Collapse of Building Under Construction

2

Professional Development Hours (PDH) or
Continuing Education Hours (CE)
Online PDH or CE course

FDA, Inc.

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1. Introduction

On September 10, 2012 at approximately 9:20 a.m., a portion of the building under construction at Carlton Ave., Brooklyn, NY 11205, collapsed killing one employee, and seriously injuring another. The building under construction consisted of five townhouses, each four stories high, known as Carlton Row Townhouses. The construction of the building was near final completion. The structure essentially consisted of load-bearing masonry walls with cold-formed steel C-joists at each floor.

The OSHA Regional Administrator, Region II, asked the Directorate of Construction (DOC), National OSHA office to provide technical assistance in the investigation of the incident and in making a causal determination. A structural engineer from the DOC visited the incident site on September 18, 2012 to observe the collapse and provide engineering assistance to the OSHA field personnel. The field personnel took photographs and video of the incident scene, and later conducted several interviews with the key contractors and eyewitnesses. The structural engineer from DOC assisted the Manhattan Area Office during the interview sessions. The Manhattan Area Office was instrumental in providing DOC all the pertinent construction documents.

2. The Project

The project consisted of building five units of townhouses in a row numbered 225 thru 233 on Carlton Avenue, Brooklyn, NY 11205. The project was known as Carlton Row Townhouses. The overall dimension of the building was approximately 98' x 53'. Each townhouse unit measured approximately 19½ ' x 52' and had four floors with a basement, also known as the cellar, see Figs. 1, 2, and Ref. 1. The project was designed as having load-bearing masonry walls with floors framed with 10" deep cold-formed joists with plywood sheathing, see Appendix and Ref. 2. The floor-to- floor heights were approximately 9'-0", 11'-8", 9'-8", and 9'-8", see Fig. 2 & Ref. 2.

John Larocca of 944 42nd Street, Brooklyn, NY 11219, signed the NY Department of Buildings' (NYBOD) documents as the agent of the partnership which owned the building under construction. Boro Architects of Brooklyn, NY was the architect. Albanna Engineering, P.C., (Albanna) was the structural engineer of record. The general contractor Professional Grade Construction Group, Inc. of Brooklyn, NY, also performed concrete work and the placement of floor joists at the site. S&B Masonry Corporation of Staten Island was the masonry contractor.

There were three kinds of concrete masonry blocks used in the project. Ten inch solid blocks were used for the party walls between the townhouses, 8" solid blocks were used for the two end walls, and 8" hollow blocks were used for the front and rear walls.

The owner decided against retaining Albanna as the special inspector. Instead, the owner contracted with Mr. Alex Levin, PE of Integrity Consulting Services, Inc. (Integrity) of Cedarhurst, NY to be his designated special inspector under the rules of NYBOD. Integrity was responsible for inspecting cold-formed steel members, masonry construction, and cast in place concrete, among other things.

Integrity conducted inspections on various dates, e.g., July 30, August 7, August 10, August 20, August 22, and September 6, 2012, see Appendix and Ref. 3. The last inspection was performed four days before the incident. All inspection reports were stamped by Mr. Levin, PE, but the actual field visits were performed by Mr. Leo Gimelstein who designated himself as ACI CCSI # 00941439. ACI stands for American Concrete Institute which conducts training programs for Concrete Construction Special Inspectors (CCSI). ACI defines a Concrete Construction Special Inspector *as a person qualified to inspect and record the results of concrete construction inspection based on codes and job specifications. The program covers inspection during preplacement, placement, and post-placement operations.* There are no documents available which could establish if the inspector had any credentials to inspect cold-formed steel framing.

All six inspections mentioned above were performed to inspect C-Joist installations. All six reports contained the identical remark that *" C-Joist installation was found in accordance with above stated documents".* The documents were identified as "*Drawings S-005.01 trough S-008.01 by Boro Architects dated 5/13/12, and Vaperstud Marino ware catalog*". As can be seen, the word " through" was misspelled in all six reports, giving rise to the belief that the same form was used with just the dates changed. As stated earlier, Mr. Levin stamped all the inspection reports.

3. Incident

The day of the incident started like any other day. Workers reported for work at or about 7 a.m. The owner of the masonry company asked the masonry supervisor, a mason and two helpers to proceed to the 4th floor deck of unit # 227. A boom truck was already at the site when the employees arrived. The day's work was to construct the party wall between the units (227 & 229 and 225 & 227), and the front and rear walls of unit # 227.

