Investigation of the August 5, 2002, Collapse of Tilt-Up Precast Concrete Wall Panel In Greensboro, NC

U.S. Department of Labor
Occupational Safety and Health Administration
Directorate of Construction

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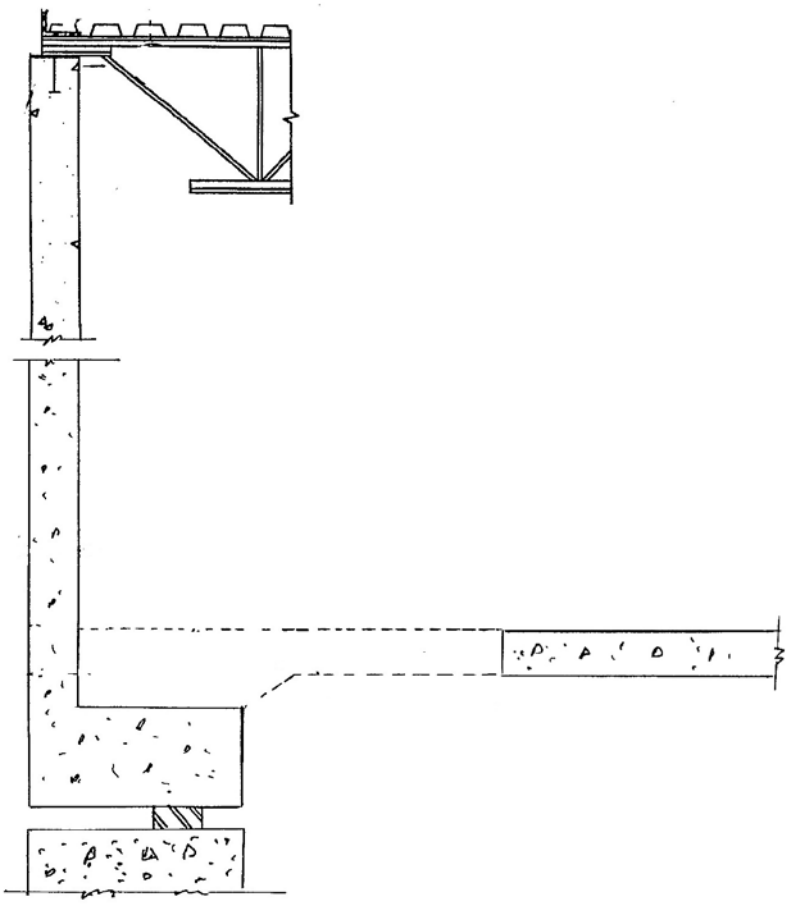


REPORT

Investigation of the August 5, 2002, Collapse of Tilt-Up Precast Concrete Wall Panel In Greensboro, NC

Report prepared by
Mohammad Ayub, PE
Dinesh Shah, PE

Report

Introduction:

The incident occurred on Monday, August 5, 2002 at about 11:30 AM in Greensboro, NC when a tilt-up concrete wall, weighing approximately 40,000 pounds, suddenly fell over three workers eating their lunch in the shade of the wall on a hot day. Approximately two hours earlier, the tilt-up wall sub-contractor, at the direction of the tilt-up wall contractor, had removed the pipe braces of the tilt-up wall, based on the report from the Testing Agency that the welds between the roof joists and the embed steel plates of the wall have been completed. As the welds were reportedly completed, the tilt-up contractor determined the braces to be redundant and hence removed them, though the bottom of the wall was not structurally supported (figure 3). There were shims placed under the wall at each end of the panel. As will be discussed later in this report, the Testing Agency's report was flawed because, in fact, the welds were not properly done and were ineffective in providing any lateral support to the wall at the top. There were no lateral supports of the wall at the bottom except for the friction between the concrete and the shims. At the bottom, the wall was neither tied to the slab on grade nor grouted over the foundation wall.

The failed wall was part of the perimeter of the building for Home Depot Store (figures 1, & 2), under construction at 2912 South Elm-Eugene Street, Greensboro, NC. The structure is comprised of steel framing with steel columns, steel joist girders and joists. The joists of the exterior bays were supported over the tilt-up wall panels. The panel in question was 6 ½" thick, approximately 23 feet high and 20 feet wide. It was supported over the foundation wall over shims at each end. The adjoining panels on either side of the failed panel were of similar construction and were also supported on shims. Later, the space between the tilt-up wall and the foundation wall was to be grouted with high strength grout; and the tilt-up wall panel was to be connected to the slab on grade by a closure strip i.e. comprising of the last 4' of the slab on grade (figure 3). At the top of the wall, there were three steel plates embedded in the wall to support the steel joists. The embedded steel plates were 6 ½" x 12" x ¼".

Field observation and measurements:

Wall:

The wall fell on the west side. It was saw cut in two pieces of 18'-l" and 4'-11" during the rescue phase. The wall measured 19'-7 5/8" in width and 23' in height. The thickness was measured to be 6 ½". See attached field measurements and shop drawing of the panel (figures 3, 4, & 5). No discrepancy was noted in the fabrication of the panel. The embed plates were measured to be 6 ½" x 12" x ¼", as called out on the contract drawings.

Embedded plates:

The three embed plates (figure 4, section E) were examined to determine whether or not any welding was done. The north embed plate shows a ½" long tack weld on the north side and a 1 ½" long weld in the north-south direction. Please note that the welds were to be made in the east-west direction along the seat of the joist. The middle embed plate did not exhibit any weld.

The south embed plate showed a weld in the east-west direction but only on one side, i.e., on the south side. This weld did not indicate any failure. In addition, there was a deposit of weld at a corner of the plate, which was away from the bearing of the joist (figure 4, section E).

The three corresponding joist bearings were then examined. The joist bearing on the north end of the wall did not exhibit any significant remnant of the weld. It is therefore concluded that the tack weld seen on the north embed plate had no structural significance. The middle joist bearing angles were void of any welds. This observation corresponded with the findings of the middle embed plate. The south joist indicated that the north end of the bearing angles was welded. The south end of the bearing was observed to be clean. It is interesting to note that the south embed plate indicated welds on the south side where as the joist bearing angles showed welds on the north side. It is believed that the welder had at one time welded the joist at a location corresponding to the welds on the embed plate but later "burned" them. It appears that the joist bearing was later moved a few inches, and the welding at the new location was not completed.

Interestingly, it was reported that immediately after the failure, the welders were noticed welding the joists on the panels on either side of the failed panel, while rescue was still going on. It is strongly suspected that the adjoining panels were also not welded.

Shims:

The number of shims placed under the failed wall could not be ascertained as they were scattered around. However, the shims placed under the panel north to the failed panel indicated that there were only three shims placed under the wall. Two were placed on the north end and only one was placed on the south end.

Grout:

The structural drawings called for 1" grout between the underside of the tilt-up wall and the top of the foundation wall (figure 2, section B). However, field observation indicated that the space for the grout varied from 2" to 4". This indicates that the construction of the concrete foundation wall was not done as per the standard practice in accordance with the contract drawings. In addition, the contractor did not grout the space beneath the panel soon after the erection of panel wall as recommended by the Tilt-Up Design and Construction Manual of Tilt-up Concrete Association (attachment C, page 2).

