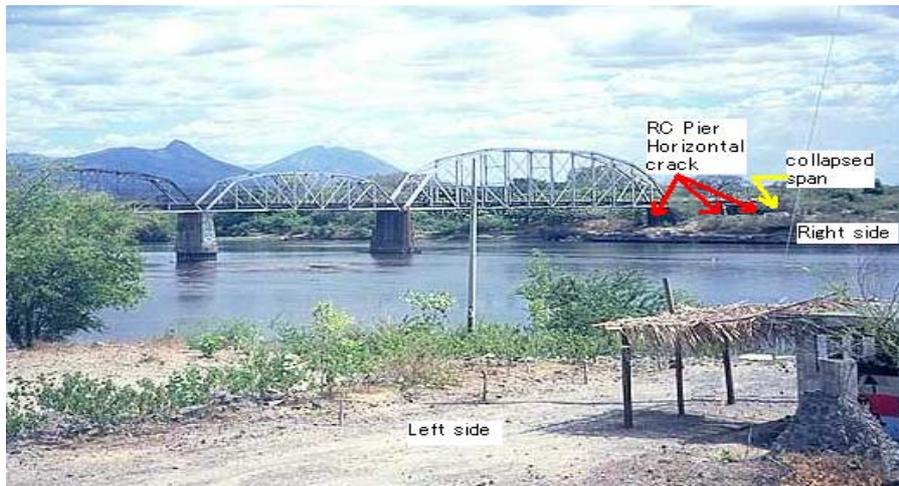


Figure 4.30. “El Puente de Oro” Railway bridge.

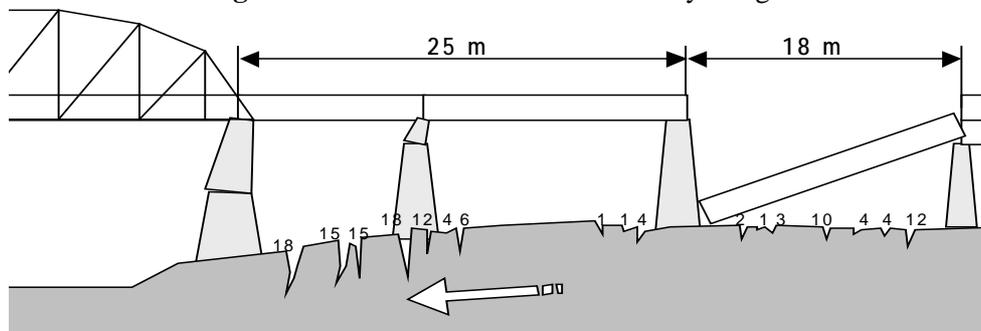


Figure 4.31. Sketch of toppled span and cracked piers caused by lateral spreading.

Local roads

Typical widespread damage consists of slope failure and rock fall debris blocking the roads and embankment deformations causing cracks especially in unpaved roads. Debris from collapsed dwellings block roads at many locations. **Figures 4.22** and **4.33** show some typical damage. Most block roads were cleared from debris and re-opened for traffic within 24 hours of the Earthquake.



Figure 4.32. Longitudinal cracks in road to Comasagua, La Libertad



Figure 4.33. Rock fall blocking the road to Teotepeque, Jicalapa, La Libertad

Summary and recommendations

There are three important areas investigate and suggest appropriate countermeasures to increase the earthquake readiness of the transportation system. These are firstly slope stability, secondly structural condition of bridges and their foundations, and thirdly road condition.

1. Slope stability along major and minor routes should be increased.
2. It is necessary to investigate the current structural condition of bridges especially the bearing systems and the strength and ductility of bridge piers and foundations. Studies on vulnerability of bridges to lateral ground spreading deformation on abutment and pier's foundations also important.
3. The road subsurface needs improvement in form compaction and addition of appropriate soil material to improve the quality of the subgrade to reduce deformations and cracking in case of an earthquake.

4.5 TELECOMMUNICATION SYSTEMS

Reportedly, telecommunication networks did not sustain any major problems. Pacific Bell reported that there was no congestion of telephone communication that followed the earthquake. The cellular phones worked normally on January 13. The intense shake of the earthquake, however, aroused the opinion of the Salvadorian telecommunication service providers that the logistics for an emergency of this kind should be reviewed and checked out through some drills for operating radio transmitters for example.

4.6 CRITICAL FACILITIES

Airport

The El Salvador International Airport in La Paz (near San Salvador) was closed on the day after the earthquake due to longitudinal and transverse cracks that appeared on its runways and approaches. The passenger terminal, airport facilities and the control tower suffered some damage of minor to moderate cracking. No water pipe was damaged, and the water supply met the emergency demand. Its emergency power system and the fact that no structural member suffered any serious damage allowed the airport to be brought back in full operation two days after the earthquake. The total loss caused by this earthquake was estimated to be about 6.7 million US dollars.

The damage to the RC passenger terminal building became more obvious as we went up the floors. The first floor suffered some minor to moderate damage mostly to secondary members such as ceiling panels, window panes, lamps and so on. Some ceiling panels came off with cables and other devices put behind them. Some finished surfaces of beams and columns were cracked and spalled (**Figure 4.34**). Infill masonry walls along the southern side of the building were completely cracked. Walls in restrooms and stairways were cracked in such a way that finished concrete cover and tiles came off. In VIP rooms, window frames were slightly bent.