Although some blocks, and two half-full jumbo bags of sand were already stored on the 4th floor deck in unit # 227 on the Friday before the incident, the masons needed additional quantities of blocks, i.e., 10" solid, 8" solid and 8" hollow blocks, pallets of cement bags and jumbo bags of sand to accomplish the day's task. It is difficult to determine the number of blocks that were already there before the crane began to transport new pallets of blocks and other materials to the 4th floor deck on the morning of the day of the incident. All transportation of materials from the ground to the 4th floor deck was directed by the owner of the masonry company. All deliveries were made by the boom truck.

Interviews with multiple eyewitnesses indicated that at least four to eight pallets of blocks, three to four pallets of cement bags and three to four jumbo bags of sand were delivered by the boom truck to the 4th floor deck. There are conflicting accounts of how the blocks were unloaded from the crane boom. Some said that except in one case, at least half of the blocks in the pallet were unloaded manually by the helpers and dispersed to various strategic locations on both sides of the deck while the crane was still holding the pallet some 6 inches above the deck. When half the pallet was manually unloaded, then the crane would lower the remaining load directly on the deck. Others said that this procedure was not followed at least on the day of the incident. The crane would directly lower the pallet on the deck, and then the masons and helpers would arrange the blocks by hand. In regard to the pallets of cement bags and the jumbo bags of sand, there is no disagreement. They were placed directly on the deck by the crane, and were not taken to various locations on the 4th floor.

Eyewitnesses reported that soon after the last jumbo bags of sand was placed on the deck near the front of the building, the front 20 feet of the floor collapsed over the third floor which started a chain of failures of the floors below, and finally the front 20 feet of all the floors were pancaked into the basement, also known as the cellar, see Fig 1 & 2.

