Investigation of the September 1, 2016, Formwork Table Collapse in West Palm Beach, Florida

U.S. Department of Labor
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Report

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1. The Background

On September 1, 2016, around 1:45 p.m., a formwork table that was being installed for pouring concrete for construction of a multistory residential building failed and collapsed in downtown West Palm Beach, Florida. The formwork table was being installed on the 15th level and three employees were engaged in the installation of this formwork table. One of the employees fell along with the formwork table and was fatally injured. The multistory building under construction was adjacent to a state highway and multiple stores nearby. No vehicles or pedestrians were hit by the falling formwork table.

The OSHA Regional Administrator, Region IV in Atlanta, requested the Directorate of Construction (DOC), OSHA National Office, in Washington, D.C., to provide engineering assistance in its investigation of the incident. One structural engineer from DOC visited the site to examine the failed table form and to obtain construction documents. Safety compliance officers from the Fort Lauderdale Area Office were also present during the visit.

2. The Project

The project was a twenty (20) story multifamily residential building named “3 THIRTY THREE DOWNTOWN” at 333 Fern Street, West Palm Beach, FL, 33401. The site was at the intersection of a busy highway S. Dixie Hwy & Fern Street, see figure 1. KAST Construction, West Palm Beach, Florida was the General Contractor (GC) and there were several sub-contractors working for the GC. The frame contractor responsible for formwork was CECO Concrete Construction LLC of Tampa, Florida. The 15th level slab was completed and the crews were installing the table forms on the 15th level (sixteenth floor). There was no thirteenth floor in the drawing that is why the sixteenth floor was at 15th level, see figure 2. There were about 34 tables for the 15th level and the formwork tables were labelled T1 through T29, see figure 3 (Level 8-20 Concrete Formwork Plan drawing F8.0) and figure 4. There was one formwork plan for levels 8 thru 20, but the dimensions of tables T1 through T29 were different.

The tables came unassembled in a truck and were assembled on the ground at the site. A typical table generally consisted of 5 ½" deep aluminum purlins supported over two 7 ½" deep aluminum mega beams. The mega beams were supported over the columns known as EFCO tower. The EFCO tower had four EZ 6-0 Posts with bracing typically consisting of EZ Window 8" and EZ Window 4". At the top, a plywood sheet 5/8" thick was nailed to the purlins. Makeup drawings for Table T27 and T28 are shown in figure 5. A typical section of the table showing EFCO Tower, Mega beams and purlins are shown in figure 6. Installed tables can be seen in figures 7 to 10.

The assembled table was then hoisted by a crane and placed at the appropriate floor location. Rough levelling and anchoring of the table was done by the table-setting crew. Once the rough levelling and the anchoring of the table were completed, the table-setting crew foreman is supposed to instruct the crane operator to release the crane. The foreman was to ensure that the table is well secured before unhooking the crane. The table-setting crews were wearing a self-retracting lifeline.

Prior to pouring concrete, the final grading crew was supposed to connect the top of the tables with the adjoining tables to create one continuous form. Additional shoring was also required if the tables had cantilevers as was the case with Table T27. The crew was supposed to make sure that tables were set as per drawing F8.0 (see figures 3 and 4), before concrete for the floor slab could be poured.

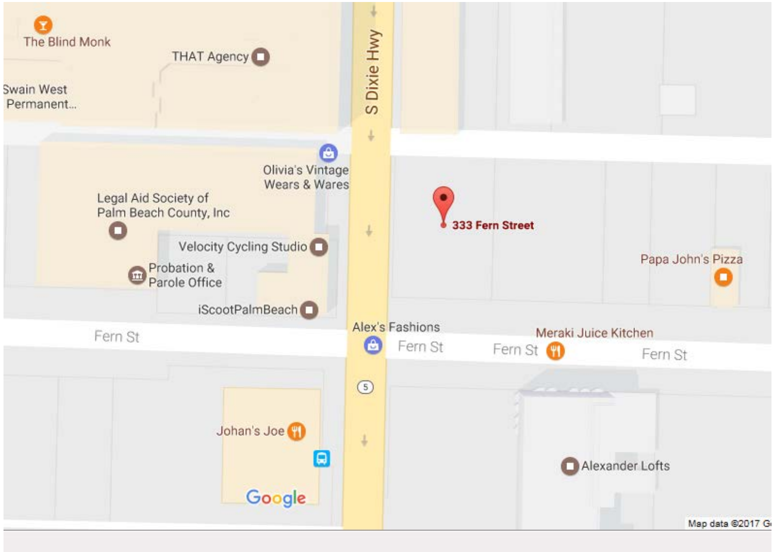

Fig. 1 – Location map (from Google Maps).

