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D WTC Steel Data Collection

D.1 Introduction

WTC steel data collection efforts were undertaken by the Building Performance Study (BPS) Team and the Structural Engineers Association of New York (SEAoNY) to identify significant steel pieces from WTC 1, 2, 5, and 7 for further study. The methods used to identify and document steel pieces are presented, as well as a spreadsheet that documents the data for steel pieces inspected at various sites from October 2001 through March 2002.

D.2 Project Background

Collection and storage of steel members from the WTC site was not part of the BPS Team efforts sponsored by FEMA and the American Society of Civil Engineers (ASCE). SEAoNY offered to organize a volunteer team of SEAoNY engineers to collect certain WTC steel pieces for future building performance studies. Visiting Ground Zero in early October 2001, SEAoNY engineers, with the assistance from the New York City Department of Design and Construction (DDC), identified and set aside some steel pieces for further study.

Of the estimated 1.5 million tons of WTC concrete, steel, and other debris, more than 350,000 tons of steel have been extracted from Ground Zero and barged or trucked to salvage yards where it is cut up for recycling. Salvage yard operations are shown in Figures D-1 through D-3. Four salvage yards were contracted to process WTC steel:

- Hugo Nue Schnitzer at Fresh Kills (FK) Landfill, Staten Island, NJ
- Hugo Nue Schnitzer's Claremont (CM) Terminal in Jersey City, NJ
- Metal Management in Newark (NW), NJ
- Blanford and Co. in Keasbey (KB), NJ

SEAoNY appealed to its membership for experienced senior engineers to visit the salvage yards on a volunteer basis, and to identify and set aside promising steel pieces for further evaluation. Seventeen volunteer SEAoNY engineers started going to the yards in November 2001. A list of engineers and others who contributed to this effort is included in Appendix G of this report.

As of March 15, 2002, a total of 131 engineer visits had been made to these yards on 57 separate days. An engineer visit typically ranged from a few hours to an entire day at a salvage yard. The duration of the

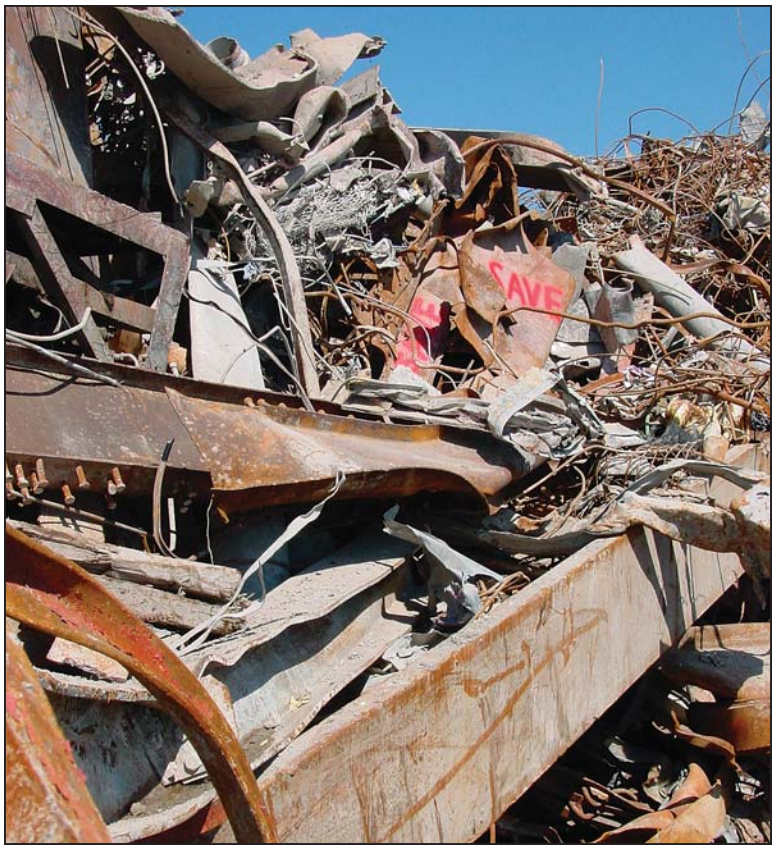

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Figure D-1
Mixed, unsorted steel upon delivery to salvage yard.

visits, number of visits per yard, and the dates the yards were visited varied, depending on the volume of steel being processed, the potential significance of the steel pieces being found, salvage yard activities, weather, and other factors. Sixty-two engineer trips were made to Jersey City, 38 to Keasbey, 15 to Fresh Kills, and 16 to Newark. Three trips made in October included several ASCE engineers. Eleven engineer trips were made in November, 41 in December, 43 in January, 28 in February, and 5 through March 15, 2002.