On the second and third floors, there were clear marks of pounding remaining on some expansion joints between building blocks. Several walls were moderately cracked. Ceiling panels came off (**Figure 4.35**), and about 80% of the air conditioners and signs fell down. A reinforced masonry wall near boarding gates was cracked along mortar block joints (**Figure 4.36**). On the third floor, about 75% of the windows were left unusable because their window frames were deformed.

Cracks were found in other RC buildings in AIES-I and AIES-II, newly extended zones of the airport. Lateral and diagonal cracks appeared on some infill walls (**Figure 4.37**). A short RC column carrying thick beams sustained heavy damage (**Figure 4.38**). Transverse and longitudinal cracks appeared on runways and their approaches (**Figure 4.39**). These cracks, however, turned out to be less serious for aircrafts to pass.



Figure 4.34. Spalling of concrete columns



Figure 4.35. Damage to ceiling panels (passengers waiting room)



Figure 4.36. Reinforced masonry wall near boarding gates cracked along mortar block joints



Figure 4.37. Lateral and diagonal cracks appeared on some infill walls



Figure 4.38. Crumbled short RC column

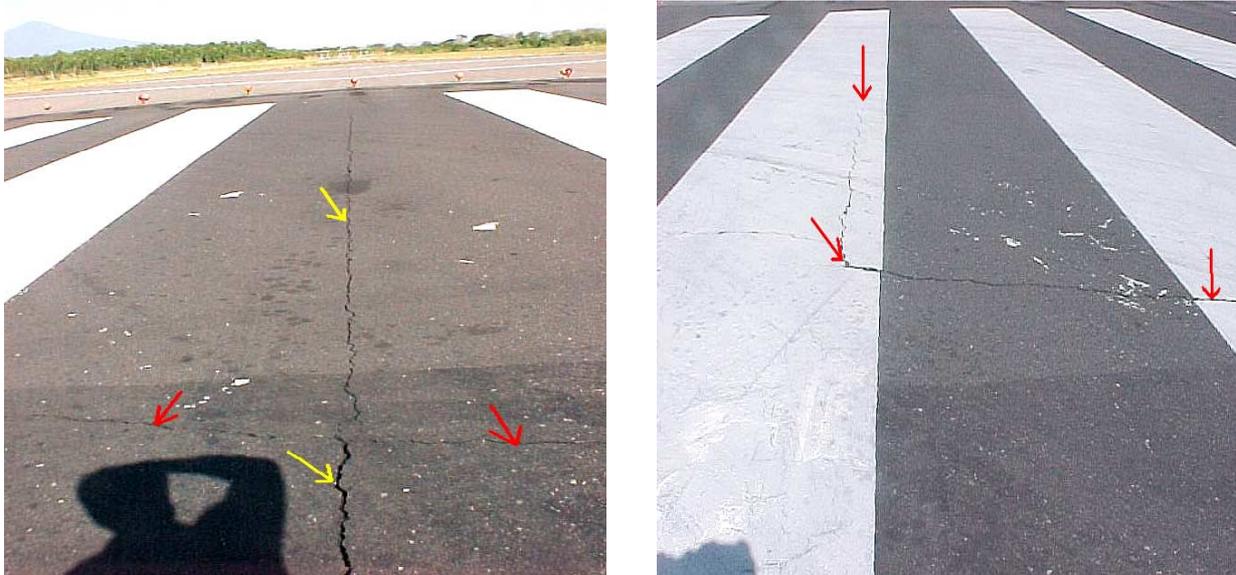


Figure 4.39. Transverse and longitudinal cracks appeared on runways and their approaches

Ports and harbors

The Earthquake caused only minor damage to port facilities. At Acajutla, a large shipping port with fisheries, only administrative buildings, employees' lodgings and some warehouses sustained minor damage of slight cracking and spalling. The total repairing cost at this port was estimated to be 59,000 US dollars. The shake was also responsible for the damage to 39 piers at Santa Ana and 4 piers at San Miguel. A wharf of La Libertad Port was severely cracked and collapsed. At "El Triunfo" port, Usulután, 20 m long wharf fell down. There was reportedly no damage to other ports.

Hospitals

This Earthquake caused nationwide disruption to medical cares at 6 hospitals and 28 health centers in the following districts: *La Libertad* (1 hospital and 4 health centers), *La Paz* (1 hospital and 6 health centers), *Sonsonate* (1 hospital and 5 health centers), *Santa Ana* (1 health center), *Usulután* (2 hospitals and 7 health centers), *San Salvador* (4 health centers), *San Miguel* (1 hospital) and *San Vicente* (1 health center). Patients at the damaged hospitals and health centers were forced to evacuate to temporary and/or provisional medical care centers. In Nueva San Salvador, San Rafael Hospital sustained serious structural damage to bahareque walls of its old building blocks, causing some sickrooms to be kept off. New blocks of the hospital also sustained some damage. Power and water outages disrupted emergency cares at this hospital for a large number of outpatients injured in the earthquake. These outpatients were thus sent to "Benjamin Bloon", a pediatrics hospital, which sustained no damage to its modern concrete building.



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