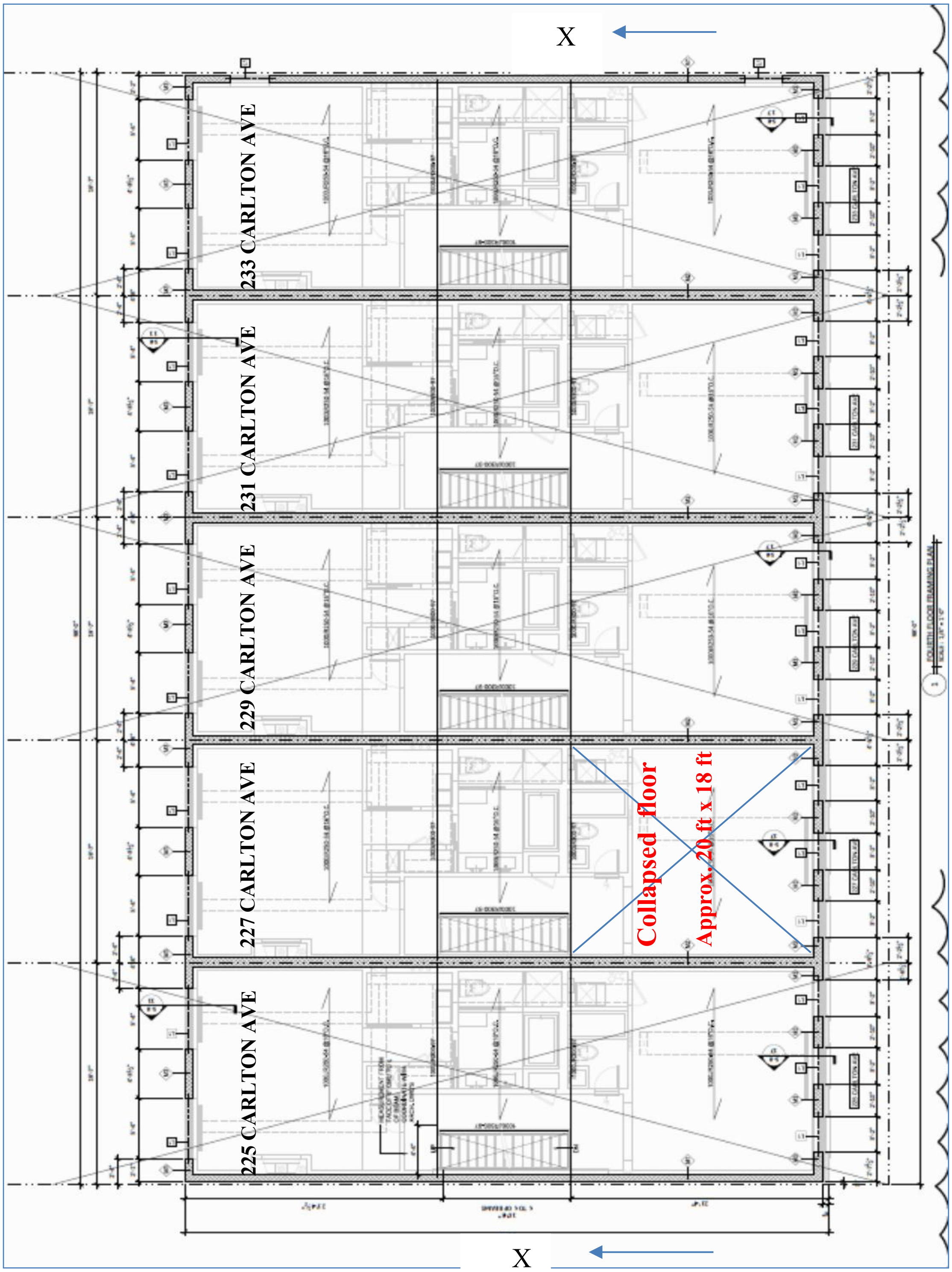

Fig. 1 Fourth floor plan - Carlton Row Townhouses - after the floors collapsed

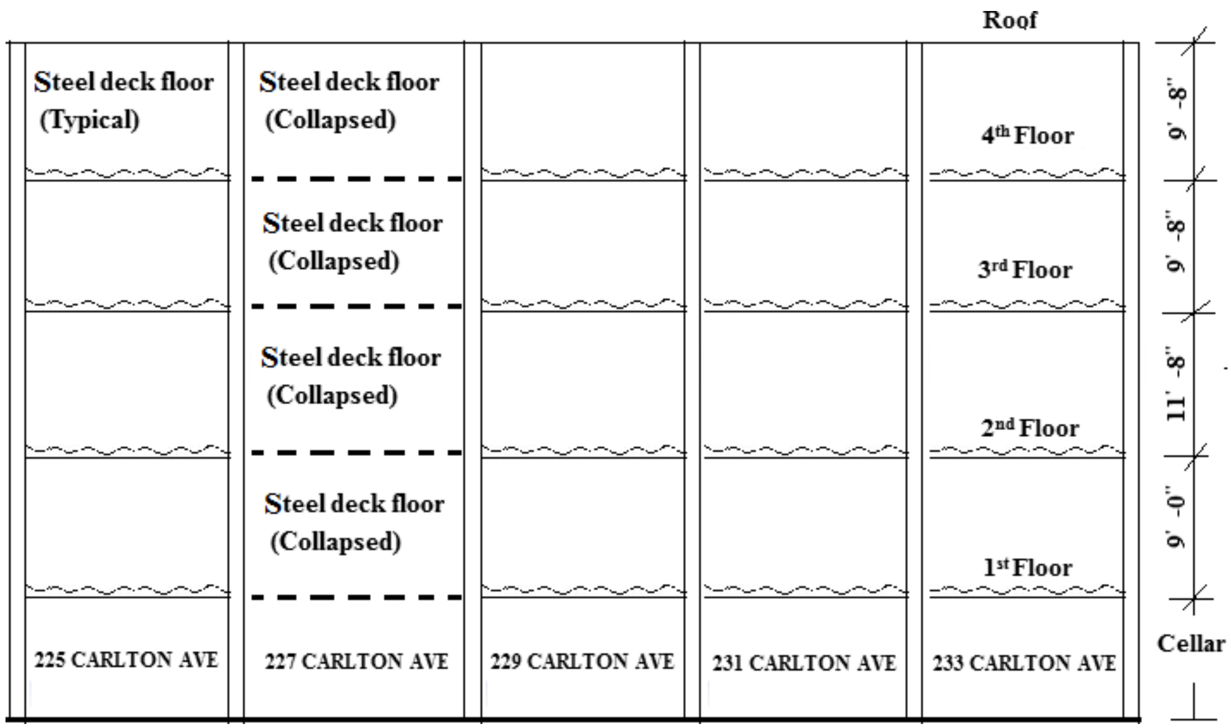

Fig. 2 Vertical section x-x of the building after the floors collapsed.

