

10 DAMAGE TO DOMES, MINARETS AND HISTORICAL STRUCTURES

Most of historical structures existing in the earthquake-affected area are in Istanbul. Istanbul is situated on two continents; Asia and Europe. Istanbul is the former capital of three successive empires- Roman, Byzantine and Ottoman. In Istanbul and its close vicinity, there are many historical structures ranging from the museums, churches, palaces, great mosques, monuments, aqueducts, underground cisterns, tunnels, dams, city walls and bazaars.

10.1 Domes and Minarets

Most of the main compounds of mosques in the earthquake affected region were generally intact or suffered very slight damage (Figures 10.2). The main compounds of mosques generally have single dome or multiple semi-spherical domes and they are structurally symmetric. Maybe for this reason, the main compounds remain intact during shaking. The main compounds of the mosques failed when the faulting occurred right underneath the structure. Figure 10.1 shows such an example in Kavaklı district of Gölcük, which failed due to secondary normal faulting.



Figure 10.1 Totally collapsed mosque at Kavaklı district of Gölcük

Minarets in the region, which are generally 20 to 25 m high are generally constructed with reinforced concrete. Failures of minarets occurred at the junctions where the cross-section configuration of the structure changes from square to cylinder by toppling. The direction of toppling was almost parallel to the strike of faulting. The total collapse or relative sliding of minarets of masonry type was observed. The damage to such minarets was observed near its balcony (erefe) in the form of relative sliding between blocks where the rigidity of the minarets changes discontinuously.



mosque stood with a few other structures amid the rubble of collapsed buildings in the town of Gölçük, 10 miles east of Istanbul.

Associated Press Photo by Enric Marti
Taken from New York Times, August 20, 1999

Figure 10.2 Intact mosque in Gölçük (Hürriyet newspaper)

10.2 Historical Structures

The Archaeological Museums are found just inside the first court of Topkapı Palace. It includes the displays of the celebrated Alexander Sarcophagus among its treasures of antiquity. The Museum of the Ancient Orient Hatti, Hittite displays artifacts from the Sumerian, Babylonian and Assyrian, civilizations. No damage was reported as a result of earthquake.

The Basilica of St. Sophia, which is now called the Ayasofya Museum was built by Constantine the Great. Following the collapse of its main dome in the earthquake of 558, it was reconstructed by Justinian in the 6th century. Its immense dome rises 55 meters above the

ground and its diameter spans 31 meters. The dome of this structure was partly collapsed in the earthquake of 1766 and it was repaired. A site investigation 7 hours after the earthquake showed no damage to this structure (Figure 10.3. This structure is well instrumented with accelerometers and the measurements on the performance of this structure should be of great value on the preservation as well as the structural stability of historical masonry structures.

Facing St. Sophia stands the supremely elegant, six-minaret, imperial Sultan Ahmet Mosque (Figure 10.3. Built between 1609 and 1616 by the architect Mehmet, the building is more familiarly known as the Blue Mosque because its interior gleams with a magnificent paneling of blue and white Iznik tiles. The cascading domes and four slender minarets of Süleymaniye Mosque dominate the skyline on the Golden Horn's west bank (Figure 10.4. Investigations of these mosques on September 2 indicated no damage.



Figure 10.3 An aerial view of Sultan Ahmet Mosque (foreground) and Ayasofya Museum



Figure 10.4 An aerial view of Beyazıt Mosque (foreground), Beyazıt Tower and Süleymaniye Mosque

Some light damage was observed at Mihrimah Sultan Mosque. This mosque has one hundred and sixty-one windows, built in 1555. The damage was concentrated at the NE corner of the structure. The separation and relative sliding in this corner resulted in the fall of limestone blocks from the outer arch of the main dome. Nevertheless, the main reason is associated with the settlement of ground at that corner before the earthquake resulted in the loosening of the walls at that specific locations. The ground shaking caused further loosening of the walls which subsequently caused the block walls from the dome (Figure 10.5).

The ancient Hippodrome, the scene of chariot races and the center of Byzantine civic life, stood in the open space in front of the Blue Mosque, an area now called Sultanahmet. Of the monuments which once decorated it only three remain: the Obelisk of Theodosius, the bronze Serpentine Column and the column of Constantine. Remains from the curved end section of the Hippodrome's wall can be seen on the south side of these three monuments. The Theodosius column is 20 m high and experienced the 29 previous earthquakes. No damage to these monuments including Çemberlitaş monument was observed during the investigation.

The Ahmet III Fountain, built in 1729, stands at the entrance to Topkapi Palace. This highly ornate, freestanding fountain is a superb example of the late Ottoman style and suffered no damage during this earthquake.



Figure 10.5 A view of damaged Mihrimah Sultan Mosque

The Istanbul city walls, once an impenetrable fortification, stretch seven kilometers from the Sea of Marmara to the Golden Horn. Restored recently, and many times previously, these walls date from the fifth century and the reign of Emperor Theodosius II. UNESCO has declared the city walls, and the area which they enclose, to be one of the cultural heritages of the world. The walls were heavily damaged in 1766 and 1894 earthquakes and they were repaired. During this earthquake, partial collapses of the walls were observed at several locations (Figure 10.6) .

The Galata Tower, a Genoese construction of 1348, rises 62 meters high over the Golden Horn. This tower is one of the landmarks of Istanbul and the site investigation did not indicate any structural damage to this structure (Figure 10.7).



Figure 10.6 Partial collapse of Istanbul City Wall (Surlar)



Figure 10.7A view of Galata Tower and Galata Bridge

The Bozdoğan-Valens Aqueduct, built in 368 A.D., supplied the Byzantine and later the Ottoman palaces with water. Today part of the remaining 900 meters of double-tiered arches straddle the major highway that runs through the old part of town. No damage was observed during the site investigation of this structure as well as the Ottoman aqueducts such as the

16th Century Moğolova and Sultan Süleyman Aqueducts built both by Sinan (Figure 10.8)

Seven water reservoirs are found in Belgrade Forest (Figure 10.9) The dams of these reservoirs are masonry and no damage was reported for these structures.



Figure 10.8 A view of Bozdolan Aqueduct



Figure 10.9 A view of Valide Sultan Dam in Belgrade Forest

References

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- Durukal, E. and Erdik, M. (1994): Comparison of system identification techniques: a case study for Hagia Sophia. *Earthquake Resistant Construction and Design*, 2, 993-100