

# Investigation of the November 13, 2013 collapse of precast walls at a garage construction site, Ft. Lauderdale, FL

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U.S. Department of Labor  
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# **Investigation of the November 13, 2013 collapse of precast walls at a garage construction site, Ft. Lauderdale, FL**

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TABLE OF CONTENTS	PAGE NO.
Introduction	5
The project	5
Events leading to the incident	11
Analysis and Discussion	18
Conclusions	22

## LIST OF FIGURES

Figure 1	Building layout
Figure 2	Second Floor Plan
Figure 3	Progress of work at the time of incident
Figure 4	Progress of work at the time of incident
Figure 5	Progress of work at the time of incident
Figure 6	Lower wall W13
Figure 7	Upper wall W14
Figure 8	Double Tee T-504
Figure 9	Double Tee T-511
Figure 10	Failed walls and deadman
Figure 11	Connection detail between wall panel and foundation
Figure 12	Shim plates
Figure 13	Slotted hole in the wall base plate
Figure 14	Lumber as a formwork for the grout
Figure 15	Deadmen offset to pipe braces and walls
Figure 16	Rebar dowels – connection between upper and lower walls
Figure 17	Typical brace detail
Figure 18	Typical adjusting screw and foot plate
Figure 19	Typical deadman
Figure 20	Collapsed walls
Figure 21	Typical detail of double tee bearing on upper wall
Figure 22	Ledge on east side ramp wall (looking north)
Figure 23	Ledge on east side ramp wall (looking east)
Figure 24	Failed anchor bolts at the foundation
Figure 25	Wall collapse (looking west)
Figure 26	Wall collapse (looking north)
Figure 27	Stored upper and lower wall at Coreslab yard
Figure 28	Stored upper wall at Coreslab yard
Figure 29	Damaged wall at Coreslab yard
Figure 30	Damaged wall at Coreslab yard
Figure 31	Stored upper and lower wall at Coreslab yard
Figure 32	Wall panel connected by clip angle to column (post-incident)
Figure 33	Wall panel connected by clip angle to column (post-incident)
Figure 34	Schematic elevation of bracings provided at time of incident
Figure 35	Two Bracings per wall (post-incident)
Figure 36	General notes

## **REPORT**

### **Introduction**

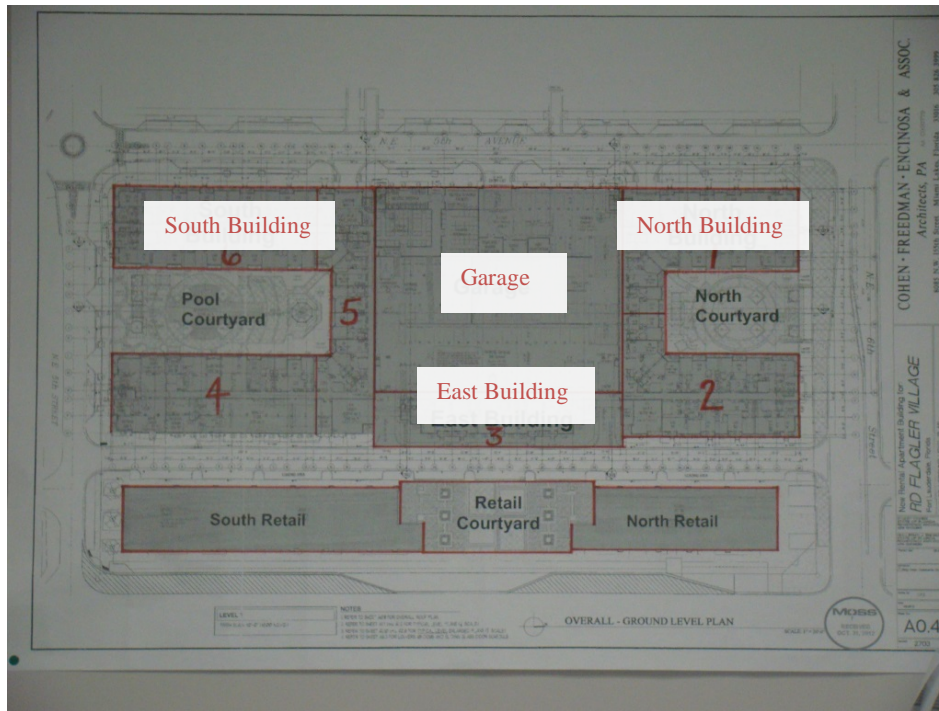
On November 13, 2013 an incident occurred at the construction site of a parking garage in Ft. Lauderdale, FL, where two precast walls weighing about 34 tons each suddenly fell. The walls were erected less than an hour before they fell. Two employees sustained injuries although this incident could have resulted in multiple fatalities. The parking garage was being constructed as a part of a larger project to construct new rental apartment buildings. The entire complex was called RD Flagler Village.