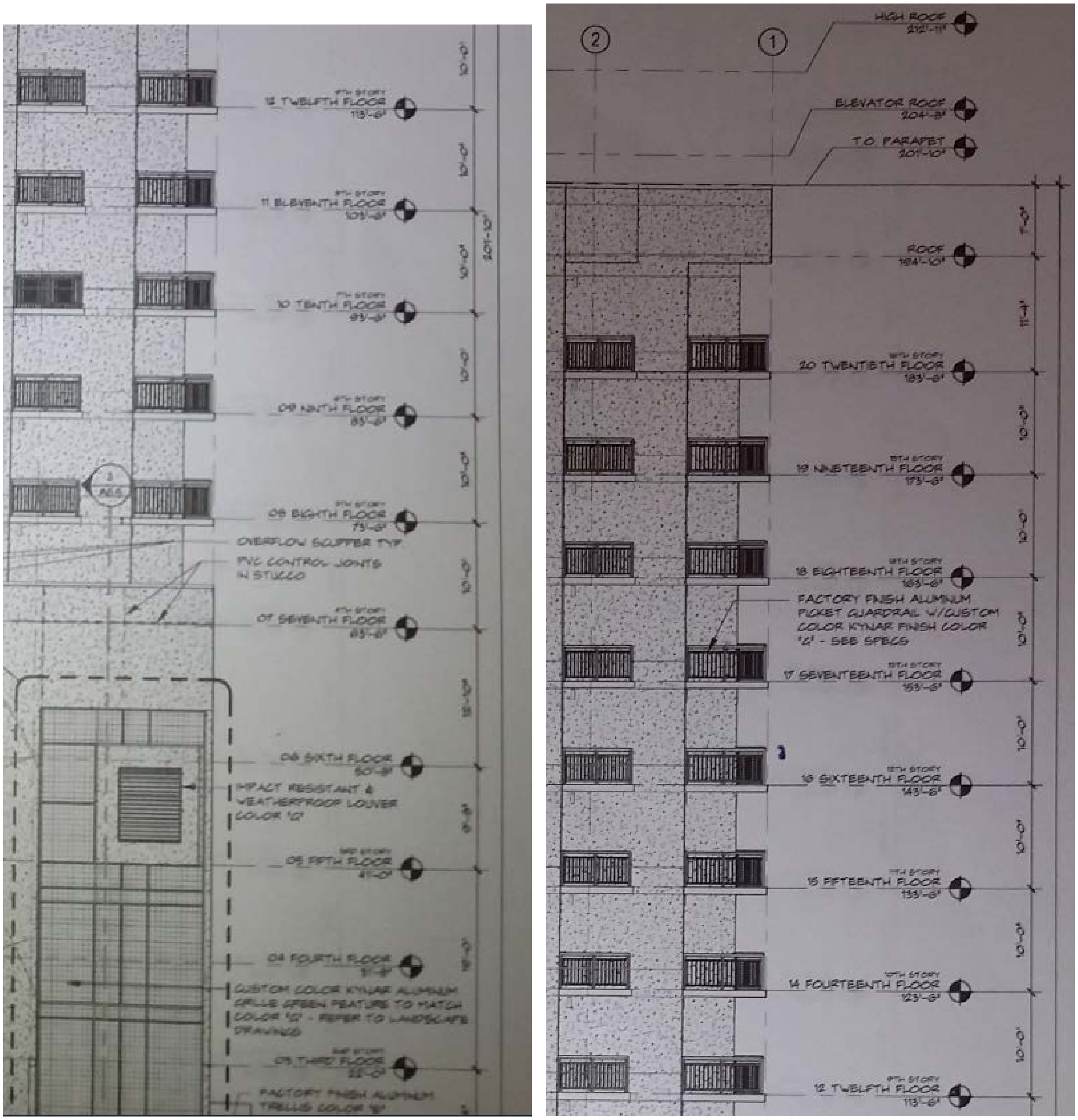

Fig. 2 – Building floor elevations.