D.3 Methods

Engineers identified steel members that would be considered for evaluation or tests relative to the fire and structural response of the WTC buildings. Pieces that were measured and determined to be significant were marked to be saved, and arrangements were made to have them moved to a safe location where they would not be processed (cut up and shipped). Some pieces were not saved, but samples, called coupons, were cut from them and saved for future studies.

D.3.1 Identifying and Saving Pieces

As shown in Figure D-4, the engineers searched through unsorted piles of steel for pieces from WTC 1 and WTC 2 impact areas and from WTC 5 and WTC 7. They also checked for pieces of steel exposed to fire. Specifically, the engineers looked for the following types of steel members:

- Exterior column trees and interior core columns from WTC 1 and WTC 2 that were exposed to fire and/or impacted by the aircraft.
- Exterior column trees and interior core columns from WTC 1 and WTC 2 that were above the impact zone.
- Badly burnt pieces from WTC 7.

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Figure D-2 Torch cutting of very large pieces into more manageable pieces of a few tons each.

Figure D-3 Pile of unsorted, mixed steel (background) with sorted, large steel pieces (center) being lifted and cut into smaller pieces (left).

Figure D-4 Engineer climbing in unprocessed steel pile to inspect and mark promising pieces.

- Connections from WTC 1, 2, and 7, such as seat connections, single shear plates, and column splices.
- Bolts from WTC 1, 2, and 7 that were exposed to fire, fractured, and/or that appeared undamaged.
- Floor trusses, including stiffeners, seats, and other components.
- Any piece that, in the engineer's professional opinion, might be useful for evaluation. When there was any doubt about a particular piece, the piece was kept while more information was gathered. A conservative approach was taken to avoid having important pieces processed in salvage yard operations.

The engineers were able to identify many pieces by their markings. Each piece of steel was originally stenciled in white or yellow with information telling where it came from and where it was going. A sample of the markings can be seen in Figure D-5.

For example, a given piece might be marked, "PONYA WTC 213.00 236B4-9 558 35 TONS." Translated, this meant the column was destined for the Port of New York Authority's World Trade Center as part of contract number 213.00. Its actual piece number was 236B, and it was to be used between floors 4 and 9 in tower B (WTC 2). Its derrick division number was 558, which determined which crane would lift it onto the building and the order in which it was to be erected. Other markings might include the name of the iron works or shipping instructions to those responsible for railway transportation (Gillespie 1999).

Additional markings (and duplicates of stenciled markings) may sometimes be found stamped into the steel pieces. These stamped markings are about 3/4 inch tall.

Figure D-5 Stenciled markings on WTC 2 perimeter column from floors 68–71.

In the absence of markings, member size is the quickest and easiest means for the engineers to establish an approximate original location for a piece. For example, the spandrel plates used in the column-to-column connections in the perimeters of WTC 1 and WTC 2 reportedly ranged in thickness from about 1-1/2 inches at the lower levels to as little as 3/8 inch at the upper levels.

The lighter perimeter columns from WTC 1 and WTC 2 appear to have used column-to-column connections with 4 bolts, whereas larger members presumably from lower floors used six-bolt column-to-column connections. Core column sizes vary, with some heavier sections at the lower floors having plates 4 inches thick or greater.

After a steel piece was identified for further study, it was set aside. As shown in Figure D-6, each piece was marked with spray paint, labeled "SAVE" and a piece number, such as "C-68." The engineers also advised site personnel of the location of these pieces so they would not be processed as scrap.

D.3.2 Documenting Pieces

To document the identified steel pieces of interest, the engineers measured their dimensions. They also drew sketches, and took photographs and videos of the pieces.