Regional Administrator, Region IV asked the Directorate of Construction (DOC), OSHA National Office, to provide technical assistance for a causal determination, and to examine whether any OSHA or industry standards were violated. A structural engineer from DOC visited the site on December 19, 2013 and conducted an inspection of the site and also examined the fallen walls which were stored in the precast manufacturer's yard. A compliance officer and a supervisory compliance officer accompanied the DOC engineer.

Photographs and construction documents were obtained and interviews were conducted to determine the activities preceding the incident. Engineering analyses were conducted to determine the mode of failure. Our findings are based upon the observations made, the analyses conducted and the construction documents examined. We thank Region IV and Ft. Lauderdale Area Office for their cooperation.

### **The Project**

The project consisted of construction of two apartment rental buildings with a parking garage nestled between them, see Fig. 1. The six-story garage was approximately 220' x 188'. The garage consisted of precast columns, precast beams and double tees. The project was owned by RD Flagler Village LLC of Ft. Lauderdale, FL.

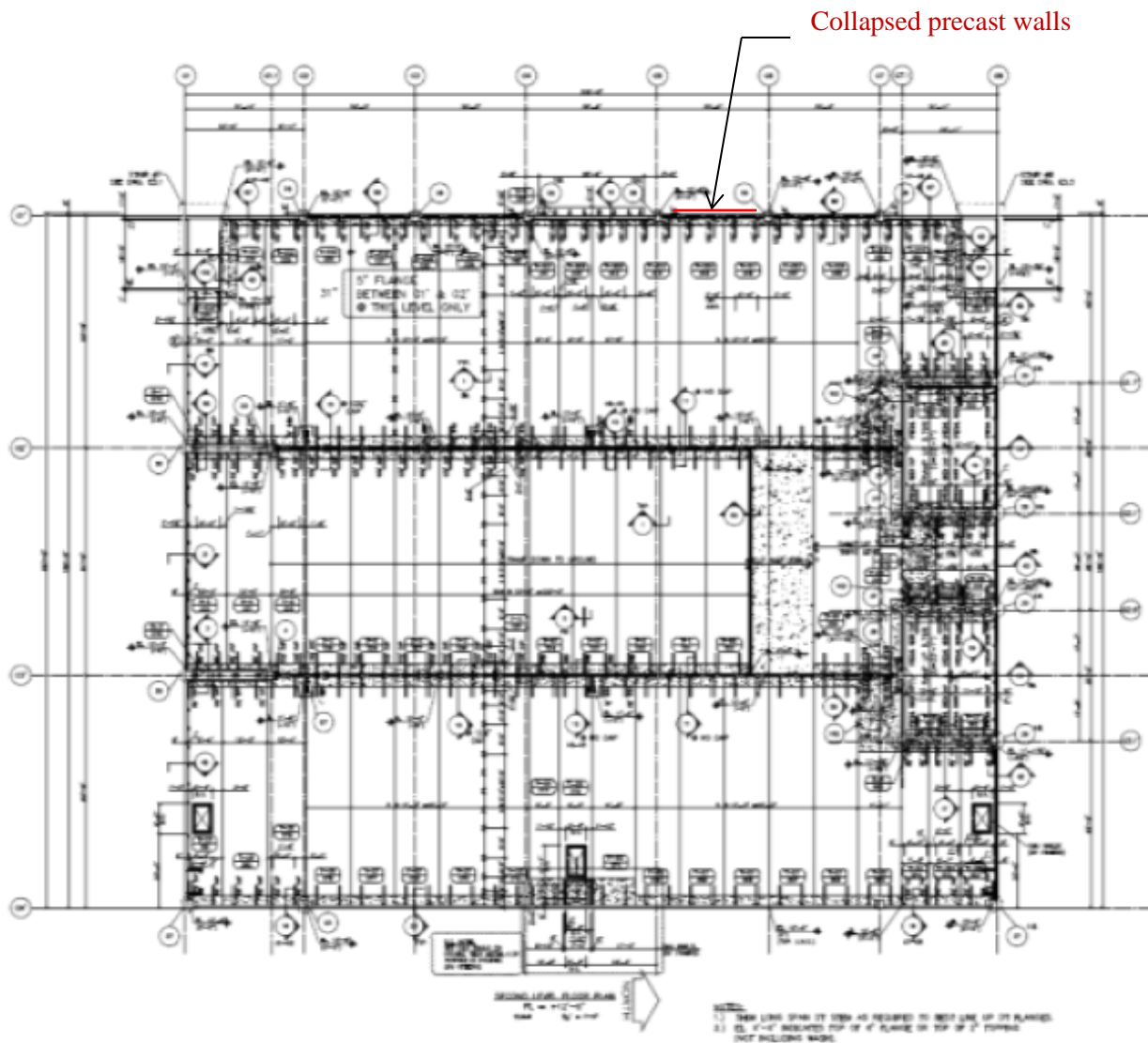


**Fig. 1** Building layout

The following were the key participants in the project:

1. Cohen Freedman Encinosa & Associates, Architects, PA of Miami Lakes, FL.
2. Moss and Associates LLC of Fort Lauderdale, FL. Construction Manager
3. Coreslab Structures (Miami) Inc. (Coreslab) of Medley, FL. Designer and fabricator of all precast elements.
4. Solar Erectors U.S. of Medley, FL. Erector of the precast concrete elements.
5. The Consulting Engineering Group Inc. of Illinois (CEG). Structural engineers assisting Coreslab in designing the precast elements.
6. B & J Consulting Engineers Inc. of Miami, FL. Threshold inspectors retained by the owner.
7. Professional Services Industries, Inc. of Fort Lauderdale, FL. Material testing retained by the owner.
8. Hershell Gill Consulting Engineers, Inc. of Miami, FL. Temporary bracing for the building against wind.
9. Florida Lemark Corporation of Doral, FL. Grouting contractor

The erection of the garage began from the north and proceeded towards the south. Two bays from grid lines G8 to G6 were nearly completed for all the floors. The immediate task preceding the incident was to erect walls on the exterior grid line G1' on the west side between grid lines G6 and G5. Following the erection of the walls, precast tees were to be placed for the second floor framing, and then to proceed further. See Fig. 2 below for the framing plan and the progress of work at the time of the incident, see Figs 3 to 5.



**Fig. 2** Second Floor Plan (Reference drawing Coreslab erection drawing E1.2)





**Fig. 3** Progress of work at the time of incident



**Fig. 4** Progress of work at the time of incident



**Fig. 5** Progress of work at the time of incident

Coreslab had a contract to design, fabricate and transport all precast members to the site. Based upon the architectural details provided by the architects, Coreslab retained the Consulting Engineers of Illinois to perform the structural design of the garage. In addition to the structural design, the Consulting Engineers also prepared details of the connections with specific requirements for embedded plates, dowels, welds, bearing pads, additional reinforcing bars, caulking, etc. Coreslab generally followed these details in fabricating the precast pieces. Only rarely did they change the design to improve transportability, and only with the approval of the consulting engineers. See Figs 6 & 7 for precast walls W13 (lower wall) and W14 (upper wall), and Fig. 8 & 9 for double tees T-504 and T-511.