Stability of the wall:

The wall derives its stability from the roof and floor diaphragm, after the construction is completed. Until such time, temporary braces are provided to prevent collapse and failure. In this case, the tilt-up wall contractor was provided with the information (attachment A) from the Testing Agency that led him to believe that the top permanent connections have been made. The bottom connection was, however, not completed as the contractor had yet to finish casting the last strip of the slab on grade, which was to tie the wall to the horizontal diaphragm. Besides, the grout underneath the wall was not placed. The only support available to the wall at the bottom was the shims without any positive connection either to the wall or to the foundation wall. The

friction between the shims and the concrete wall cannot be relied upon to provide stability to the wall, as there were no positive connection between the shims and the wall, and shims were subject to movements. Field observations of the two impressions left on the underside of the failed tilt-up wall panel indicated that shims were not placed directly under the wall but under the cantilevered heel of the panel. Therefore, when the temporary braces were removed, the shims did not provide even a minimal degree of stability to the wall, and failure occurred soon thereafter.

The contract specification on erection, LA-l2l-5619-00, Part 3, Section 3.06, Paragraph G, Note S (attachment D) states *"provide adequate bracing until all structural steel, purlins, beams, joist and deck is placed, backfill placed and floor slab leave out placed."*

North Carolina OSH standard 1926.704 (a) states *"Precast concrete wall units, structural framing, and tilt-up wall panels shall be adequately supported to prevent overturning and to prevent collapse until permanent connections are completed."*

American National Standard, ANSI AlO.9-83, Section 9.4 states *"Precast concrete wall units, structural framing, or tilt-up wall panels shall be braced until permanent connections are completed."*

The Tilt-Up Design and Construction Manual of Tilt-up Concrete Association (attachment C, page 4) states that the temporary braces should be removed *after the roof structure and floors have been connected to the wall so that the permanent lateral bracing system is operational.*

The General Notes of contract drawing Sl.0 on Tilt-Up panels, note 10 (attachment B) states *"…The contractor is solely responsible for providing all necessary bracing as required for construction loads, for stability, and for resistance to wind and seismic forces until the entire structure is complete. …"*

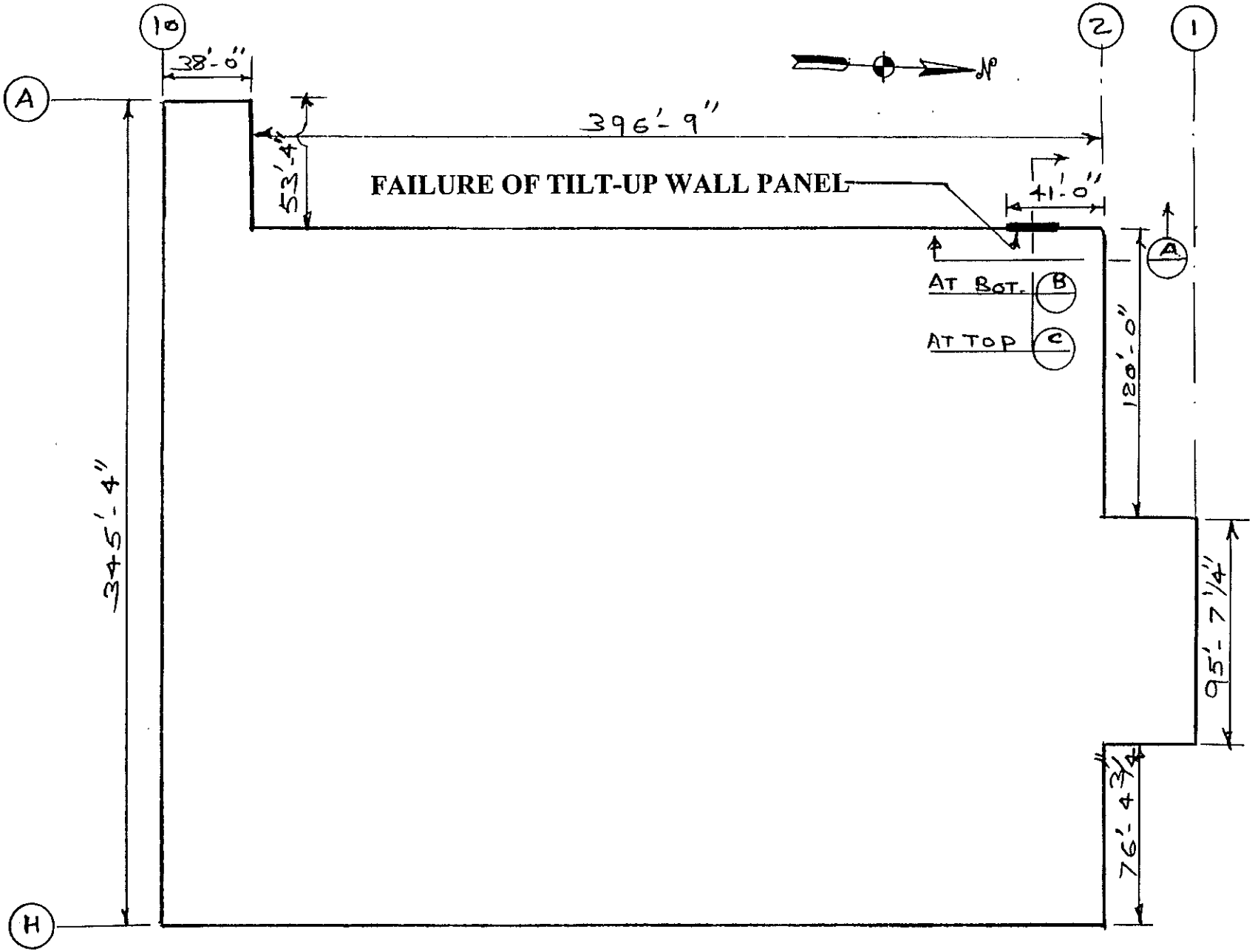
Conclusion:

1. The failure occurred because the contractor prematurely removed the temporary braces of the tilt-up wall panel before permanent connections at the top and bottom of the panel were made. This was a violation of the contract specification, North Carolina OSH Standard, ANSI Standard, and tilt-up wall industry standards.

   The stability of the wall is derived from the connection between the wall and the roof joists, and between the wall and slab on grade or foundation wall. The temporary bracing must only be removed after **all** permanent connections are completed i.e. grout placed under the panel, closure strip of the slab on grade cast, and the connections at the top of wall completed.