(Not to scale)

Two employees fell with the collapsing floors. One employee was killed and the other sustained serious injuries. The supervisor held on to the front wall, and was saved. The fourth employee stood on the unfailed portion of the 4th floor deck.

The failed portion of the deck involved approximately 16 C-Joists spaced at 16" o.c. Post-incident observations indicated that the joists were bent and were pulled out of their pockets in the masonry walls. The metal (steel) deck fell in straight pieces, indicating that they were not screwed to the top flange of the C-Joists.

A pallet of 10" solid blocks (75% solid) contains approximately 70-71 blocks, each weighing 70.6 pounds, according the block supplier. The pallet was four rows high, and had a footprint of 4' x 5'. Each pallet, therefore, weighed approximately 5,000 pounds, approximately 250 pounds per square foot. A pallet of cement bags, approximately 40" x 48"could contain 40 bags of cement, each weighing 75 pounds. One pallet of cement would, therefore, weigh approximately 3,000 pounds, 225 pounds per square foot. A jumbo bag of sand holds one cubic yard of sand and weighs approximately 2,200 pounds.

Post-incident observations indicated that the 4th floor deck of the adjoining unit # 225 had 10" solid, 8" solid and 8" hollow blocks piled at different locations. Some 10" solid blocks were also piled up on the incomplete party wall between units # 225 and 227. On the unfailed portion of the fourth floor deck of unit # 227, there were also 10" solid and 8" hollow blocks. Below is the tabulation of the blocks observed on the two 4th floor decks. Fig. 3 shows the approximate distribution of the masonry blocks on the two 4th floors as observed after the incident.

Table 1 Blocks observed on the two 4th floor decks

Unit	8" Hollow	8" Solid	10" Solid
225 4th floor	108	217	131
227 4th floor	27	-	124
Total	135	217	255

