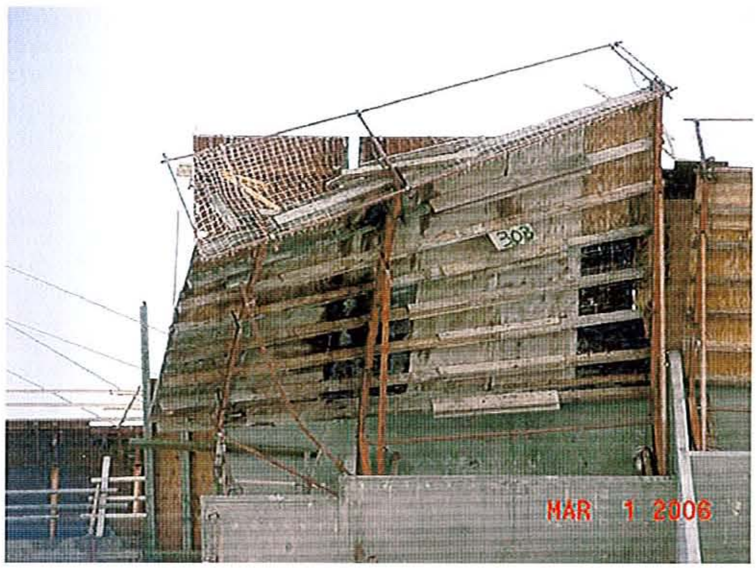
Investigation of the March 1, 2006, Collapse of Stripping Platform at San Marco Place, Jacksonville, FL

U.S. Department of Labor
Occupational Safety and Health

August 2006



REPORT

Investigation of the March 1, 2006, Collapse of Stripping Platform at San Marco Place, Jacksonville, FL

Report Prepared by
Mohammad Ayub, PE
Office of Engineering Services
Directorate of Construction

REPORT

On March 1, 2006, at noontime, two construction workers fell twenty stories to the ground and died when the platform they were working on suddenly failed. The platform, known as a "Stripping Platform", was erected about ten days earlier. Platform's purpose was to facilitate rolling out the tunnel forms after concrete was poured on the 21^{st} floor. The platform was supported on structural framing resting on the top of the concrete slab on the 19^{th} floor and on the underside of the 20^{th} floor slab, see figures 1 to 6. There were three other employees on the platform at the time of the failure but they hung onto the railing and the net, and were rescued without any major injuries.

The incident occurred at the construction site of a 22-story condominium building known as "San Marco Place" in downtown Jacksonville, FL. The following were the key participants in the project:

1. The Haskell Company of Jacksonville, FL was the general contractor/ construction manager/Architect.
2. Structural Consultants Associates of Houston, TX was the structural engineer of record.
3. Total Concrete Structures (TCS) was the concrete subcontractor.
4. Skyline Forming (SF) was the subcontractor to TCS.
5. Millennium Forming (MF) was a subcontractor to SF.
6. Outinord Universal (OT) of North Miami Beach, FL was a subcontractor to TCS. Outinord designed and furnished the tunnel forms. OT guided and supervised MF in erecting the tunnel forms and stripping platforms.

Haskell is a design-build company. For this project, they prepared the architectural drawings but the structural design and drawings were outsourced to SCA. Except for the lower floors, Haskell designed the condominium building with parallel walls on each floor spaced generally at about 13' to 19', suitable for tunnel forming. The structural framing of the upper floors consisted of a series of 6" concrete walls instead of conventional dry or CMU walls. The concrete walls ran in two directions, thus providing more than adequate lateral load resistance. The floor to floor height was designed to be 10' high except between the 20^{th} & 21^{st} floors and the 21^{st} & 22^{nd} floors. The floor slabs were typically 6" thick except on the 21^{st} floor where it was 10" thick.

TCS contracted with OT to design and furnish the tunnel forms and stripping platforms. Excluded from the contract were placing, shoring and re-shoring of the concrete slabs. OT was, however, contracted to provide technical assistance and education to TCS's employees to ensure that OT's design was faithfully executed. In case of any deviation from OT's design, OT, though not empowered to stop the work, had enough clout to have the deficiencies corrected immediately.