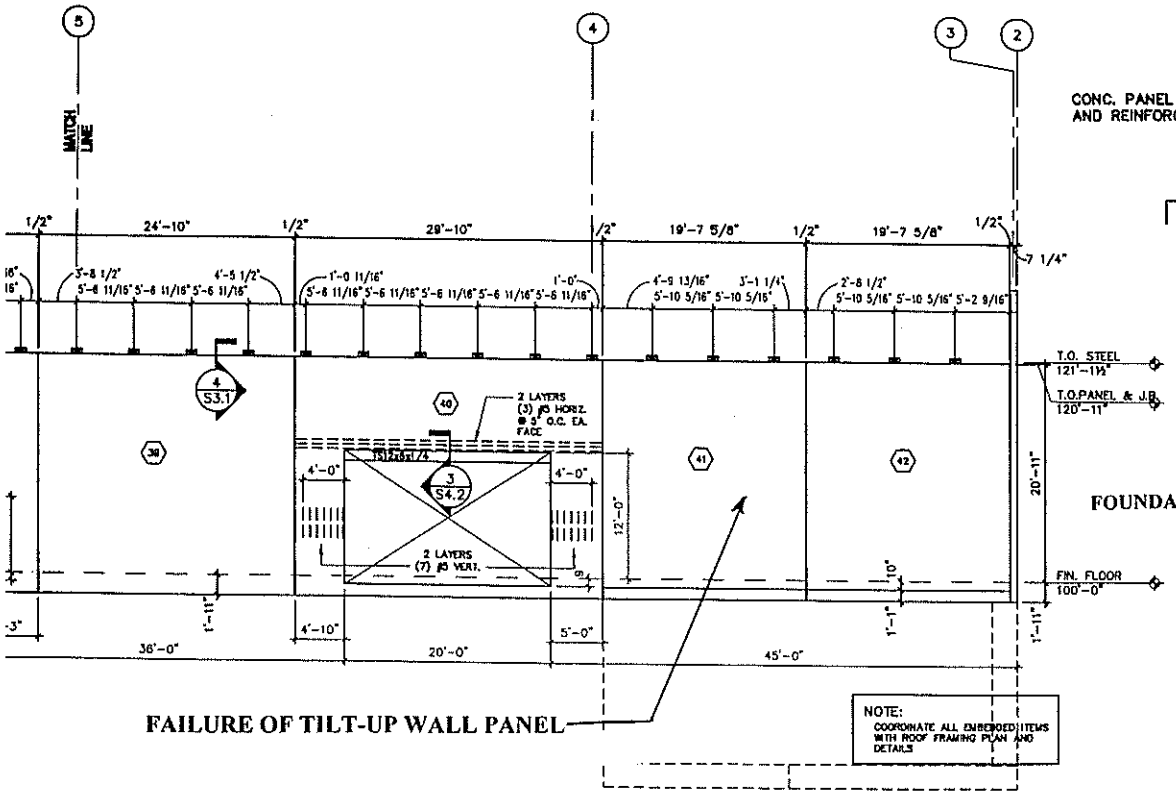
2. The Testing Agency erred in providing a report that the welded connections between the wall and the joists have been completed. This is not supported by the facts discovered after the failure.

3. The tilt-up contractor did not construct the foundation wall as per the construction documents. Instead of 1”, the space of the grout was observed to be to 2 to 4”. Further, the location of the shims under the wall did not follow any uniform pattern. In addition, the contractor did not grout the space beneath the panel soon after the erection of panel wall as recommended by the Tilt-Up Design and Construction Manual of Tilt-up Concrete Association.



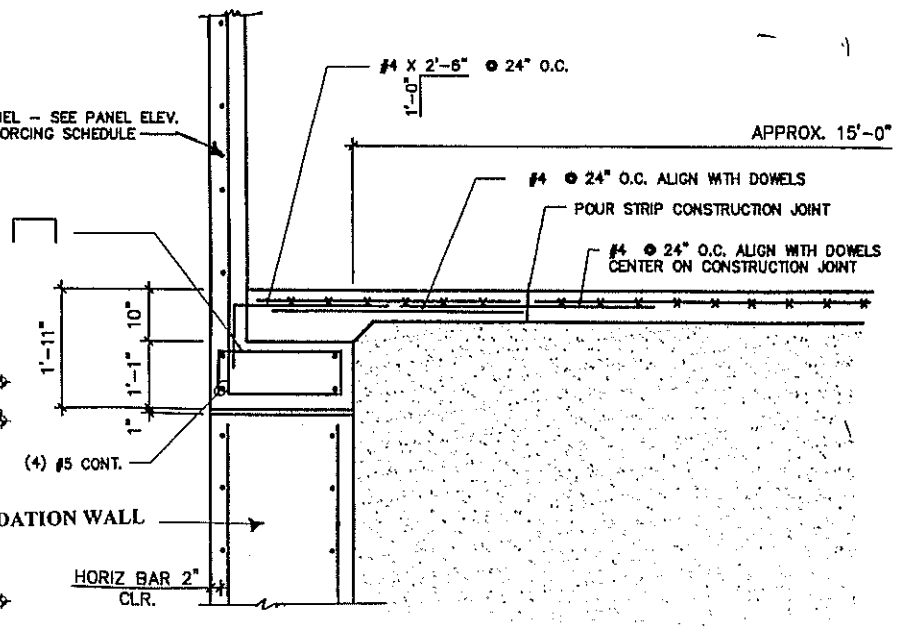
SCHEMATIC PLAN (BOUNDARY OF TILT-UP CONCRETE WALL PANEL)

FIGURE 1

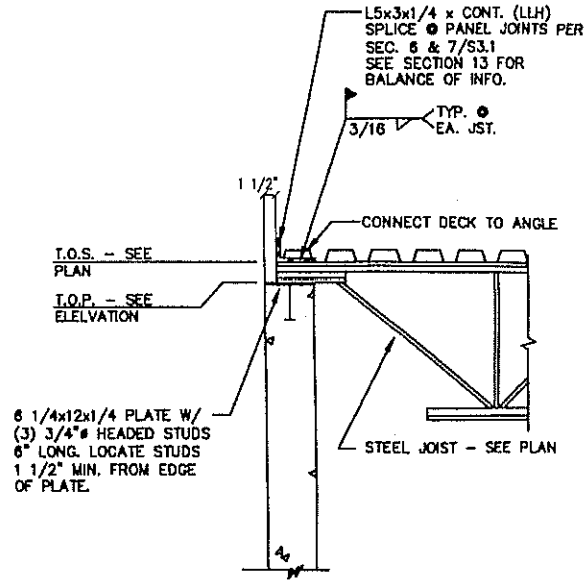


FAILURE OF TILT-UP WALL PANEL

TILT-UP WALL PANEL ELEVATION A-A



SECTION B (AT BOTTOM OF TILT-UP PANEL)



SECTION C (AT TOP OF TILT-UP PANEL)