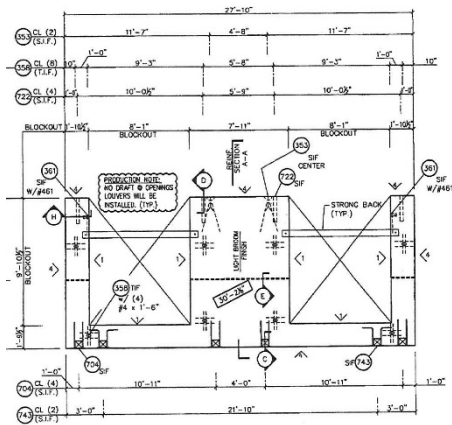


Fig. 6 Lower wall W13

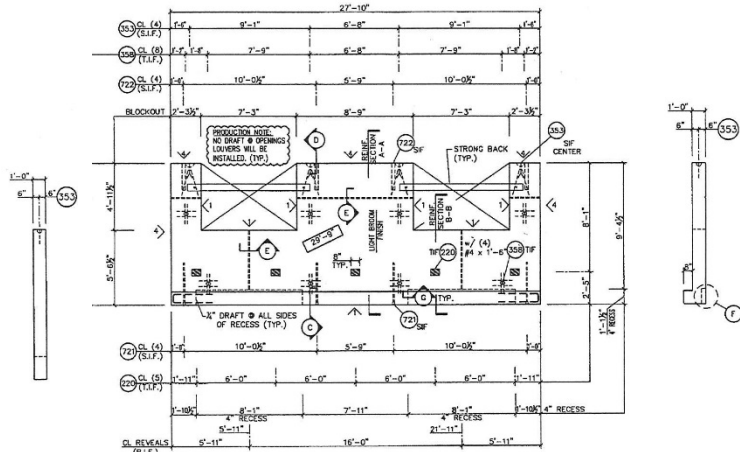


Fig. 7 Upper wall W14

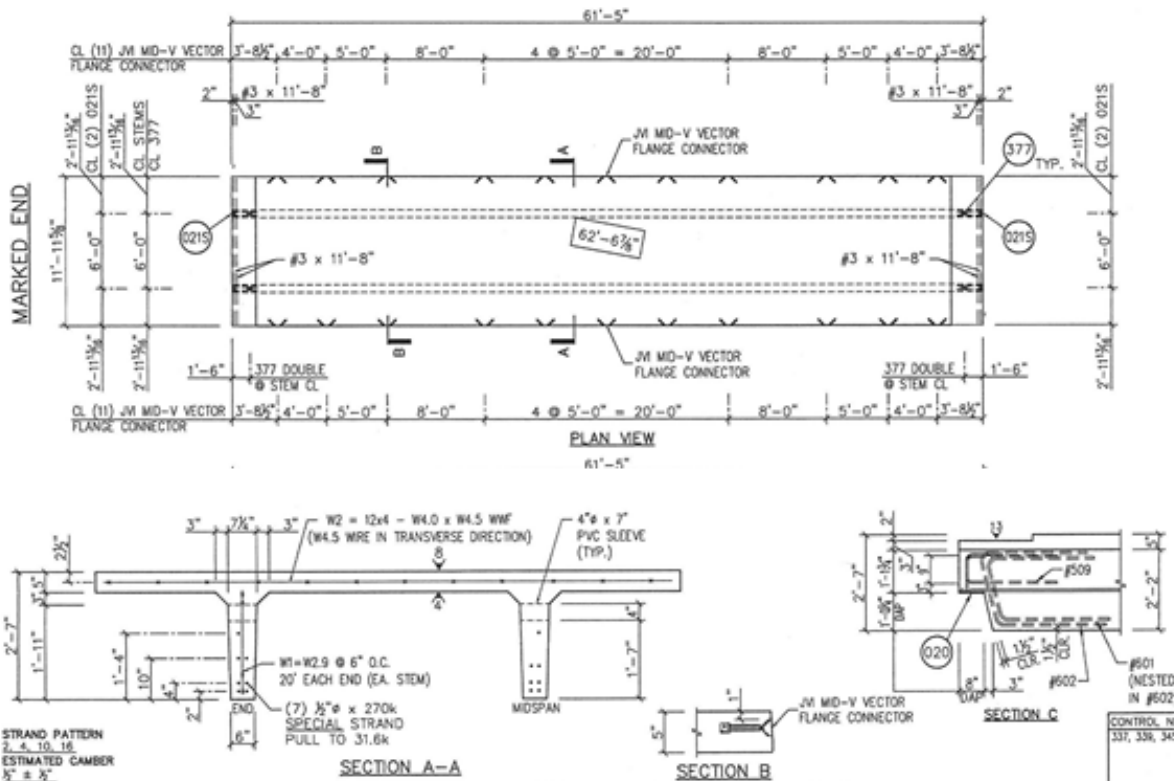
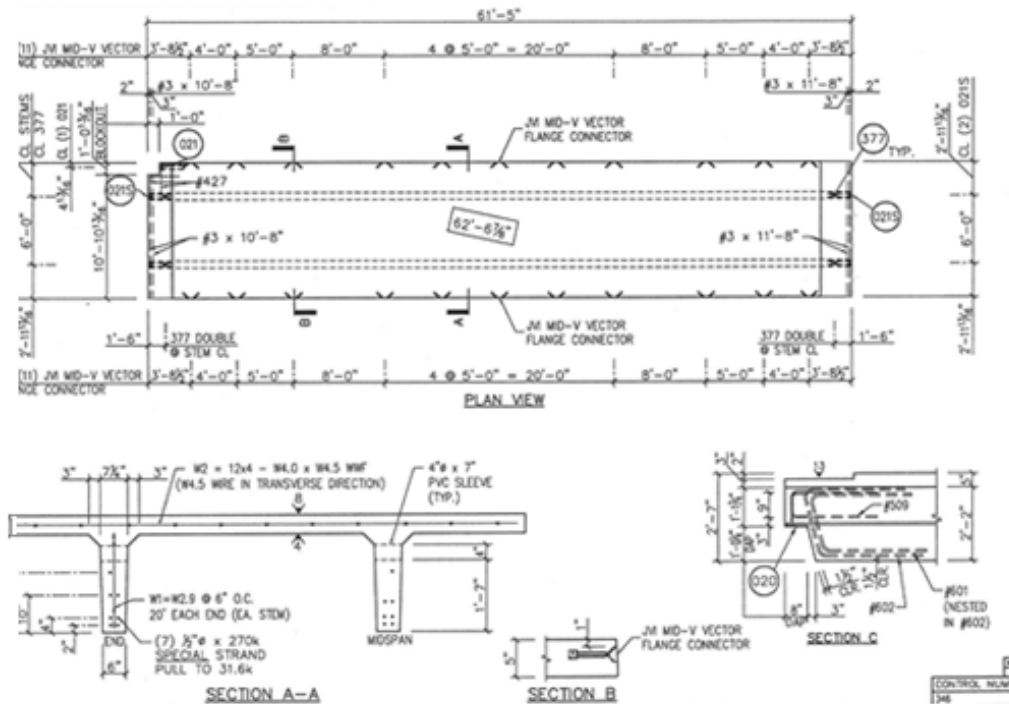


Fig. 8 Double Tee T-504



**Fig. 9** Double Tee T-511

Solar Erectors is a subsidiary of Coreslab. Solar Erectors was given the job of erecting the parking garage. Solar Erectors had a full time superintendent at the site with supervision provided by Solar Erector's erection manager for the Miami area. This arrangement between Coreslab and Solar Erectors was not new as they have worked together on numerous projects.