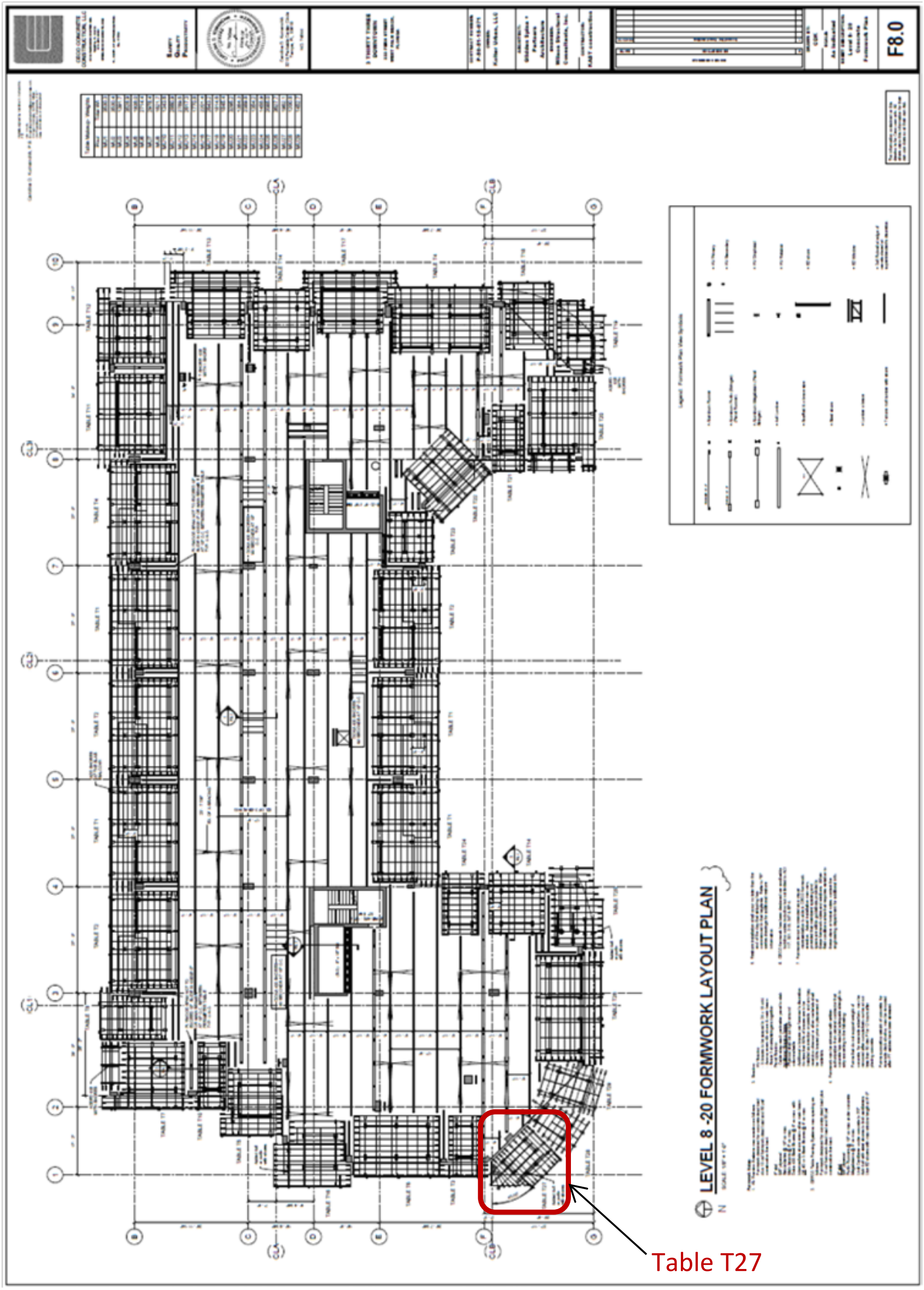

Fig. 3 – Formwork Plan Level 8-20 (CECO drawing F8.0).

