

concrete is placed through a tremie to create a reinforced concrete wall around the site perimeter. After the concrete wall is cured, excavation of the substructure begins. As the excavation progresses below surrounding grade, tiebacks are drilled through the exposed concrete wall and through the surrounding soil into the rock below to provide stability for the excavation. At the WTC site, these tiebacks were temporary and were replaced in the final construction by the subterranean floor slabs that provided lateral support to the walls.

A further challenge to the construction of the substructure was the presence of two existing subway lines across the site. The Interboro Rapid Transit System 1 and 9 subway lines, operated by the MTA, ran north to south across the middle of the site adjacent to the east wall of the substructure. A second subway system, PATH, operated by the Port Authority, made a 180-degree terminal bend beneath the western half of the site. This subway tunnel was temporarily supported across the excavation and incorporated into the final construction with a station provided for this line inside the slurry wall, just west of the 1 and 9 subway lines, and below the Plaza area just east of WTC 1 and partially below WTC 6. Although significant damage was sustained by the buildings, subterranean structure, and subway system, only the performances of the above-grade buildings were assessed in this study.

1.3 Timeline and Event Summary

On the morning of September 11, 2001, two hijacked commercial jetliners were deliberately flown into the WTC towers. The first plane, American Airlines Flight 11, originated at Boston's Logan International Airport at 7:59 a.m., Eastern Daylight Time. The plane was flown south, over midtown Manhattan, and crashed into the north face of the north tower (WTC 1) at 8:46 a.m. The second plane, United Airlines Flight 175, departed Boston at 8:14 a.m., and was flown over Staten Island and crashed into the south face of the south tower (WTC 2) at 9:03 a.m.

Both flights, scheduled to arrive in Los Angeles, were Boeing 767-200ER series aircraft loaded with sufficient fuel for the transcontinental flights. These aircraft are described in Appendix E. There were 92 people on board Flight 11 and 65 people on board Flight 175. Figure 1-2 shows the approximate flight paths for the two aircraft.

The north tower was struck between floors 94 and 98, with the impact roughly centered on the north face. The south tower was hit between floors 78 and 84 toward the east side of the south face (Figures 1-3 and 1-4). Each plane banked steeply as it was flown into the building, causing damage across multiple floors. According to Government sources, the speed of impact into the north tower was estimated to be 410 knots, or 470 miles per hour (mph), and the speed of impact into the south tower was estimated to be 510 knots, or 590 mph. As the two aircraft impacted the buildings, fireballs erupted (Figure 1-5) and jet fuel spread across the impact floors and down interior shaftways, igniting fires (Figure 1-6). The term fireball is used to describe deflagration, or ignition, of a fuel vapor cloud. As the resulting fires raged throughout the upper floors of the two WTC towers, thousands attempted to evacuate the buildings. It was estimated by the Port Authority that the population of the WTC complex on September 11, 2001, was 58,000 people. This estimate includes the PATH and MTA stations and the Concourse areas. Almost everyone in WTC 1 and WTC 2 who was below the impact areas was able to safely evacuate the buildings, due to the length of time between the impact and collapse of the individual towers.

At 9:59 a.m., 56 minutes after it was struck, the south tower collapsed. The north tower continued to stand until 10:29 a.m., when it, too, collapsed. The north tower had survived 1 hour and 43 minutes from the time the jetliner crashed into it. A total of 2,830 people lost their lives in the collapse of the WTC towers, including 2,270 building occupants, 157 airplane crew and passengers, and 403 firefighters, police personnel, and other emergency responders.