The threshold inspector retained by the owner had a representative full time. The representative told OSHA that his task was to review the cast-in-place concrete, precast concrete, anchoring, grouting, shimming, welding, etc. to assure conformance with the approved construction documents. He wrote reports almost daily and forwarded them to all the parties including Coreslab, Moss and the others. He was not given any instructions regarding the erection of precast elements, and the methods and means of erection were left upto the individual erector. The inspector's representative had no authority to stop the work, but he could talk to the construction manager if he saw any things out of the ordinary. In the time leading up to the incident, he did not report anything to the construction manager, although he knew that only one brace was used to support the walls instead of the usual two, and that welds were not performed between the double tee and the wall, and between the flanges of the adjoining tees.

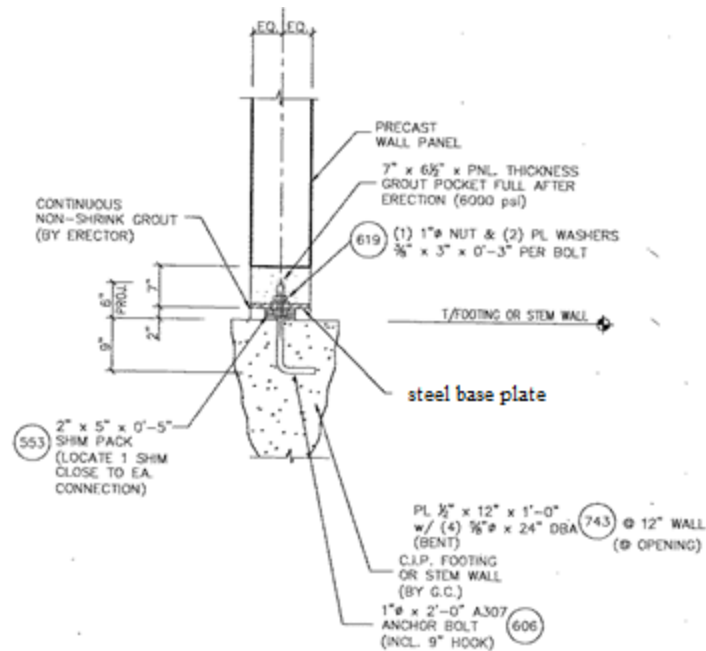
### **Events leading to the incident:**

The work began in earnest on November 13, 2013 early in the morning, but the crane did not become operational until 8:00 A.M. The first task was to erect two walls, W-13 weighing about 34 tons between the first and second floor, and W-14, also weighing 34 tons between the second and third floor. Both walls were 12" thick and approximately 28' long. The lower wall was 11'-8" high, and the upper wall was 10'-6" high. The walls were located on the west side of the garage between column grid lines G5 and G6. After the walls were erected, two double tees, T-504 and T-511; were to be placed over the ledge of the upper wall, W-14, and the ledge of the ramp wall on the east side. The site was a tight space and congested (see Fig. 10); so the precast pieces were ordered a day earlier and were shipped the next morning.



**Fig. 10** Failed walls and deadman

The foreman ordered the crane operator to bring the lower wall, W-13, and to gingerly place it over the five protruding dowels projecting from the foundation, see Fig. 11.



**Fig. 11** Connection detail between wall panel and foundation

The bottom of the wall had five steel shim plates (see Fig. 12), embedded in the concrete along with a provision to provide washer plate and nuts over and under the steel plate. The dowels had leveling nuts below the steel plates. The plates were provided with slotted holes in the longitudinal direction, but not in the transverse direction, see Fig. 13.



**Fig. 12** Shim plates



**Fig. 13** Slotted hole in the wall base plate

Before the wall was lowered onto the grade beam, two sets of 5"x 5" were placed over the grade beam, one at each end. The dowels matched reasonably well with the location of the holes in the base plate, avoiding the need to elongate the holes by burning. The wall was plumbed, then the levelling nuts were tightened below the steel plates, and the nuts above the plates were also

tightened. An additional three set of shims were placed under the wall. Shortly thereafter, the erection foreman ordered Florida Lemark to begin grouting below the base of the wall. As was the practice, Lemark used an air blower to clean the space of any debris, and then placed two pieces of lumber as a formwork for the grout, see Fig. 14.



**Fig. 14** Lumber as a formwork for the grout

Immediately thereafter, a pipe brace, approximately 3 1/2" in diameter was placed about three feet from the top of the wall, with a drilled red head anchor. The bottom of the brace was anchored with a bolt to a concrete deadman, 5' x 5' x 2' deep located about 12 to 13 feet away from the bottom of the wall. It is believed that the deadman was located off the center of the wall, thereby rendering the brace skewed; see Fig. 15 and 26.