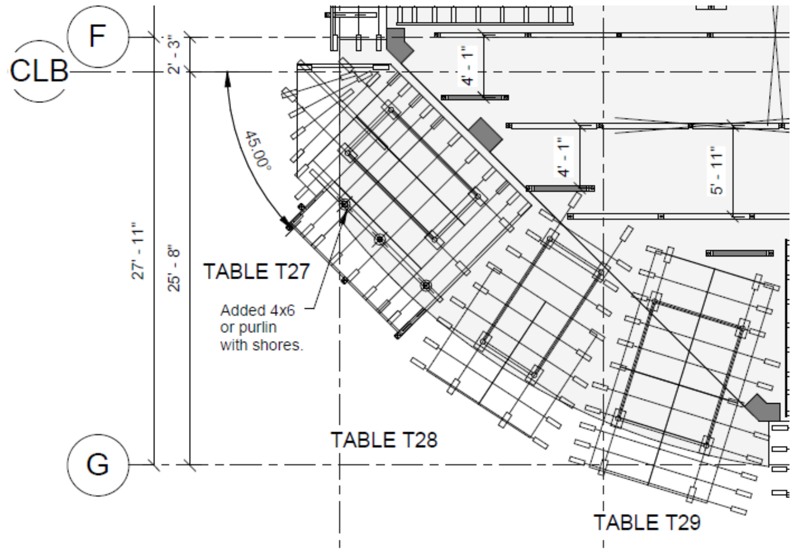

Fig. 4 – Formwork plan showing Table T27. (From CECO drawing F8.0 – see fig. 3)

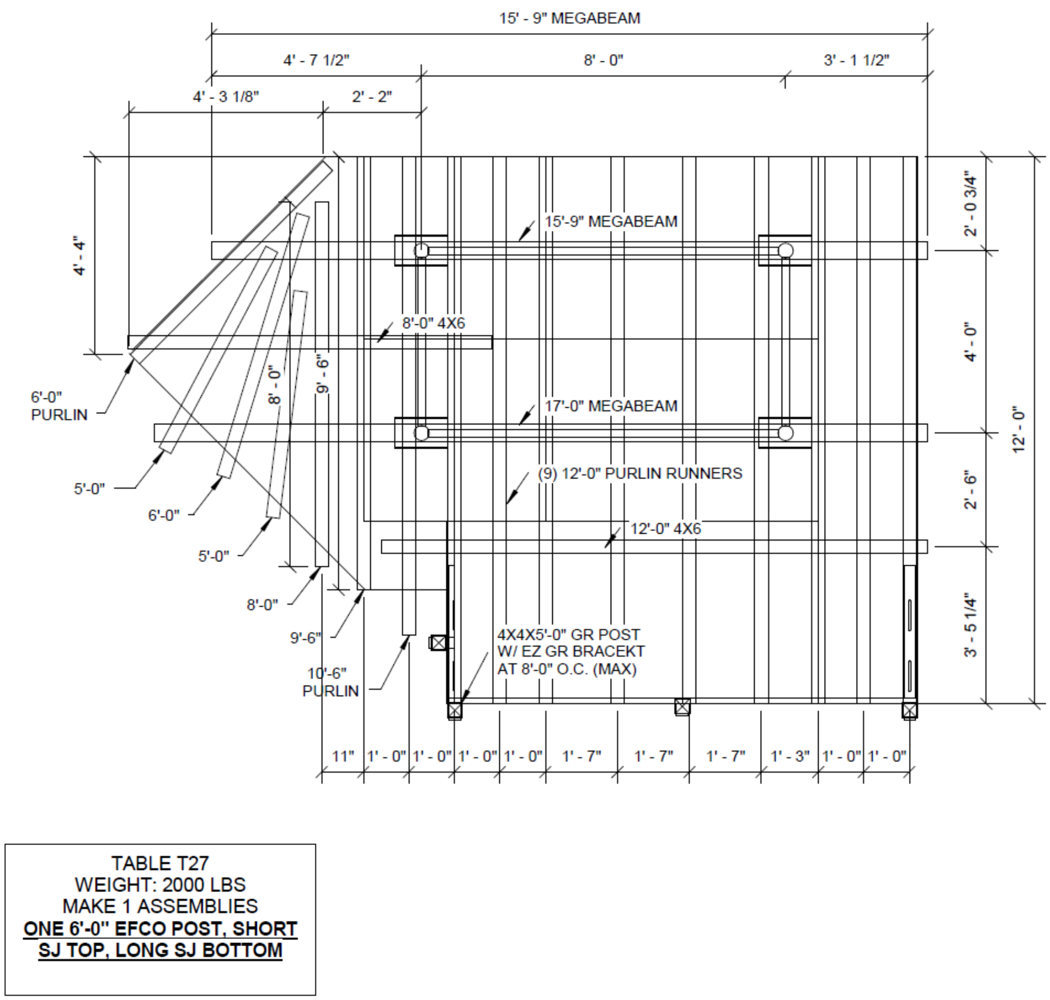

Fig. 5 – Makeup drawing for Table T27. (From CECO drawing MU1.4)