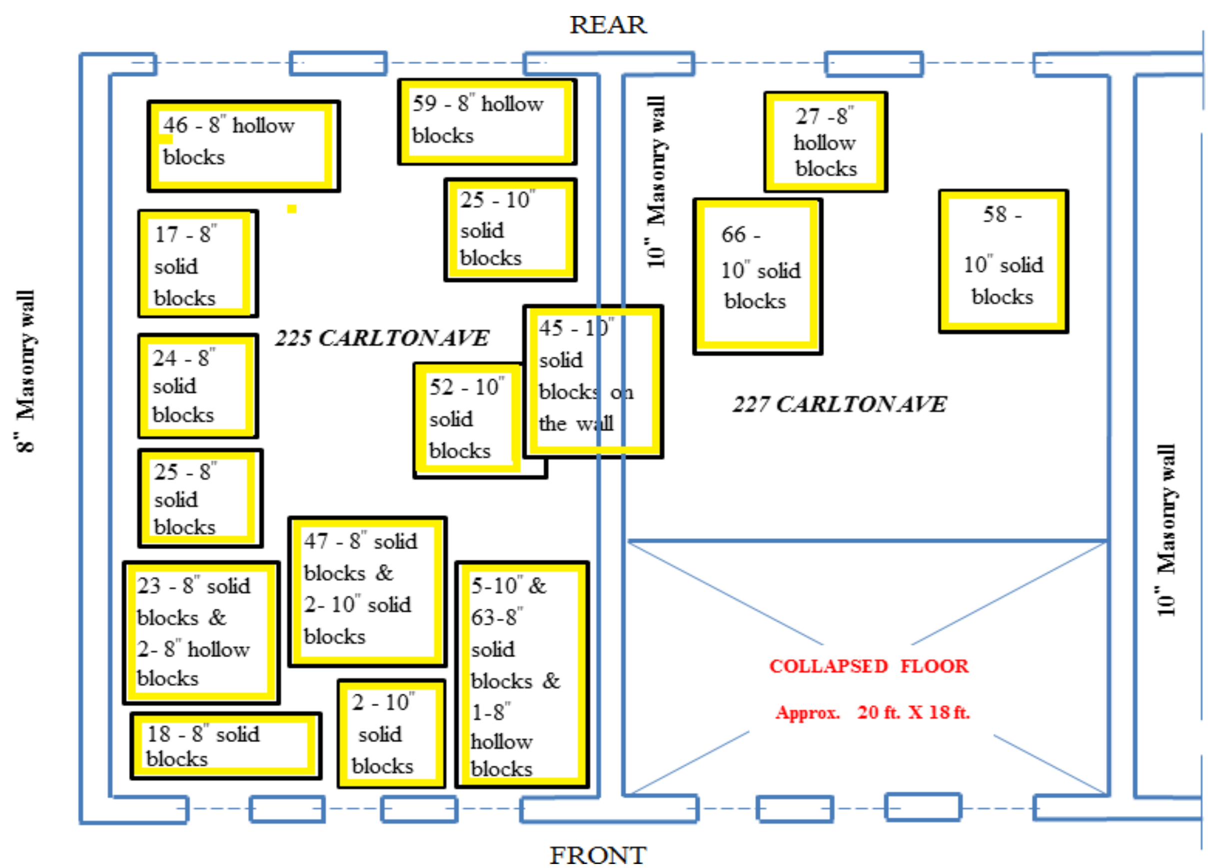

Fig. 3 Masonry blocks observed on the two 4th floors after the incident (Not to scale).

No pallets of cement bags or jumbo bags of sand were found on the 4th floor, either in unit # 225 or unit # 227. This would indicate that all the jumbo sand bags, three according to the majority of the eyewitnesses, and two pallets of cement bags, 10" solid blocks, 8" hollow blocks which were placed near the front of the 4th floor on unit # 227, and a concrete mixer fell with the collapsing floor.

It is estimated that approximately 4 jumbo bags of sand, three pallets of cement bags and approximately 55-10" solid blocks fell with the collapse, weighing a total of approximately 21,500 pounds. The three pallets of cement bags were reported to have been placed near the party wall away from the center of the C-joists, but the three sand bags delivered on the day of the incident were reportedly placed near the center of the C-Joists. It is noted that there were already two half full jumbo bags of sand on the floor from previous deliveries.

There is no inconsistency in the eyewitnesses reports that the cement bags were not spread out; rather they remained on the pallet. Also, the three jumbo sand bags also remained intact. In the same area, 10" blocks were also placed after being spread out from the pallets.

Post-incident observations indicated that there was no uniformity in the providing of lateral bracings to the floor joists. First, the temporary deck which could have provided lateral support to the joists was screwed to the top flange of the joists barely at few locations. Observations on the 4th floor and other floors indicated that the deck was screwed very sparingly, and, therefore, could not be relied upon to provide any lateral support to the floor joists. Second, there was a 2" wide steel strap screwed to the bottom flange of the joists at most locations. However, the top strap which was critical in providing lateral stability was not provided at most of the locations, see Fig. 4. Third, the blockings were provided only at the ends, but not at every 10' as required. Fourth, the straps which were provided at the bottom flange (see Fig. 5) were not spaced at 7' intervals, as required.

Fig. 4 Floor joists with no straps at the top flange.

Fig. 5 Floor joists with straps only at the bottom flange.

4. Structural Analysis and Discussion

We reviewed the structural design of the building to examine whether the structure as designed by the structural engineer of record would support the intended loads. The design loads used by the engineer to design the structural elements of the building were found to be in accord with the applicable 2008 NYC Building Code (Ref. 4). Our analysis indicated that the structural elements specified on the structural drawings were correctly proportioned to support the intended loads, if constructed in accord with the structural details provided on the structural drawings (Ref. 2) and the manufacturer's requirements (see Appendix). The floor joists on the fourth floor deck and at other locations were not braced (blocked and bridged) during construction of the building as per the structural drawings and standard industry practice. This deficiency was compounded by the masonry contractor who placed excessive construction materials on the deck, eventually leading to the partial collapse of the building as discussed earlier.

Bracing of the compression flange of load-carrying members is critical to their ability to carry loads. If bracings are either omitted or placed at intervals greater than what was called for by the designer, the member cannot be expected to carry the loads as indicated on the published tables, see Appendix.

It is well-recognized in the construction industry that while the structural engineer of record is responsible for the adequacy of the completed structure, the contractor is responsible for its stability during construction. The means and methods of construction are the prime responsibility of the contractor.