FIGURE 2

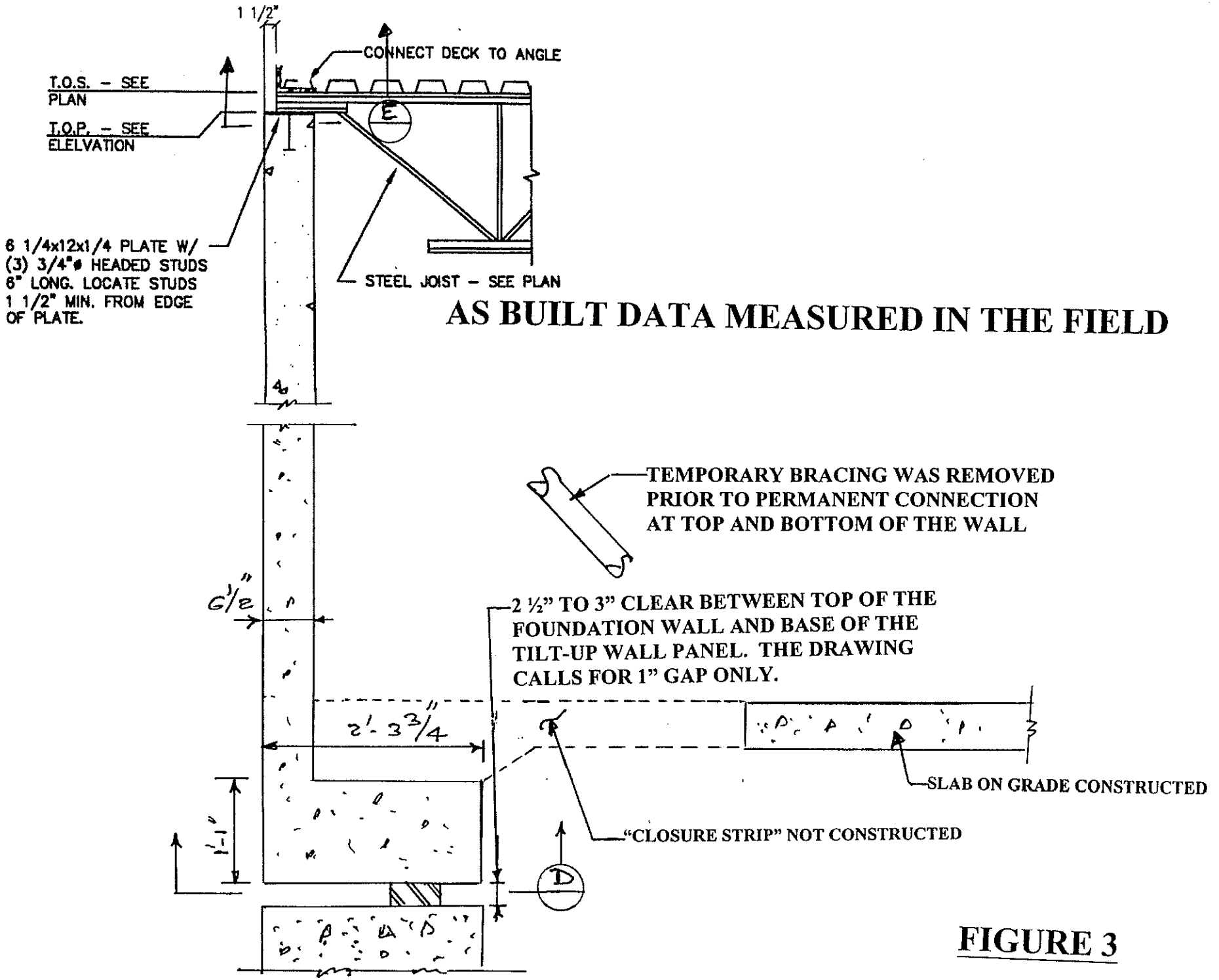
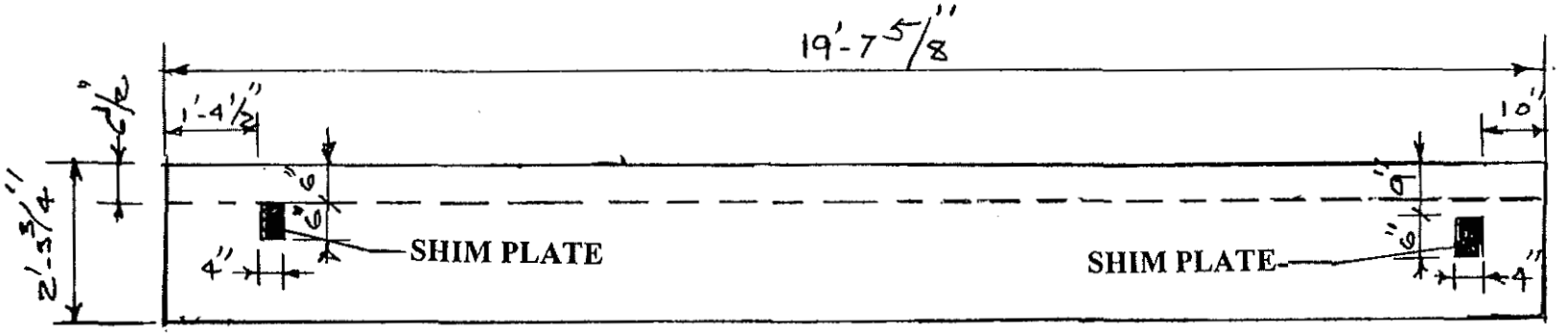
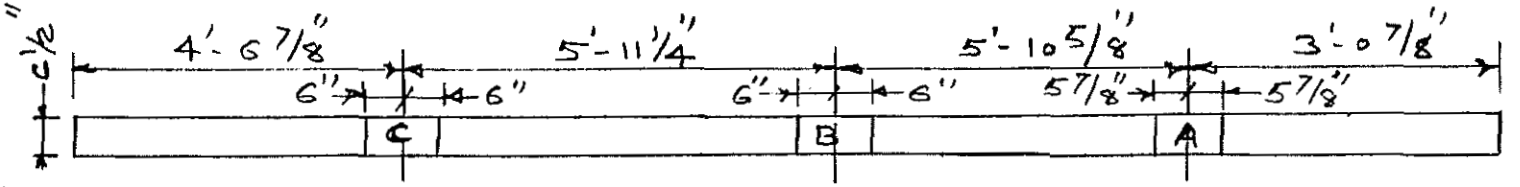

1 1/2"
CONNECT DECK TO ANGLE
T.O.S. – SEE PLAN
T.O.P. – SEE ELELVATION
E
6 1/4x12x1/4 PLATE W/ (3) 3/4"ø HEADED STUDS 6" LONG. LOCATE STUDS 1 1/2" MIN. FROM EDGE OF PLATE.
STEEL JOIST – SEE PLAN
AS BUILT DATA MEASURED IN THE FIELD
TEMPORARY BRACING WAS REMOVED PRIOR TO PERMANENT CONNECTION AT TOP AND BOTTOM OF THE WALL
6 1/2"
2 ½" TO 3" CLEAR BETWEEN TOP OF THE FOUNDATION WALL AND BASE OF THE TILT-UP WALL PANEL. THE DRAWING CALLS FOR 1" GAP ONLY.
2'-3 3/4"
SLAB ON GRADE CONSTRUCTED
"CLOSURE STRIP" NOT CONSTRUCTED
D

FIGURE 3



SECTION D (SHIM PLATE LOCATION AT BOTTOM OF TILT-UP PANEL)

FIGURE 4



SECTION E (1/4" THK EMBED PLATE LOCATION AT TOP OF TILT-UP PANEL)

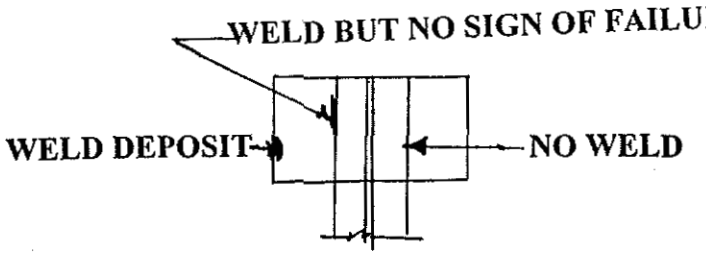


PLATE "C"

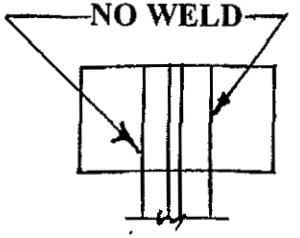


PLATE "B"

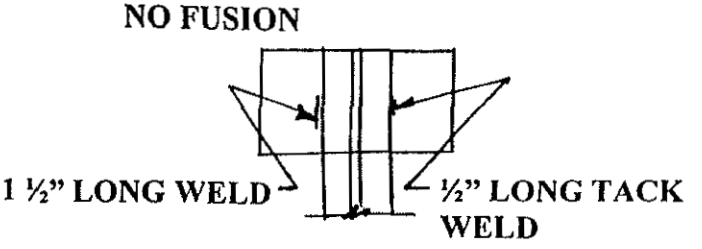


PLATE "A"

BRACE TO:	NO. REQ'D:	L:	X:	BRACE LOAD:	DEADMAN LOAD:
FF	2	17.00'	8.50'	3442 lbs.	1721 lbs.