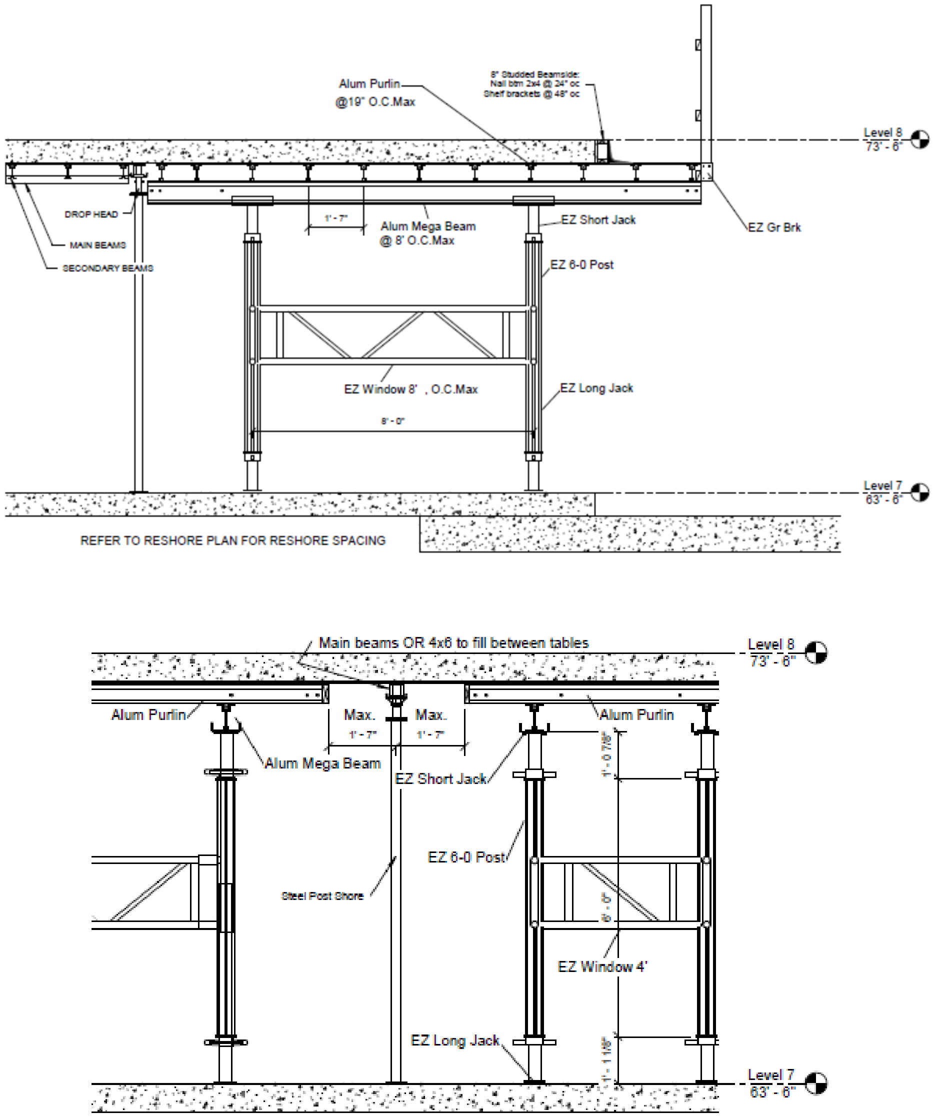

Fig. 6 – Formwork table sections. (From CECO drawing F8.1)