The cold-formed steel joists used to frame the floors of the building were 16-gauge JoistRite sections (Fig. 6 & Appendix) spaced at 16" o.c. (structural drawings S-002.01 to S-006.01 in Ref. 2). JoistRite is a cold-formed steel section manufactured by Marino WARE, see Appendix.
The structural drawings called for plywood sheathings to be placed on the floor joists.
The contractor, however, decided to place a temporary steel deck (see Fig. 7) on the floor joists during construction to avoid damaging the permanent plywood floor with construction materials.

Fig. 6 Floor joists spaced at 16" o/c.

Fig. 7 Temporary steel deck on 225 Carlton Ave. supporting construction loads.

Cold-formed steel structural members are highly susceptible to local and lateral-torsional buckling at stresses lower than the yield stress of steel when they are subjected to compression in flexural bending and axial compression, see Refs. 5 & 6. The decrease in the stress level below the yield stress, due to local and torsional buckling, led to a significant reduction in the load-carrying capacity of these members. Therefore, cold-formed structural members must be blocked, bridged, and stiffened to avoid local and lateral-torsional buckling.

The JoistRite technical guide for the construction of floor joists developed by Marino WARE required providing steel straps and solid bridging transverse to the span direction and web stiffeners at all support and concentrated load locations, see Appendix. The guide stipulated that the joist ends must be built solidly into masonry construction with a minimum of 4" bearing on concrete masonry walls prior to placing any load on the joists. Additionally, the guide stated that all bridging, bracing, blocking, strapping, and web reinforcement must be in place prior to loading of floors.

The technical guide specified, "*The compression flange of the section should be braced by the attachment of continuous diaphragm-rated sheathing or decking. The JoistRite blocking shall be located at first and second spaces, each end, and 10'-0"o.c. between and attached to joists through pre-drilled holes. Additionally, mechanical bridging shall be installed at intervals not to exceed 7'-0" on center. The installation of bridging shall be completed before loading the floor/roof system.*" (Italics ours). Fig. 8 shows the bridging/blocking requirements for floor joists by Marino WARE.