The steel member dimensions helped to determine the approximate building location of a piece prior to the disaster. The engineers measured and recorded dimensions using metal tape rules, vernier calipers, or other measuring devices. See Figures D-7 through D-9.

Figure D-6 Steel pieces marked "SAVE."

Figure D-7 Engineers measuring and recording steel piece dimensions.

Figure D-8
Engineer measuring spandrel plate thickness (t_s).

Figure D-9 Measurement of 1/4 inch for web thickness (t_w).

The measured and recorded dimensions (shown in Figure D-10) included the following:

- depth of the piece (d)
- thickness of the web (t_w)
- length of flange (b_f)
- thickness of the top flange (t_{tf})
- thickness of the bottom flange (t_{bf})
- thickness of the spandrel plate (t_s)

Note that the thickness of the spandrel plate may be different from that of the top flange.

D.3.3 Getting Coupons

Samples, or coupons, were cut by yard personnel. A coupon is a sample of steel cut from a larger portion of a steel member or piece. The collected coupons cut are intended for off-site examination in a laboratory.

Where possible, coupons were selected to yield sufficient material for a number of destructive (and mutually exclusive) tests on steel from essentially the same condition. Coupons were sized to be 12 inches by 12 inches, which is considered adequate for most purposes. Where possible, coupons included two faces of attached plates forming a portion of the member. They were also selected so that heat effects from the cutting operation did not affect the coupons' intended test areas.

Figure D-11 shows a steel piece clearly marked with spray paint that shows salvage yard personnel where to cut the coupon. A coupon that has been cut is shown in Figure D-12.

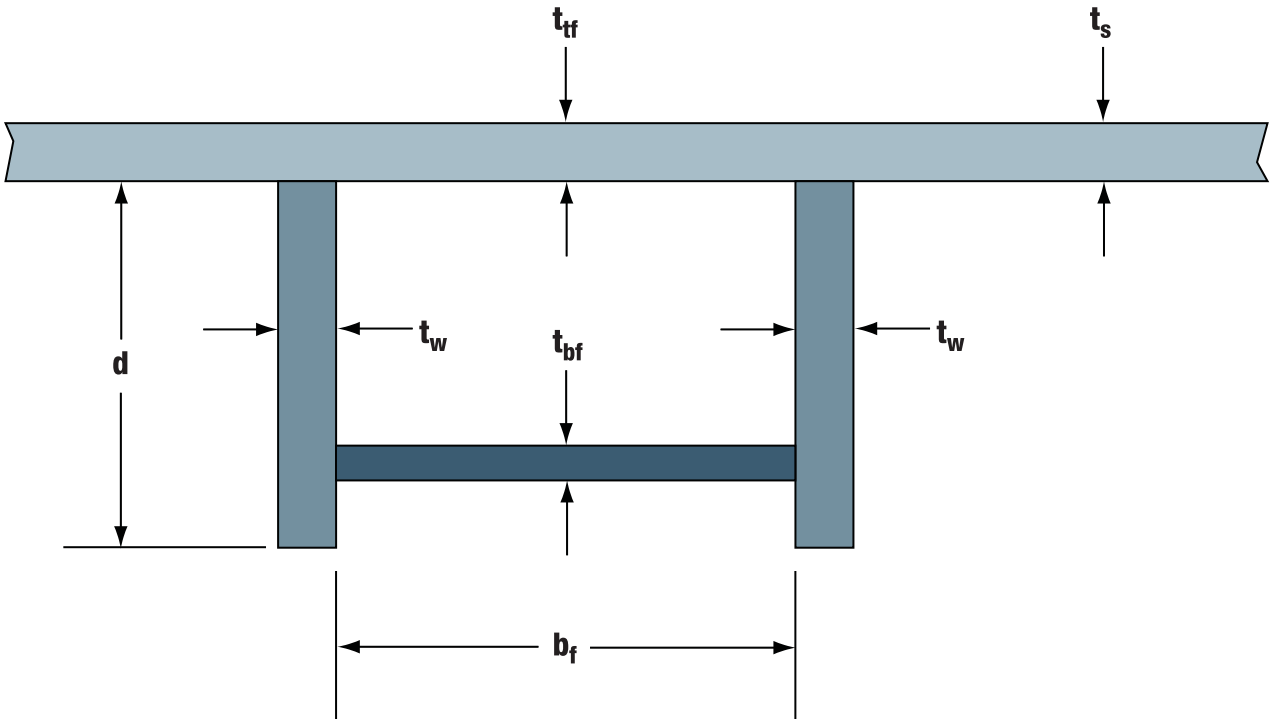

Figure D-10 Measured dimensions of the steel pieces.