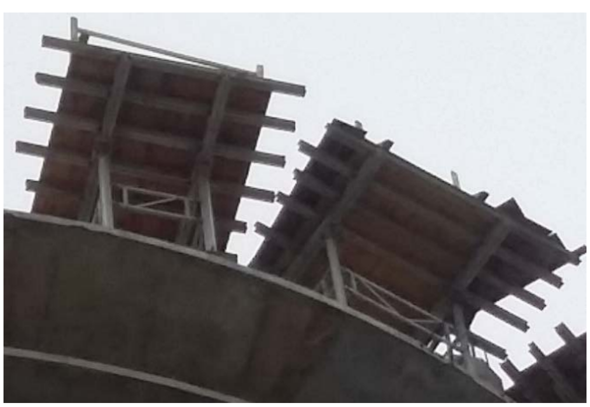

Fig. 7 – Formwork tables installed by table-setting crew.

Fig. 8 – Formwork table installed by table-setting crew.

Fig. 9 – Formwork tables installed by table-setting crew. Fig. 10 – Formwork table installed by table-setting crew.

3. The Incident

On the day of the incident, the table-setting crews arrived at the site around 6:30 a.m. They held a planning meeting for about half an hour, and placement of the tables on the 15th level began around 7 a.m. Approximately 10 tables were placed on the 15th level. Table T27 was the last table that was placed that day. (For the plan and markup drawing of table T27, see figures 3 and 4 above.) The table-setting crew for Table T27 included a foreman and two other employees. The crews were using a Falcon MP20G-Z7/20FT personal fall arrest system (PFAS).

Once Table T27 was placed on the floor, it needed to be leveled. The table-setting crew performed the levelling and finished anchoring the Table T27 legs. Then the foreman signaled the unhooking of the crane. Later in the afternoon, under high winds, Table T27 bounced off the floor and fell to the ground (see figures 11 to 14). While the table tumbled over, it became entangled on one of the employee's PFAS. The PFAS (see figure 15) snapped and the employee fell from the 15th level to the ground and was fatally injured. The wind gust that afternoon was over 30 mph.

Fig. 11 – After Collapse.

Fig. 12 – After Collapse.

Fig. 13 – Collapse photo. (T27 after collapse)

Fig. 14 – Collapse photo. (T27 after collapse)

Fig. 15 – Miller Falcon MP20G-Z7/20FT cable lifeline used by employees.

4. Discussion

The discussion will be limited to formwork Table T27. The table was subject to the prevailing high wind that hurled it off the 15th level along with an employee whose fall protection became entangled with the formwork table. Table T27 was different from other tables used at the jobsite in how it was shaped and how it was supported on the floor. The shape was changed in accordance with the architectural geometry. Additional supports were required due to six-feet long cantilevers on two sides of the formwork table.

Table T27 essentially consisted of two 7 ½" deep beams – 17' and 15'-6" long. Over the beams, 5 ½"deep purlins were placed perpendicular to the beams. 5/8" plywood was placed over the purlins to form the sheathing over which concrete was to be directly placed during the concrete pour. The table was assembled on the ground with legs or posts, beams and purlins. The assembly was initially done with four legs, although three additional legs (see figure 4) were to be provided later at the time of concrete pouring. The legs were braced in two orthogonal directions by bracings (see figures 9 and 10). The table with the beams, purlins, four legs, bracings and the plywood weighed approximately 2,000 pounds. The table assembly was successfully hoisted to its final location, thereafter it was levelled, and then two hold down straps with ratchet strap screws were installed near the rear legs (see figures 9, 10). The screws pulled out of the concrete (hole in the concrete slab is shown in figure 16). One screw recovered from the debris is shown in figure 17. Other screws recovered are also shown in figures 18 and 19. It is not certain where these other screws belonged.

Fig. 16 – Screw pulled out from concrete.

Fig. 17 – Wedge-Bolt Screw Anchor found in debris.

Fig. 18 – Wedge-Bolt Screw Anchor.

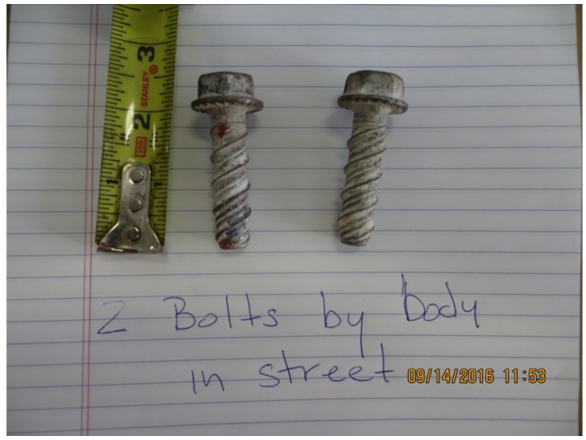

Fig. 19 – Wedge-Bolt Screw Anchor.