Tunnel forms consist of pre-fabricated standard steel forms, generally used in pairs to form an inverted L-shape to form a tunnel, and hence the name. When cantilever slabs are to be poured, only one tunnel form as an inverted L-shape is used. The concrete walls and slabs are poured together. The day after the pour, the tunnel forms are ready to be rolled out onto the stripping platform from where a crane lifts them to the next higher floor.

Typically, the tunnel forms are 8' in height but higher heights can be attained by add-ons. They come in varying widths, with a maximum of 20'. At the perimeter of the building, stripping platforms are provided to help employees who lubricate the contact surface of the steel forms to prevent them from sticking to the concrete. The tunnel form is rolled out to approximately 45% of its length; employees then attach a lifting triangle to the top of the lifting beam of the tunnel form. The lifting triangle is then fastened to the crane hook. It must be noted that the tunnel forms cantilever approximately 45% of their length, sparing the stripping platform of any dead load of the tunnel forms.

The area of interest where the platform failed was bounded by column lines F.5 to C.9.5 and 1 to 3.5. The platform was known as "Wood Platform 303", as per OT's drawings. The platform consisted of two layers of ¾" plywood supported over 4x6 wood joists spanning in the east-west direction, spaced at about 2'-3" o.c. The wood joists were in turn supported by three steel frames; the east frame, the west frame and the outer false frame. The east and west frames were about 13'- 9" apart. The false frame was approximately 6'-6"east of the east frame. The plywood platform and the 4x6 joists cantilevered about 3'-6" beyond the false frame. The east and west frames were identical and oriented in the north south direction. The north end of the frames were facing the outside of the building. The frames consisted of a horizontal member, equivalent toW6x16, a 3½" round column, and two diagonal braces, on the north and south sides respectively. The exterior and interior braces were 3½"and 3" round pipes, respectively, see figures 1 thru 6. In addition to the main structural members, the east and west frames were braced by round pipes. Each of the east or the west frames was supported at two locations. The bottom of the columns was supported on the top of the 19th floor slab and the top of the interior brace was supported on the underside of the 20th floor slab, see figures 3 thru 5.

The false frame consisted of a horizontal steel channel member equivalent to C 4x7 running in a north-south direction. Unlike the east and west frames, the false frame was not supported by any vertical column. Instead, it was supported by two sloping braces, hereafter called the outside brace and inside brace. Both were approximately 1 7/8" round pipes, see figures 1 thru 7.

As stated earlier, the platform was erected about ten days earlier and had been used on a number of lower floors, beginning from the sixth floor, without any reported problems. In this instance, however, the tunnel forms 16 & 17 extended approximately 8' north of the edge of the slab, though it is highly questionable whether any load from tunnel forms 16 & 17 was imposed on the platform. There was another difference which arose from the fact that the clear floor height between the 21st floor and the 20th floor was 10'-2" instead of the usual 9'-6". Due to the increased height, the contractor placed three 2x12 to make up the difference in height. Our analysis indicates that the cribbings had little impact on the incident. Therefore, the platform was essentially used in the same manner as it was on the lower floors. In our analysis, we have discounted any load from the tunnel forms on the platform.

There were five employees on the platform at the time of the incident. The tunnel forms No. 16 and 17 were in place and were being leveled. Concrete was not placed over the forms. The forms protruded about 8 feet beyond the edge of the slab. As stated earlier, the forms were practically imposing no load on the platform. The failure occurred under the dead load plus the loads of the five employees.

The failure resulted in the platform tilting downward at the northeast corner. The column of the east frame buckled making a right angle at about 1'-8" above the base. The exterior and interior braces of the east frame bowed approximately 2" and 4", respectively. Most significantly the outside brace of the false frame buckled about 15". The inside brace of the false frame also buckled approximately 5½". Other bracing members also were distressed, see Figures 7 thru 18.

Structural Analysis:

The purpose of the structural analysis was to determine whether the platform framing was appropriately designed to support the loads imposed on it on the day of the incident and whether the design was based upon a factor of safety of four, as required by OSHA standards. The factor of safety is required under live loads only. The following assumptions were made:

1. Tunnel forms No. 16 and 17 did not impose any load on the platform.
2. A load factor of 1.0 was used. No capacity reduction was employed.
3. The critical buckling load of the exterior brace of the false frame was computed on the classic Euler's formula and as per LRFD provisions of AISC specifications.
4. The weight of the five people was assumed to be 200 pounds each plus 50 pounds each for the equipment was added, as per industry practice. Analysis was also done assuming the weight of the employees to be 150 pounds plus 50 pounds for the equipment.
5. The five workers were placed at different locations at the north east end of the platform to determine the stresses.
6. Only gravity load was considered. Wind was disregarded.
7. The yield strength of the exterior brace of the false frame was considered to be 35,000 psi.