Figure D-11 Burnt steel piece marked for cutting of coupon.

Figure D-12 Coupon cut from WTC 5 showing web tear-out at bolts.

D.4 Data Collected

The steel data are compiled in a spreadsheet that includes data from each of the four salvage yards visited by the SEAoNY and WTC BPS Team engineers (the spreadsheet is presented at the end of this appendix). The data are organized according to the salvage yard where each steel piece was examined. The data include the piece identification mark that was sprayed on the piece, the measured dimensions, a brief description of the piece indicating why the piece was selected for further evaluation, information identifying photographs and/or video taken, and the status of any coupon taken. Pieces that were searched for and inspected include perimeter or core columns near the impact area of WTC 1 or WTC 2, burnt pieces from WTC 7, and connection pieces from WTC 5 (see Figures D-12 through D-18).

The steel pieces range in size from fasteners inches in length and weighing a couple of ounces to column pieces up to 36 feet long and weighing several tons. As of March 15, 2002, a total of 156 steel pieces (not including most of the fasteners and other smaller pieces) had been inspected. In addition, seven pieces were set aside from Ground Zero with assistance from the DDC.

It is important to note that the quality of the pieces, rather than the number of pieces, is significant to this study. Not all of these pieces were kept for further study. This is because:

- some pieces were later determined not to be relevant to understanding building damage;
- once a coupon was taken, the full piece was discarded; and
- pieces were accidentally processed in salvage yard operations before they were removed from the yards for further study.

Figure D-13
WTC 1 or WTC 2 core column (C-74).

Figure D-14 WTC 7 W14 column tree with beams attached to two floors.

Figure D-15
Built-up member with failure along stitch welding.

Figure D-16 Engineer inspecting fire damage of perimeter column tree from WTC 1 or WTC 2.

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Figure D-17 Seat connection in fire-damaged W14 column from WTC 7.

Figure D-18 WTC 1 or WTC 2 floor-truss section with seat connection fractured along welds.

It was expected that most steel members from the impact zones would have reached the yards early in the WTC site excavation process because pieces from the higher floors would be removed first from the debris at Ground Zero. However, barges of steel that were being unloaded in February and March at the Jersey City and Newark salvage yards were found to have pieces from the higher floors.

D.5 Conclusions and Future Work

The ongoing volunteer effort of the SEAoNY engineers is securing WTC steel pieces that will provide physical evidence for studies on WTC building performance. As of March 15, 2002, seventeen engineers, visiting four salvage yards, have identified approximately 150 pieces. Pieces have been identified that are from WTC 1, 2, 5, and 7. Documentary photographs and videos have been taken and coupons collected.

Future studies are expected based on the pieces and data collected. Coupons have been collected for metallurgical tests to determine the temperatures to which they were subjected and their steel characteristics. The National Institute of Standards and Technology (NIST) is currently conducting environmental tests, abating asbestos as necessary, and shipping available pieces to its Gaithersburg, MD, facility for storage and further study. As of May 2002, a total of 41 steel pieces had been shipped to NIST.

D.6 References

Gillespie, A.K. 1999. *Twin Towers, 1999, The Life of New York City's World Trade Center*. Rutgers University Press, New Brunswick, NJ. ISBN 0-8135-2742-2.

Steel Data Collection Spreadsheet

SEAoNY Summary of Identified WTC Steel Pieces at Salvage Yards as of March 15, 2002

Note: As of May 2002, of the 156 steel pieces listed in the spreadsheet, 41 are at the National Institute of Standards, 19 were discarded after coupons were taken, 45 are at the salvage yards, and the rest either were discarded after they were documented or were accidentally processed in the salvage operation before or after being documented.