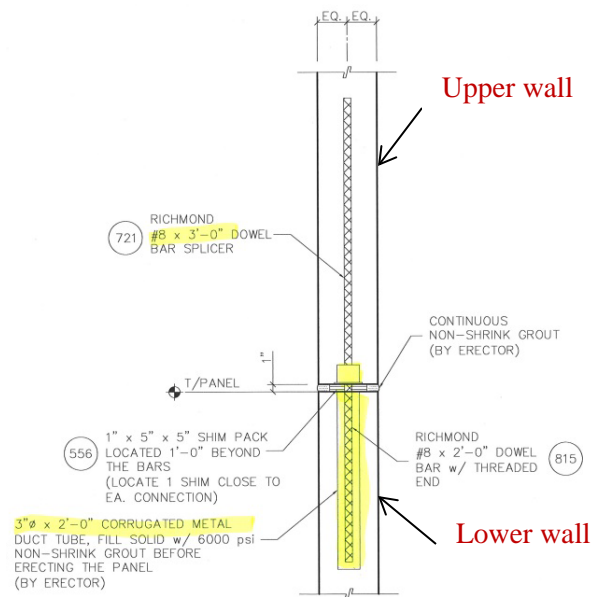
The foreman ordered the upper wall, W-14, to be brought in. Meanwhile, Lemark placed the soupy and flowable grout in the four holes provided at the top of the lower wall to receive the #8 dowels from the bottom of the upper wall. The dowels were screwed in at the site to the insert cast in the wall, see Fig. 16. The wall was carefully placed over the lower wall with the dowels finding their way into the holes. The holes were 3" in diameter, providing some leeway for adjustment. As before, the dowels were directed into the holes and steel shims were placed over the top of the lower wall. Before the crane could release the load, the upper wall was plumbed in both directions and a diagonal brace (see Fig. 17 for typical brace) approximately 5 1/2" in diameter was anchored with a red head bolt near the top of the wall, see Fig. 18.



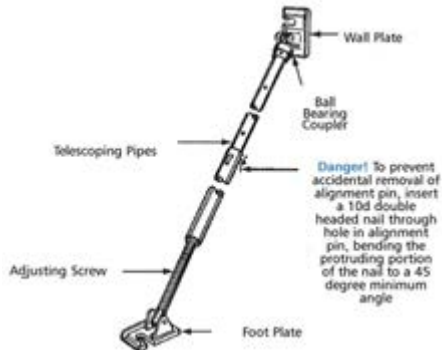


**Fig. 15** Deadmen offset to pipe braces and walls

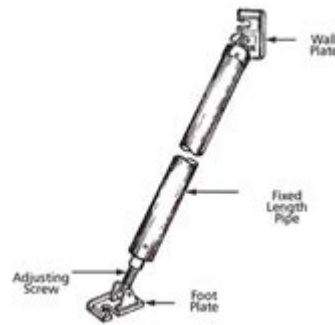
Deadmen



**Fig. 16** Rebar dowels – connection between upper and lower walls



**Fig. 17** Typical brace detail (from Dayton superior website)



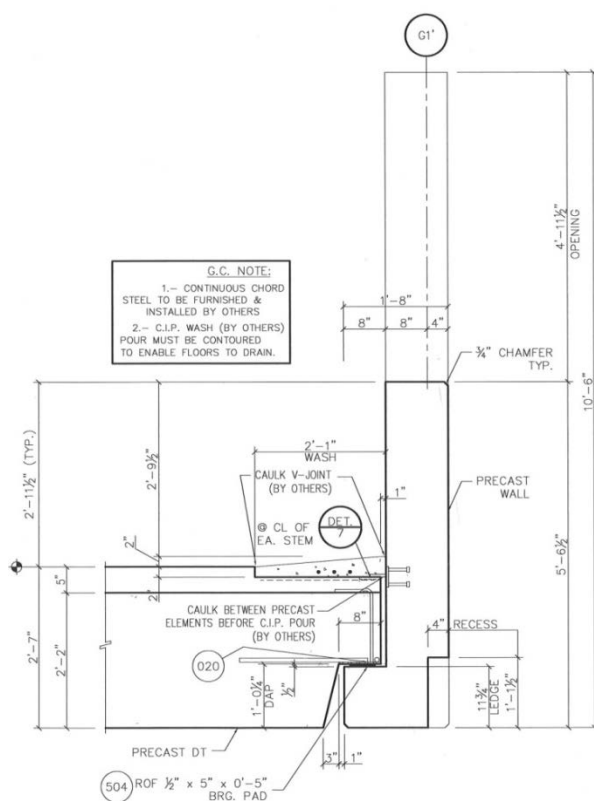
**Fig. 18** Typical adjusting screw and foot plate.

The brace was again anchored to a concrete deadman 5' x 5' x 2' deep with a single bolt, see Fig. 19 for deadman. After the brace was placed, the wall was again plumbed by tightening the bolts at the top and bottom of the brace. Additional shims were placed, and the crane then released the load. As in the case of the lower brace, the deadman for the upper brace was also not centered on the wall and was considerably offset, see Fig. 15, 20 and 26.





The foreman then ordered the crane to bring in a double tee marked, T-511. The two stems of the double tee were placed on the concrete ledge provided at the bottom of the upper wall with a bearing pad between the stems and the ledge, see Fig. 21.