P41

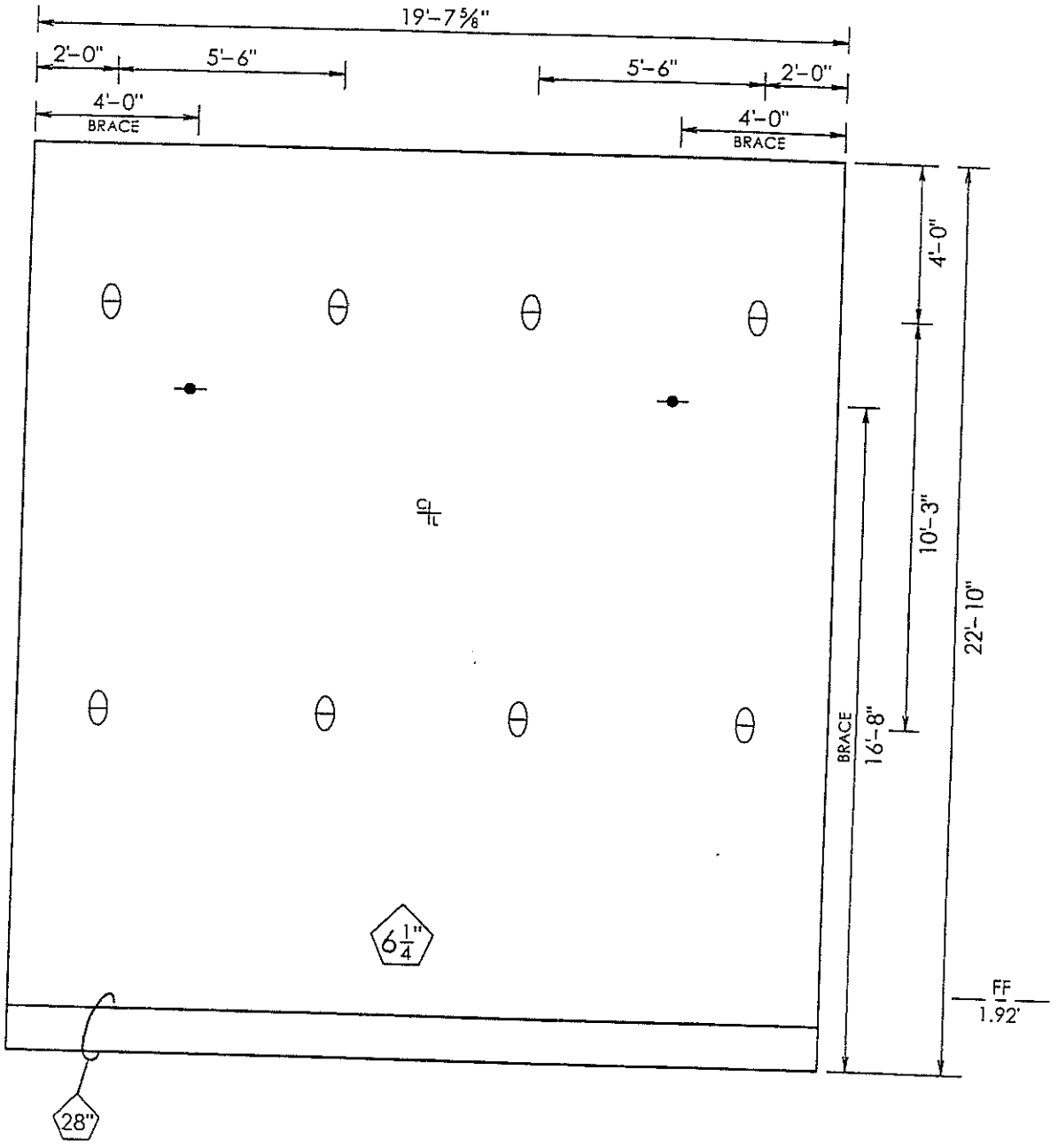


FIGURE 5

LENGTHS:	MAJOR SPREADER BAR:		LEFT MINOR SPREADER BAR:		RIGHT MINOR SPREADER BAR:		SEE SPECIAL DETAILS:
UPPER MINOR:	LFT: 5.07 '	RT: 5.07 '	LFT: 2.75 '	RT: 2.75 '	LFT: 2.75 '	RT: 2.75 '	

BURKE	CGX: 9.82'	CGY: 9.88'	CLY: 13.70'	P: 28.4 K	AREA: 448.4 SF	VOLUME: 10.1 CY	WEIGHT: 39.44 K
ERING	CHK'D BY:	DRAWN BY: ML	DATE: 5/20/2002	TITLE: HOME DEPOT # 3651	JOB #: TAM2413CHA	SHEET: 36	OF:

Client: home depot

**Project: Home depot / south elmn eugene st.
Greensboro, North Carolina**

Date: August 3, 2002

PSI#

Remarks: on August 3, 2002 PSI inspector Dennis Campbell reported to the above referenced project as requested. This visit was for visual inspection of structural steel. Listed be low are the results of this visit.

Area of inspection: Lines 1 to 12, A to H

Ground floor:

Anchor bolts- meets requirements, for snug tight. (Note) base plates have not been grouted at this time

Roof framing:

Joist-to-Joist girder- meets requirements

Joist to embeds- meets requirements

Roof deck- meets requirements

Lap screws- installed as required

Bridging- tie inns to wall - in process not ready for inspection

Intermittent joist bottom cord to stabilizer plates- not installed at this time

Joist girder bottom cord brace - complete meet requirements.

Garden center:

Beams to embed- welding in process

Joist to beams- welding complete.

Bridging- horizontal bridging installed as required. X bridging have not been tightened at this time.

Diagonal angle not installed at this time

Inspectors: Dennis Campbell CWI#89040101

Client: home depot

**Project: Home depot / south elmn eugene st.
Greensboro, North Carolina**

Hand Delivered 8/6/02

Date: August 2, 2002 **PSI#**

Remarks: on August 2, 2002 PSI inspectors Tim Rissel and Dennis Campbell reported to the above referenced project as requested. This visit was for visual inspection of structural steel. Listed be low are the results of this visit.

Area of inspection: Lines 1 to 12, A to H
Ground floor:
Anchor bolts- meets requirements

Joist-to-Joist girder- meets requirements

Joist to embeds- meets requirements

Roof deck- several welds did not meet the requirements lines 7 to 1, A to H these were marked with red paint.

Lap screws- in process lines 7 to 1, A to H. A small area in the 7 to 8 area these were marked with a red "S"

Bridging- tie inns to wall - in process not ready for inspection

Intermittent joist bottom cord to stabilizer plates- not installed at this time

Joist girder bottom cord brace - in process not ready for inspection

Garden center- erection in process

Inspectors: Tim Riesel
Dennis Campbell CWI#89040101

GENERAL NOTES: (REFERENCE DRAWING S1.0)

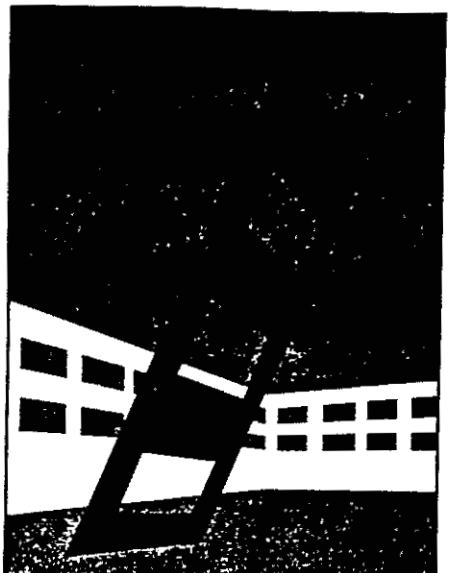
TILT-UP PANELS:

1. CONCRETE FOR TILT-UP PANELS SHALL HAVE A 28 DAY COMPRESSIVE STRENGTH OF 4000 P.S.I. AND A DENSITY OF 145 P.C.F.
2. REINFORCING SHALL CONFORM TO ASTM A615, GRADE 60, UNLESS NOTED OTHERWISE.
3. MINIMUM CONCRETE COVER FOR REINFORCING STEEL FOR TILT-UP PANELS SHALL BE 3/4 INCH U.N.O.
4. FABRICATOR OF TILT-UP PANELS SHALL BE RESPONSIBLE FOR THE DESIGN OF ALL LIFTING HARDWARE AND FOR THE DESIGN OF TILT-UP PANELS FOR LIFTING STRESSES AND SHALL PROVIDE LIFTING INSERTS AND ANY ADDITIONAL REINFORCING STEEL REQUIRED FOR LIFTING PANELS INTO PLACE. THE FABRICATOR'S ENGINEER SHALL SIGN AND SEAL ALL SHOP DRAWINGS FOR THE TILT-UP PANELS AND LIFTING DESIGN DRAWINGS.
5. FABRICATOR SHALL BE SOLELY RESPONSIBLE FOR PROVIDING ANY ADDITIONAL REINFORCING STEEL FOR THE MANUFACTURE, HANDLING, STORAGE, TRANSPORTATION AND ERECTION OF ALL TILT-UP PANELS. REINFORCING STEEL SHOWN ON THE PLANS REPRESENTS THE MINIMUM ACCEPTABLE QUANITY FOR ERECTED INPLACE - PANELS.
6. CONCRETE PANELS SHALL NOT BE LIFTED UNTIL THE TILT-UP PANELS HAVE ATTAINED A MINIMUM STRENGTH AS DETERMINED BY THE LIFT DESIGN PROFESSIONAL AND A MINIMUM OF 72 HOURS CURING FROM THE TIME OF CONCRETE POUR. MAKE JOB CURED CYLINDERS AT THE CONTRACTORS'S EXPENSE TO VERIFY LIFTING STRENGTH.
7. TILT-UP PANELS SHALL BE LIFTED AND SUPPORTED DURING MANUFACTURING. STOCKPILING, TRANSPORTATION, AND ERECTION OPERATIONS ONLY AT THE LIFTING OR SUPPORT POINTS, OR BOTH AND ONLY WITH THE LIFTING DEVICES EMBEDED IN THE MEMBERS BY THE FABRICATOR.
8. THE FABRICATOR, ERECTOR AND GENERAL CONTRACTOR OF THE TILT-UP PANELS SHALL NOT ALLOW ANY VEHICULAR TRAFFIC ON CERTIFIED PAD OR SLAB - SEE NOTE ON FDN. PLAN. ANY CRACKING OR DAMAGE TO THE FLOORS CAUSED BY ERECTION EQUIPMENT, CONCRETE TRUCKS, ETC. WILL REQUIRE REMOVAL AND REPLACEMENT OF THE DAMAGED OR CRACKED AREAS AT NO ADDITIONAL COST TO THE OWNER.
9. ALL DEPRESSIONS, BLOCK-OUTS, COLUMN DIAMONDS, JOINTS, ETC. IN FLOOR SLABS THAT ARE TO USED FOR CASTING PANELS SHALL BE FILLED WITH LEAN CONCRETE OR GRANULAR FILL AS REQUIRED SO AS TO DEVELOP A SMOOTH UNIFORM FINISH FOR ENTIRE PANEL. REMOVE ALL LEAN CONCRETE AND GRANULAR FILL AFTER PANEL CASTING OPERATION IS FINISHED.
10. TILT-UP PANELS HAVE BEEN DESIGNED TO SPAN VERTICALLY AS SIMPLE SPANS FROM FLOOR TO ROOF AND ARE DEPENDENT UPON THE COMPLETED ROOF STRUCTURE, METAL ROOF DECK, AND COMPLETION OF ALL WALLS FOR STABILITY AND FOR RESISTANCE TO WIND AND SEISMIC FORCES. THE CONTRACTOR IS SOLELY RESPONSIBLE FOR PROVIDING ALL NECESSARY BRACING AS REQUIRED FOR CONSTRUCTION LOADS, FOR STABILITY, AND FOR RESISTANCE TO WIND AND SEISMIC FORCES UNTIL THE ENTIRE STRUCTURE IS COMPLETE. THE SHORING SHALL NOT RELY ON ANY MOMENT RESISTANCE CAPACITY OF THE FOOTINGS.

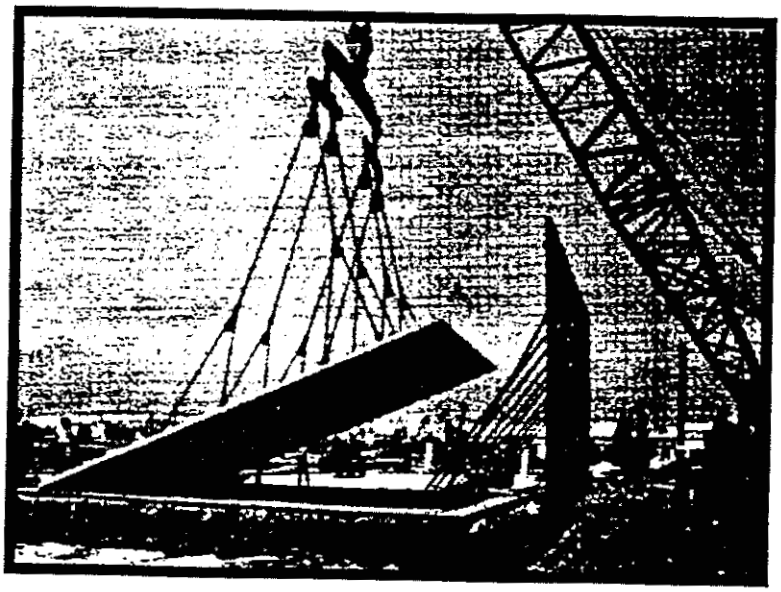
Fifth Edition

The Tilt-Up Design and Construction Manual

Hugh Brooks
Civil and Structural Engineer



A COMPREHENSIVE REFERENCE MANUAL FOR TILT-UP DESIGN AND CONSTRUCTION



- Totally Revised and Updated Structural Section
- New Tilt-up Building Photographs
- Updated and Easy-to-Use Supplier Section
- Updated Introduction with New Facts and Figures