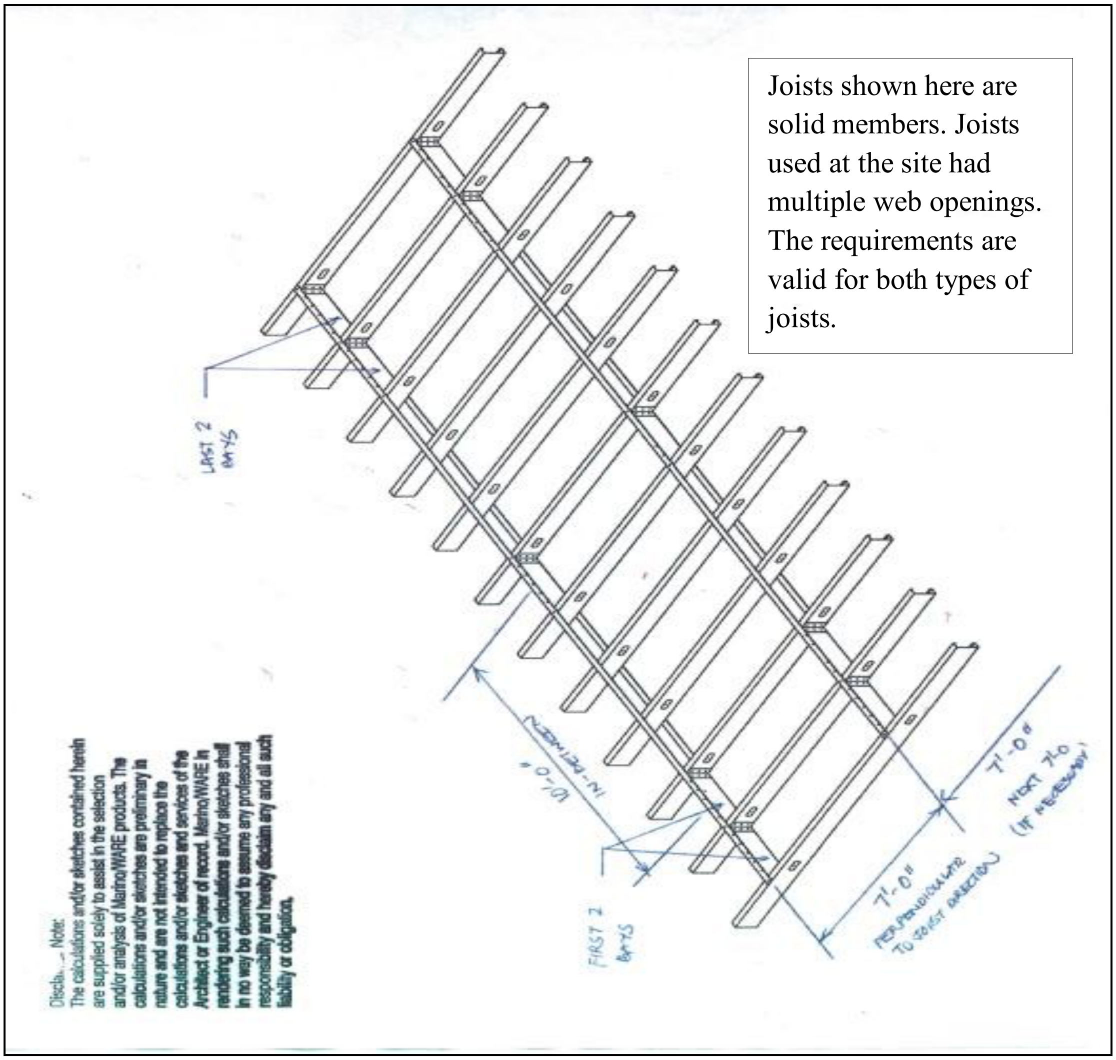

Fig. 8 Bridging/blocking requirements by Marino WARE - sketch provided by Marino WARE (Note the 7' requirements).

The JoistRite steel floor system installation guide recommended avoiding construction loads exceeding design live loads of floors and to install temporary bracings and joist bridging at the time of erection of floors to maintain structural integrity. It suggested that heavy loads of material, equipment, etc. be placed directly over structural supports, bearing walls or as directed by the architect or engineer to circumvent overloading the floor system during construction, see Appendix.

The 4th floor of unit #227 partially failed when construction loads (concrete blocks, bags of sand and masonry cement) were stacked up on the floor and collapsed on the 3rd floor creating a chain reaction on the floors below. All the floors ended up in the basement (cellar). Fig. 9 shows the area of the of the 4th floor unit #227 that collapsed due to construction loads.

Fig. 9 A partially collapsed 4th floor due to construction loads.

We analyzed the portion of the floor that failed to determine how much load it could support before it would actually fail. We, therefore, went over and above the safe allowable loads to determine the floors ultimate capacity, disregarding any factor of safety. But we needed to knowfor our computations at what intervals the contractor provided lateral bracings; this information was not readily available. Therefore, we examined three possibilities. First, that the bracings were provided only one foot away from the end supports, providing a spacing of 16'-9" between braces. Second, that bracings were located five feet from each end support, as was noticed at some locations, providing a spacing of 8'-9" between braces. Third, that the contractor had provided bracings at seven feet on centers as called for by the manufacturer and the structural engineer. We also needed to know for our calculations the magnitude of the loads placed by the masonry contractor on the fourth floor deck. The exact amount of construction materials and their precise locations on the deck were not possible to determine because the eyewitnesses accounts differed, as discussed earlier. However, there was unanimity on certain facts:

- Three pallets of cement bags were placed, all of which fell with the floor.
- Three jumbo bags of sand were placed, with two additional partial sandbags from the previous week, all of which also fell with the floor.
- Three pallets of 10" solid blocks were placed but were dispersed to various locations by hand. To account for this, we only considered partial loads of two layers of 10" solid blocks spread over an area of 3'x4' located at 4" from each support. We assumed that all other loads of blocks were placed at locations other than the failed area.

The following five load combinations were considered to determine the capacity of the floor joists.