15

The bearing pads were already glued to the bottom of the stems with heavyweight glue before the tees were brought in. The stems were supported on a similar ledge of a ramp wall on the east side, see Fig.s 22 and 23. It was reported that when the tee was placed over the ledge of the west wall, the upper wall tilted towards the interior span. The wall was then plumbed by tightening the brace. The crane then released the load. It must be noted here that the tee was neither welded to the junction of the wall and the tee flange, nor was the tee flange welded to the flange of the adjoining tee which was already in place. Such omissions would later be found to have significantly contributed to the instability of the wall, and to its eventual failure. It was reported that the concrete deadmen were in short supply, and since the site provided only limited space for maneuvering, the braces were connected to the deadmen wherever they were originally located. It should also be noted that on the east side, the tee could not have been welded to the wall because the upper wall was not yet placed.



**Fig. 22** Ledge on east side ramp wall  
(looking north)



**Fig. 23** Ledge on east side ramp wall  
(looking east)

The foreman then ordered the second tee, marked T-504, to be brought in. As the crane brought in the double tee, T-504, and as it was very near its final position but still held by the crane, the upper wall and the lower wall folded, and fell towards the west, see Fig.s 24 to 26. The upper wall fell over the fallen lower wall. The double tee, T-511, dropped over to the ground. The crane continued to hold the other double tee, see Fig. 3.

Following the incident, the two fallen walls and the two double tees were transported and stored in the Coreslab yard, see Fig.s 27 to 31.



**Fig. 24** Failed anchor bolts at the foundation



**Fig. 25** Wall collapse (looking west)



Deadman for  
lower brace

Deadman for  
upper brace

Note deadmen extent of offset

**Fig. 26** Wall collapse (looking north)



**Fig. 27** Stored upper and lower wall at Coreslab yard



**Fig. 28** Stored upper wall at Coreslab yard





**Fig. 29** Damaged wall at Coreslab yard



**Fig. 30** Damaged wall at Coreslab yard



**Fig. 31** Stored upper and lower wall at Coreslab yard

### **Analysis and discussion**

Our review indicated that the structural design of the wall and the double tees were in general conformance with the applicable codes. The issues we will address include the method and means of erection which was left completely to the erection crew. Solar Erectors did not provide any step-by-step guidance to its superintendent and his crew on the manner in which the walls could be safely erected. It was reported during the OSHA interview that the erection manager displayed an indifferent attitude when he was asked by the superintendent to provide additional deadman and supporting steel clip angles to secure the wall to the already erected columns. Furthermore, the superintendent could not compact the ground for the deadman nor was he able to move the deadman. See Fig.s 32 and 33 for the steel clip angle used after the incident.

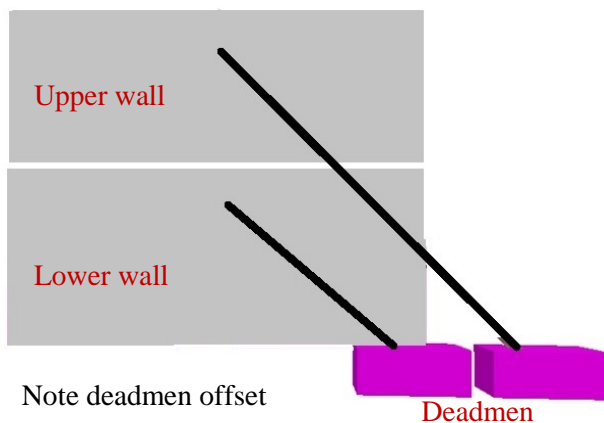


**Fig. 32** Wall panel connected by clip angle to column (post-incident)



**Fig. 33** Wall panel connected by clip angle to column (post-incident)

The most glaring flaws in the erection of the two walls were the use of only one brace to support each wall, and the off-set location of the two deadmen where the braces were anchored by foot plates. The braces were, therefore, inclined in two directions, as shown in Fig. 34 and 26, thereby increasing the force on the braces and foot plates. The normal practice in the industry is to provide two braces normal to each wall, and to center the deadman on the braces, see Fig. 35 (being practiced after the incident).



**Fig. 34** Schematic elevation of bracings provided at time of incident



**Fig. 35** Two Bracings per wall (post-incident)

There were numerous errors which took place during the erection of the walls. First, the bottom of the lower wall was not completely grouted over its support, although shims were placed. The shims provide bearing capacity to transfer the gravity load, but they have no flexural strength in the event of an overturning failure. At the time of the incident, only 1/3 of the area below the

wall was grouted. The anchor bolts were tightened during the plumbing phase, but they could not be relied upon to resist any flexural loads. Second, when the top wall was placed, the grout in the dowel holes was still wet and in a semi-liquid state providing little strength to the walls in the event of an overturning failure. Third, the first tee (T-511) that was placed was released by the crane before any temporary welds were placed between the tee and the wall. Fourth, the tees were not provided with any temporary welds to the adjoining tees at the flanges to provide additional strength.