TCA®
TILT-UP CONCRETE ASSOCIATION

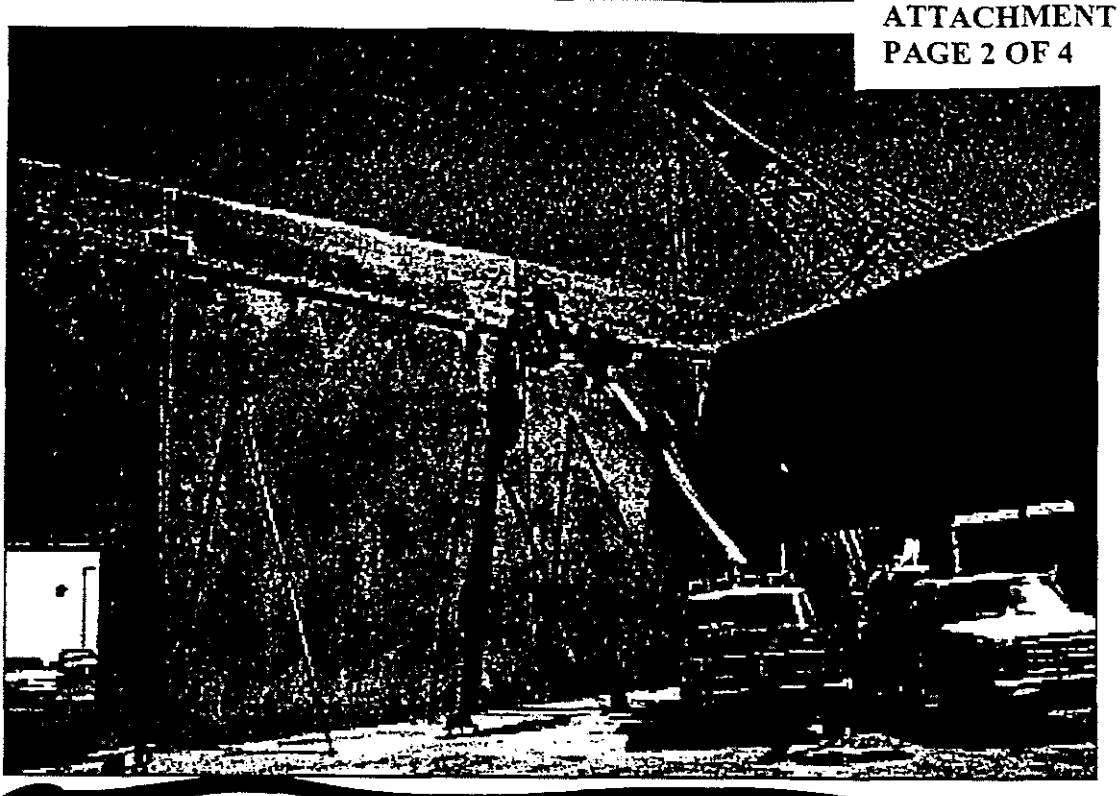


Figure 8.1
Welding larger splices

Grout the Space Beneath the Panels

This should be done as soon as possible after the panels have been erected to prevent settlement of the footing and to reduce shrinkage cracks at the lower corners of the panels (due to the panel shrinking between constraining setting pads).

The space beneath the panel is usually 1-1/2" (38 mm), and should be filled solidly with grout for full bearing under the full length of the panel. Use a low-slump grout mix. This can be placed from the chute of a ready-mix truck as it circles the building. A vibrator is recommended to assure good penetration under the panel. Complete penetration of the grout is evidenced by the grout emerging from the opposite side of the panel. For an illustration of this operation, see Figure 8.2.

Place the Closure Strip

The closure strip of concrete ties the panel to the floor slab. First backfill the space with sand or compacted fill soil. Place strips of building paper over the joints between panels to prevent dirt and concrete from oozing through. If the depth of the backfill is more than a few feet the dowels projecting from the panel should be tack welded to those extending from the floor slab into the closure strip. This will prevent the wall from pushing out from the pressure exerted by the backfill. Then place the concrete. The closure strip should be finished and cured the same as the floor slab, and crack control joints should be sawed to match those in the floor. See Figure 8.3.

Figure 8.2
Grouting under panels

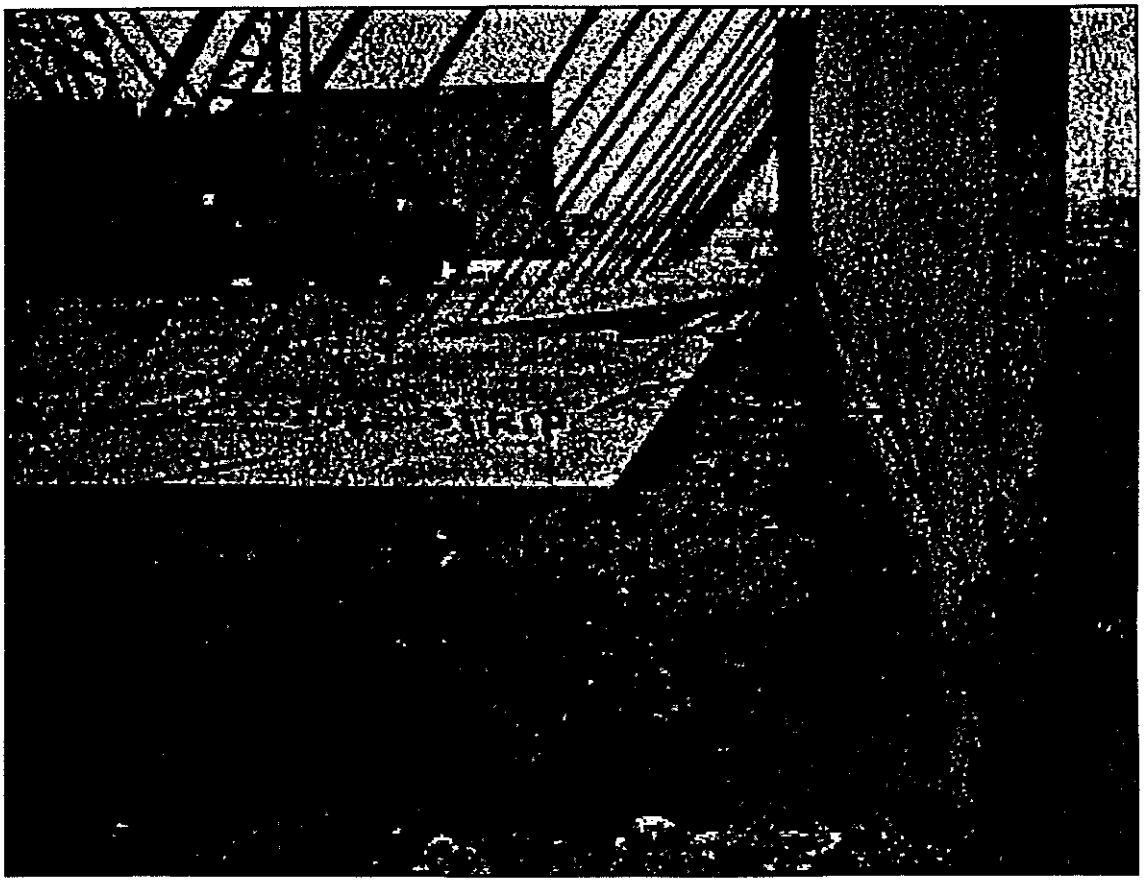
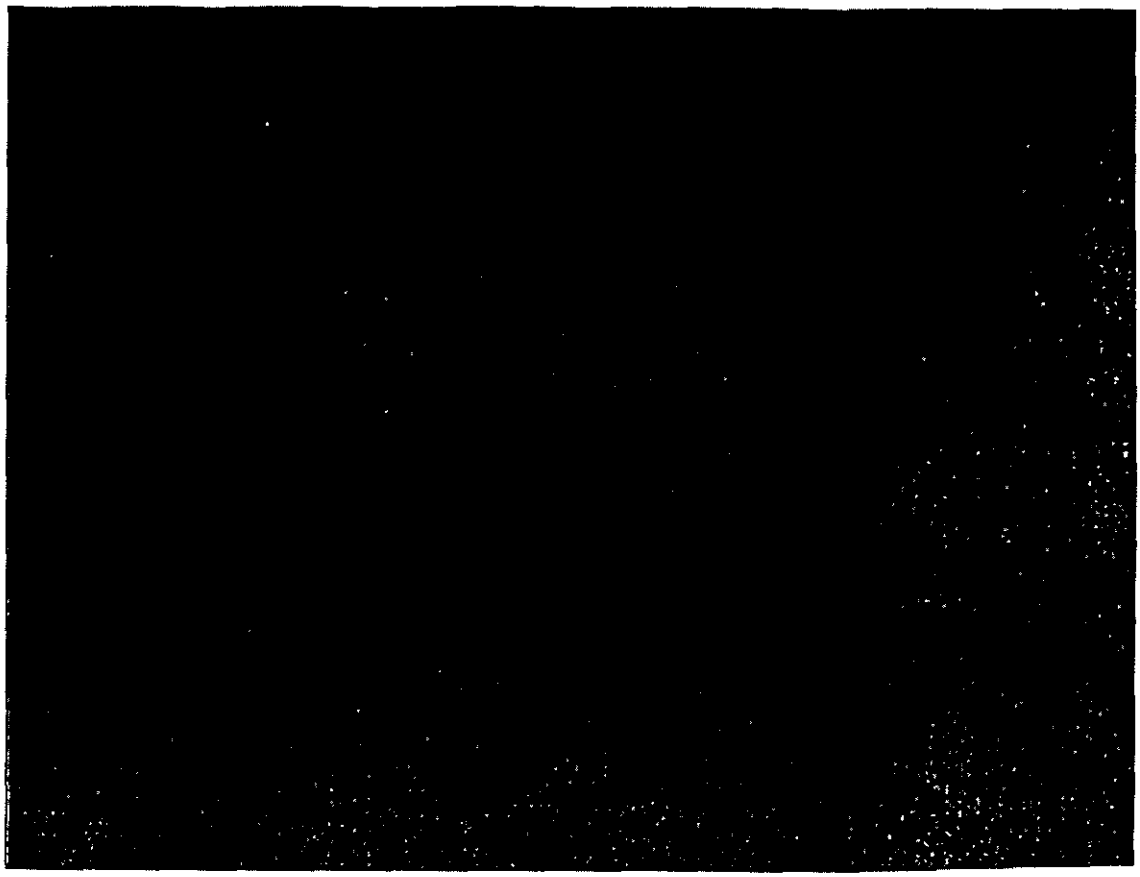


