

floor was either ejected from the building or folded into the general debris during the partial collapse. In the area between the 8th and 16th floors, the damage area generally increased as the partial collapse progressed downward to include, and sometimes exceed, portions of the two bays bounded by columns C-8 to E-8 and C-7 to E-7, with column D-8 missing in the area of the 12th floor.

At the point of impact and at the floors immediately below, it appears the impact debris sliced through the spandrels. However, at lower elevations, the spandrel beams were not fractured and separation occurred at the spandrel-to-column connections. In the typical failure mode of the girder-to-column-flange connection, the weld and heat-affected zone of the top flange plate pulled out of the column and left a crater in the flange. The bottom flange plate was overloaded in bending at the column face without creating a crater in the column flange. The beam shear connection was typically left in place. The shear failure occurred mostly in the beam web and, in some cases, through the bolt line in the shear connection plate.

Girders that were connected to the column web had their top flange plate overloaded in tension at the weld zone interface. Normally, a crater was created where the top flange plate was welded to the column web. The bottom flange sat on a stiffened seat. Typically, the seated connection was left in place; however, the beam pulled off of the seat, separating at the fillet welds and leaving behind the fillet welds that attached the beam flange to the seat top plate. Figure 6-6 shows the stiffened seat at the weak axis side of the column. Figure 6-7 shows that the shear connection remains on the flange side, but only a piece of beam remains hanging on the web side.

Floor-beam-to-girder connections typically used a partial-depth end plate welded to the floor beam web and bolted to the girder with A307 bearing bolts. Typically, failure occurred in one of two modes, either the bolts were overloaded in tension and the connection pulled off, or the partial end plate sheared at or near the weld line. At most of the connections, it appears there was some amount of bolt failure. Figure 6-8 shows a shear connection with half of the end plate remaining in place.

As the spandrel connections failed and the floor slabs collapsed, a portion of the rubble accumulated into a two-story pile while the remainder fell out of the building onto the low-rise roof on the north side of the building. The impact debris finally came to rest on the two-story-deep pile of debris that was on the 8th floor. Figures 6-9 and 6-10 illustrate the damage. A major component of WTC 2, approximately 40 feet tall by 30 feet wide, remained lodged in the debris pile and was clearly visible as it hung from the face of the building. Yet despite this weight, the floor supporting the debris deflected a maximum of 6 inches. Figure 6-11 shows the extent of debris in the lobby of the building.

6.4 Architectural Damage Description

In addition to the destruction of the canopy structure north of column line 8, and the collapse of the floor areas between the 8th and 23rd floors, there was general damage to the entire north façade of the building. Nearly every window was broken on the western half of the north face, between column lines B and E below the 23rd floor. This window breakage would appear to be attributable to the following causes:

- Localized damage in the areas impacted by column trees falling from WTC 2.
- Smaller debris blown from WTC 1 and WTC 2. In particular, several small chunks of lightweight concrete, which appeared to be from WTC 2 floor slabs, were thrown through the north windows of the building. These debris items ranged in size from small fragments that caused bullet-size holes in the windows to large chunks with a maximum dimension of approximately 12 inches. Many of these chunks landed as far as 15 feet from the exterior building line and appeared to be traveling almost horizontally when they penetrated the building façade.