The incident occurred before the concrete was poured; hence, neither the three additional supports were provided or required, nor any connection with the adjoining tables were made to form a continuous sheathing for placement of concrete. At the time of the incident, the table was standing alone, independent of any lateral support from the sheathing diaphragm that was to be provided later.

The table was subjected to lateral loading causing the ratchet strap screws to become loosened and creating the uplift of the table.

The incident has highlighted several areas of deficiencies which contributed to the collapse:

1. <u>Structural adequacy of the table at the time of its placement under high winds</u>
   The table was installed on the 15th level to support the concrete to be placed on the 16th level. The top of the table was approximately 152 ft. above ground. After the table was installed, wind increased in the afternoon. Wind data obtained from the National Climatic Data Center recorded a wind speed of 23 mph, gusting to 31 mph. These wind speeds are recorded at 33 ft. above the ground. The gust wind speed is magnified many times greater as the height increases.
   A review of the available structural design indicated that the initial structural stability of the table was not considered during early phase of erection. The table placed on the 15th level must be designed to withstand loads from wind gusts, a normal occurrence in the area of the jobsite. This is particularly critical because the table is not connected to the adjoining tables to provide lateral support at the initial stage of erection. Consideration

of high winds would require additional vertical supports or diagonal bracings anchored to the floor before the crane would release the table. Our computations indicate that the wind gusts could produce uplift on the rear legs, destabilizing the table. Structural computations indicate that the table was designed for its final condition at the time of concrete placement. OSHA requires the table to be supported and braced for all loads.

2. Means of anchoring the legs to the floor

   The anchorage of the legs to the concrete floor was done in a haphazard manner. Only the two front legs were anchored; the two rear legs were not anchored. The legs were provided with four holes, but only one anchor was provided in the front legs. Instead of using the required ½" diameter bolts with a minimum embedment of 2", concrete smooth nails were used as the erection crew was reported to have run out of the bolts (see figure 20 to 23). No consideration was given to the low withdrawal capacities of smooth nails. Even the embedment of the nails in the concrete slab was questionable.

3. Failure to comply with its own "best practices"

   The table-setting crew was supposed to anchor the table to the concrete before unhooking the crane. The table-setting crew did not follow the CECO best practice document for anchoring the table to the concrete slab. The best practice document states, *"… perimeter panels must be secured to prevent movement due to wind. The preferred method is to use ratchet straps with 1/2" drop-in or cast-in anchors and a shoulder eye bolt. Consult with engineering for approval to use other methods for securing perimeter panels."*

   On the day of the incident, the ratchet straps were anchored to the concrete floor using a ½" diameter Powers wedge-bolt screw anchor with a 2" embedment, a deviation from the best practice document, see figures 24 and 25. The crews also ran out of the screws and substituted cement nails for a few tables to anchor the EZ posts (see figures 21 and 23).

4. Lack of instructions to employees erecting the formwork table

   Table T27 was different from other tables used at the site. It was distinctive because it had a six-foot of cantilever on two sides. Three additional shores were added in the PE stamped drawing F8.0 to limit the cantilever (see figures 3 and 4). The table-setting crew did not add the three additional shores, and the table was installed with a cantilever of 6 feet on two sides (see figures 4 and 26). The table setting-crew was working from an unsigned makeup drawing (see figure 5) where the additional shores were not shown. CECO did not design the formwork and its anchoring system for different phases of construction. The field crew did not have proper coordination with the design drawings. The crew did not have proper instructions for anchoring the tables. CECO did not check the stability of the individual tables at different stages.

5. Fall protection arrest system

   The table-setting crew was wearing a self-retracting Miller Falcon MP20G-Z7/20FT cable lifeline. According to the Miller Falcon website, the lifeline wire rope for this Personal Fall Arrest System (PFAS) was 7x19, 3/16" in diameter. The maximum working load is 310 pounds and maximum arresting force is 900 pounds. The wire rope catalog states that the breaking strength of a 7x19 galvanized wire rope is 4,200 pounds. The deceased employee's self-retracting lifeline got entangled with the falling Table T27 weighing approximately 2,000 pounds severing the 3/16" wire rope (see figures 27 to 29).