Figure 8.3
Closure strip awaiting backfill

It is important to compact the backfill. Loosely placed backfill can cause the slab to crack, particularly at doors subject to forklift traffic.

At door openings, the closure strip is slightly depressed at the opening so water will drain.

Figure 8.4
Concrete placement at interior columns



At this time also pour interior column blockouts. See Figure 8.3.

Removing Formliners

Plastic formliners can usually be easily removed by prying them loose. They should have been sprayed with bond breaker to facilitate this. Foam plastic formliners can also be pried off but often require water blasting to completely remove them. See Figure 8.5.

Remove the Temporary Braces

This should only be done after the roof structure and floors have been connected to the wall so that the permanent lateral bracing system is operational.

D. Finish

1. All exposed concrete edges shall be chamfered at edges. Chamfer to be 3/4".
2. All faces shall be true, well defined surfaces. Warped, cracked, broken, spalled, stained or otherwise defective units will be rejected.
3. Exterior face of panels shall be cast down to avoid the appearance of lifting devices on the exterior panel surface. Panel finish shall be smooth and clean, ready to receive specified finish.
4. Interior face to have light broom finish. Panels shall be clean and ready to receive specified finish.
5. Curing compounds and bondbreakers which are not compatible with the specified finish shall be removed from the tilt-up panels.

E. Casting Tolerances

1. Overall height and width:
   a. 10 feet or under: ± 1/8"
   b. 10 feet to 20 feet: + 1/8" and - 3/16"
   c. 20 feet to 30 feet: + 1/8" and - 1/4"
   d. Each additional 10 feet: ± 1/16" per 10 ft.
2. Angular deviation of plane of side mold: 1/16" per 6" depth, but at least 1/16".
3. Thickness: + 1/4" and - 1/8"
4. Openings: ± 1/4"
5. Out of square (difference in length of the two diagonals) 1/8" per 6 feet or 1/4" total, whichever is greater.
6. Bowing and warpage tolerance: 1/360 of panel dimension.

3.06 ERECTION

A. Erector Qualifications: Have at least two years of successful experience in erection of tilt up wall panels, similar to size and amount as required for this project.

B. Concrete panels shall not be lifted until the tilt-up panels have attained a minimum strength as determined by the lift design professional and a minimum of 72 hours after completion of pouring of the concrete. Contractor shall make job cured cylinders at the Contractor's expense to verify lifting strength.

C. Tilt-up panels shall be lifted and supported during manufacturing, stock piling, transporting and erection operations only at the lifting or support points, or both and with the lifting devices embedded in the members by the fabricator.

D. Fabricator shall be solely responsible for providing any additional reinforcement steel for the manufacturer, handling, storage, transportation and erection of all tilt-up panels. Reinforcement steel shown on the plans represents minimum acceptable quantity for erected in-place panels.

E. Transportation, site handling and erection shall be performed with acceptable equipment and methods, and by qualified personnel.

F. Prior to erection, check all bearing surfaces for elevation, alignment and location. Report any discrepancies to the Architect of Record for correction. Proceeding with erection implies acceptance of existing conditions.

G. Erection shall include, but not be limited to:

1. Placing, aligning and leveling the members in final position in the structure.
2. All shims and grouting of panels to bring to proper elevation and alignment.
3. All anchors, clip angles, plates, bolts, fastening devices, etc., to anchor wall panels to structural steel. All anchorage devices shall be removable, shall permit movement caused by thermal stresses and shall be subject to the approval of the Architect of Record.
4. Remove any lifting hooks.
5. Provide adequate bracing until all structural steel, purlins, beams, joist and deck is placed, backfill placed and floor slab leave out placed.
6. All channels, angles, clips, etc., below grade, shall be encased in 3" of concrete.

H. Damaged units:

1. Any members superficially damaged during erection shall be rejected or shall be repaired by experienced workmen if approved by the Architect of Record.
2. Units badly damaged shall be rejected and shall be replaced by the manufacturer.
3. The Architect of Record shall be the sole judge of this damage and repair.

I. Erection tolerances:

1. Face width of joint
   a. Panel dimension (normal to joint) 10 ft.: ± 3/16".
   b. Panel dimension (normal to joint) 10 ft. to 20 ft.: +3/16 and -1/4".
   c. Each additional 10 ft.: ± 1/16".
2. Panel alignment: 1/4". (Maximum difference in any direction between adjacent panels).
3. Location of openings: ± 1/4".

3.07 CURING AND PROTECTION

A. Beginning immediately after placement, tilt-up panels shall be protected from premature drying, excessively hot or cold temperatures, and mechanical injury, and shall be maintained with minimal moisture loss at a relatively constant temperature for the period necessary for hydration of the cement and hardening of the concrete.

B. For concrete surfaces not in contact with forms, apply curing compound immediately after completion of placement and finishing. The compound shall be applied in accordance with the recommendations of the manufacturer immediately after any water sheen which may develop after finishing has disappeared from the concrete surface. For any surface against which additional concrete or other material is to be bonded or finish applied, unless it is proven that the curing compound and/or bondbreaker will not prevent bond and is compatible with the finish, positive measures shall be taken to remove it completely from areas to receive bonded applications or finish.

C. Temperature, Wind, and Humidity

1. For hot and cold weather procedures see 03300 "Cast-in-Place Concrete.