When the double tee was placed on the ledge of the wall, it moved and tilted towards the east as could have been expected due to the eccentric load. The brace was, therefore, tightened to plumb the wall. Our calculations indicate that a horizontal force of approximately 5,000 pounds would have to have been applied by tightening the “adjusting screw” at the bottom of the top brace, see Figs 18 and 19. This would result in a tensile force of approximately 12,000 pounds on the brace which the brace was capable of resisting although its factor of safety would be compromised. However, the weakest link was the foot plate which was subjected to shear, axial tension and a bending moment. The “foot plate”, see Fig. 17, is made of ductile iron conforming to ASTM- A536, grade 65-45-12. This had yield strength of 45,000 psi. Our calculations indicate that the “foot plate” was subjected to a bending moment of approximately 17,000 in-kips at the slotted hole location, resulting in a stress of approximately 61,000 psi, well in excess of 45,000 psi. The calculations were performed on the basis of plastic section modulus and ultimate strength without a load factor and a reduction factor.

It is believed that if two braces for each wall were provided and if the deadmen were centered on the braces as is now practice after the incident (see Fig 35), the incident would not have occurred since the forces in the “foot plate” would have been below their failure load, even if the tees were not welded to the wall and the adjoining tee flanges. If due diligence had been applied as could be expected from the Solar Erectors manager and superintendent, they would have immediately realized that this was an incident waiting to happen.

The selection of the pipe braces to support the upper and lower wall was done arbitrarily without any thought given to the structural capacity of the braces, the foot plate and the manner of anchorage to the deadman. This is significant for two reasons. First, braces in the interior side of



the wall were not provided, thus subjecting the braces on the exterior side of the wall to forces arising out of tilting of the upper wall. Second, both deadmen were grossly offset.

To facilitate the fabrication and erection, Coreslab marked every precast element with individual numbers. In the erection drawings, Coreslab stated that “*Grout columns and walls within 24 hours prior to erection of pieces unless noted otherwise (u.n.o.).*” However, the grouting contractor Lemark did not place the grout underneath the lower and upper wall and thus compromised the structural stability of the wall.

Also, in the erection drawings, Coreslab stated that “*The Erector shall adequately brace and secure all members during erection, until all final connections are made.*” Further, Coreslab stated that “*The stability of the structure during erection is the sole responsibility of the erector.*” The erector failed to follow all of these important instructions and this affected impacted the stability of the both lower and upper walls. See Fig. 36 for notes.

- 3.4 GROUT: Dry pack under column base plates, bolt pockets and load bearing wall panels. Grout shall be mixed and applied in accordance with the manufacturer's recommendation. Grout columns & walls within 24 hrs. prior to erection of pieces unless noted otherwise (u.n.o.).
- 3.5 BEARING PADS: Beam, double tee bearing and connection pads shall be placed at locations indicated on these drawings. Pads shall be preferably attached to one of the connecting members with contact cement to hold them in place during erection. Bearing pads which are not properly aligned shall not be accepted.
- 3.6 The Erector shall adequately brace and secure all members during erection, until all final connections are made.
- 3.7 The stability of the structure during erection is the sole responsibility of the Erector.
- 3.8 The erection sequence shall be studied in detail by the Erector. Any question shall be addressed to Coreslab Structures Engineering Department two weeks prior to starting erection.
- 3.9 All columns and load bearing wall panels shall be grouted as soon as possible after plumbing and bracing. Columns shall be braced during erection and maintained in a stable condition until all beams and double tees are in place and all permanent connections to lateral load resisting members are completed. Grout immediately, do not add load until after
- 3.10 Non-load bearing spandrels must be erected using all four erection points provided to avoid lateral instability.
- 3.11 Written consent from Coreslab Engineering is required prior to any field cutting of the precast units or connections. Coreslab assumes no responsibility for the members whose capacity has been altered by field cutting done without the consent of Coreslab Engineering.
- 3.12 DAYTON SUPERIOR grouts shall have three sets of grout cubes taken for each 6 days of grouting. Use steel molds available at plant. Grouting of couplers shall be in strict accordance with manufacturer's specifications. Any misaligned dowels shall be addressed by Coreslab Engineering.

**Fig. 36** General notes (reference drawing - Coreslab Erection drawing)

## **Conclusions**

1. The precast walls collapsed because the temporary pipe braces were subjected to high tensile forces, resulting in the failure of the foot plate of the brace supporting the top precast wall. Unfortunately, there was apparently very little planning done to ensure that the walls were erected in a safe manner. Numerous factors contributed to the collapse of the walls which had the potential to fatally injure multiple employees. The entire erection was performed in an unprincipled manner. OSHA Standard 1926.704(a) was violated.
2. The crane released the double tee before it could be welded to the walls and to the adjoining tees.
3. The top and the lower walls were supported by only one brace each instead of two as practiced in the industry.
4. The deadman concrete blocks where the braces were anchored were considerably off-set from the center of the braces, thus increasing the forces on the braces, and reducing their effectiveness. The deadman block for the top brace was offset by as much as fifteen feet.
5. The deadman blocks were placed without any leveling or compaction of the soil.
6. The foreman and his crew were given only limited instructions on the method and means of erection by Solar Erectors or Coreslab structural engineer who happened to be at the site at the time of the incident. The representative of the independent laboratory in charge of quality control did not comment on the erection procedure although it took place within in his plain sight.