1. Capacity of the floor joists to support 10" solid concrete blocks stacked in two layers and placed over 3' on the floor at 4" from the end supports of the joists, i.e., 207 lb./ft. applied on a joist over 3' .
2. Capacity of the floor joists to support 40 bags of Type S 75# masonry cement on a 40" by 48" pallet placed on the floor at 2' from the end supports of the joists.
3. Capacity of the floor joists to support the combination of loads assumed in cases 1 and 2, above.
4. Capacity of the floor joists to support a 1 metric ton (approximately 2,200 lbs.) bag of sand assumed to be supported by two joists, i.e., 1,100 lbs. applied on a joist over 3' at the mid span.
5. Capacity of the floor joists to support the combination of loads assumed in cases 1, 2, and 4, believed to be the actual conditions immediately prior to the collapse.

Our computations indicated that if the JoistRite floor joists that spanned 18'-9" were braced only at 1 foot from their end supports, the floor could support an ultimate uniform load of about 22psf. The ultimate flexural capacity of the the16-gauge JoistRite section for a laterally unbraced length of 16'-9" was approximately 1.27 ft.-kips. This is considered an unlikely scenario because then the failure would have occurred much earlier.

If the JoistRite floor joists were braced only at 5 feet from their end supports, i.e., for a laterally unbraced length of 8'-9", the floor could support an ultimate uniform load of about 77 psf. The ultimate flexural capacity of the 16-gauge JoistRite section (Section ID 1000JR250-54) for a laterally unbraced length of 8'-9" was approximately 4.51 ft.-kips. This is a likely scenario.

However, if the floor joists were braced at 7' as required by the manufacturer, the floor could support an ultimate uniform load of 107 psf. The ultimate flexural capacity of the 16-gauge JoistRite section was found to be approximately 6.24 ft.-kips. This is an unlikely scenario because post-incident observations did not support that the bracings were at 7' on centers.

For purposes of clarity, we have summarized the results of the calculations we performed for each of the five cases listed above in the following Table.

Table 2 Maximum flexural moment demand & ultimate flexural capacity (ft.-kips)

Case	Demand	Unbraced length(ft.)					
		16'-9"		8'-9"		7'-0"	
		Capacity	Demand* / Capacity	Capacity	Demand* / Capacity	Capacity	Demand* / Capacity
1	1.00	1.27	OK	4.51	OK	6.24	OK
2	2.77	1.27	Fails	4.51	OK	6.24	OK
3	3.05	1.27	Fails	4.51	OK	6.24	OK
4	4.85	1.27	Fails	4.51	Fails	6.24	OK
5	7.25	1.27	Fails	4.51	Fails	6.24	Fails

Note: No load factor or strength reduction factor was applied.
* If demand-capacity ratio is greater than 1.0, the joist would not support the load; but for a demand-capacity ratio less than or equal to 1.0, the joist can support the load.

5. **Conclusions**

1. The building partially collapsed because
    - the fourth floor joists were braced neither in accord with the manufacturer's requirements nor in accord with the structural engineer's instructions, **and**
    - The masonry contractor placed excessive construction materials (sand and cement bags and blocks) on the 4th floor.
2. The masonry contractor placed construction materials on the 4th floor deck without ascertaining the load capacity of the 4th floor.
3. The special inspector retained by the owner, as per New York City Department of Buildings requirements, performed poorly in that he certified that the floor joists had been placed in accord with the requirements of the documents. The inspection report was stamped by a professional engineer. The floor joists were not installed as required by the drawings and other documents. The inspection reports were therefore misleading and contributed to the building's collapse.
4. The contractor temporarily substituted steel deck for plywood but neither fastened it to the floor joists nor used 2" wide straps.

6. References

1. Architectural Drawings, Drawing Nos. A-100.00, A-101.00, A-102.00, A-150.00, A-151.00, A-152.00, A-200.00, and A-201.00.

2. Structural Drawings, Drawing Nos. F0-002.00, S-001.01, S-002.01, S-003.01, S-004.01, S-005.0, S-006.01, S-007.01, and S-008.01.

3. Integrity Consulting Services, Inc. Inspection Report. C-joists installation inspections (Inspector: Leo Gimelstein). July 30, August 7, August 10, August 20, August 22, and September 6, 2012.

4. 2008 NYCBC. New York City Building Code. International Code Council. July 2008.

5. AISI S100-2007-American Iron and Steel Institute - Specification for the Design of Cold-Formed Steel Structures, Washington, D.C., December 2007.

6. AISI S100-2007-C - American Iron and Steel Institute - Commentary on North American Specification for the Design of Cold-Formed Steel Structures, Washington, D.C., December 2007.