   Two employees anchored their fall protection arrest system to the bracings of the nearby formwork tables (see figures 30 and 31) without ascertaining the capacity of the bracings to withstand a force of 5,000 pounds. The formwork tables were not properly designed to resist lateral loading and the legs were not anchored properly.

The contractor was responsible for ensuring the stability of the formwork tables during installation.

29 CFR 1926.703(a)(1) states "*Formwork shall be designed, fabricated, erected, supported, braced and maintained so that it will be capable of supporting without failure all vertical and lateral loads that may reasonably be anticipated to be applied to the formwork. Formwork which is designed, fabricated, erected, supported, braced and maintained in conformance with the Appendix to this section will be deemed to meet the requirements of this paragraph*."

29 CFR 1926.703(b)(6) states *"All base plates, shore heads, extension devices, and adjustment screws shall be in firm contact, and secured when necessary, with the foundation and the form"*.

In 1926.703(a)(1), the industry standard referenced in the Appendix is ANSI A10.9-1983 (non-mandatory). In ANSI A10.9-1983:

Section 7.1.1 states *"Formwork shall be designed, fabricated, erected, supported, braced and maintained so that it will support all vertical and lateral loads (see 7.3.3) that may be applied until such loads can be supported by the structure."*

Section 7.4.5 states *"Forms being raised or removed in sections shall not be released until braced or secured. Personnel shall be prohibited from riding forms being moved or suspended from hoisting devices, except slip forms designed for that purpose."*


Fig. 20 – EZ post anchoring.


Fig. 21 – EZ post anchoring with nails.


Fig. 22 – EZ post anchoring. (no screws)


Fig. 23 - EZ post anchoring. (see the nail)


Fig. 24 – Ratchet Strap anchoring.


Fig. 25 – Ratchet Strap anchoring.

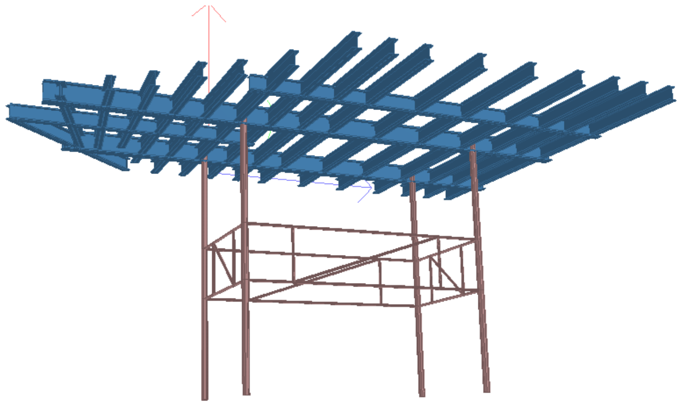

Fig. 26 – 3D model of Table T27. (see the front and side overhangs)

Fig. 27 – Snapped PFAS.

Fig. 28 – Snapped PFAS.

Fig. 29 – Snapped PFAS.

Fig. 30 – PFAS tied to the bracing of a table.

Fig. 31 – PFAS tied to the bracing of a table.

5. Conclusions

1) The formwork table failed because of the inadequate fastenings of the formwork legs at their bases, and lack of continuity of the sheathing at the top of the formwork to provide a diaphragm to resist lateral loads. The lateral loads arose from the gust of high winds approximately 150 ft. above the ground.

2) The 16 ft. x 12 ft. formwork table was unsymmetrical, and had 6 ft. cantilever projections on two sides due to architectural requirements. The gust of wind produced an uplift force on the rear legs, bouncing the formwork off the floor.

3) CECO neither checked the stability of the formwork nor designed the formwork for different phases of construction – a grievous error.

4) The deceased employee's self-retracting fall protection's wire rope became entangled with the falling formwork and severed the 3/16" wire rope thus resulting in his death.

5) CECO failed to follow its own best practices for securing the formwork legs to the concrete floor.

6) Two employees anchored their fall protection arrest equipment to the bracings of the formwork table without ascertaining the capacity of the bracings to withstand a force of 5,000 pounds or maintain a safety factor of two.