Commercially available STAAD.Pro. 2005 was used to model the platform and its framing. A number of analyses were done to determine the impact of the live loads on the structural integrity of the platform. The column supports on the concrete slab were modeled as pinned connections and so were the supports of the frame at the underside of the floor slab above.

First only dead load was considered. The dead load was computed to be approximately 4,460 pounds, including the dead load of the two layers of plywood, eight 4x6 joists, the east and west frames, the false frames and all the bracings. Under these conditions, the platform was not distressed. See table I for the magnitude of the vertical reactions.

Second, in addition to the dead load, five workers each weighing 250 pounds, including their equipment loads, were considered. The five workers were placed on the top of the false frame channel at the spacing of the wood joists. The first worker was placed at the junction of the most exterior 4x6 joist and the false frame channel. The assumption that all four supports were pinned proved to be inaccurate and, therefore, the pinned support of the rear west frame was removed. The outside brace of the false frame was subjected to an axial compressive force of 1,065 pounds. The force on the outside brace did not vary, regardless of the assumed end conditions of the outside brace, i.e., whether pinned or fixed.

Third, in addition to the dead load, five workers were placed at the extreme edge of the platform parallel to the east side, spaced at 2'-3" o.c. beginning from the northeast corner. Again, the workers were spaced over the location of the 4x6 joists. The axial force in the false frame's outside brace then jumped to 2,150 pounds.

Fourth, in addition to the dead load, three employees were placed over the most exterior north joist, evenly spaced over the 3'-6" cantilever, and two employees were placed over the next exterior joist over the cantilever. The force in the outer brace was computed to be 2,400 pounds. When the weight of the employees was reduced to 200 pounds inclusive of the equipment weight, the force was reduced to 1,920 pounds, still greater than the failure load.

Fifth, in addition to the dead load, only three workers were considered. They were placed at the outer edge of the platform parallel to the east side, beginning from the northeast corner. They were spaced over the top of the 4x6 joists. The outer brace axial strength was reduced to 1,550 pounds.

All the above analyses did not consider the increased live load to account for the factor of safety as required by OSHA. The analyses were conducted based on the actual loads. Intuitively, the structural framing looked precarious because of the lack of any vertical support of the false frame. The false frame was supported on two inclined braces, with the outer brace being approximately 16' long. The analyses confirmed that the outer brace of the false frame was the most critical member. The brace was sized to be approximately 1.9" round pipe with a wall thickness of approximately 1/8". The analysis indicated that the platform framing was highly sensitive to the location and number of workers on the platform. The farther the employees were located in the northeast corner of the platform, the higher was the axial force in the outer brace of the false frame. It is likely that the employees were closer to each other than was assumed in the analysis, which could further increase the axial load.

The buckling load of the outer brace was computed to be 2,174 pounds as per Euler's formula and 1890 pounds as per LRFD provisions of AISC. Euler's formula is derived under ideal conditions, therefore, LRFD formula is more reliable and is the industry standard. Under the loading pattern of the fourth analysis, discussed above, the axial force in the outside brace of the false frame was computed to be 2,400 and 1,920 pounds under the weights of employees of 250 and 200 pounds respectively, inclusive of equipment weights of 50 pounds. The weights did not include any factors of safety.

The same platform was used a number of times from the sixth floor and above without any reported problem. Lack of earlier failures could be attributed to less than five employees on the platform or employees at locations away from the northeast corner of the platform. From the very beginning, the platform was in a precarious structural state even though no failure had previously occurred.

Conclusions:

1. Outinord's structural design was flawed in that the false frame was not appropriately supported and the outer brace was not correctly proportioned. When the live loads of five employees, without any factor of safety, were placed near the northeast corner of the platform, failure became imminent.

2. Outinord's structural design did not incorporate the required factor of safety of four under live load. OSHA standard 1926.451(a) (1) was violated.

3. Outinord's structural design was not performed as per the industry standard.

4. Wind was not a contributing factor.

TABLE I

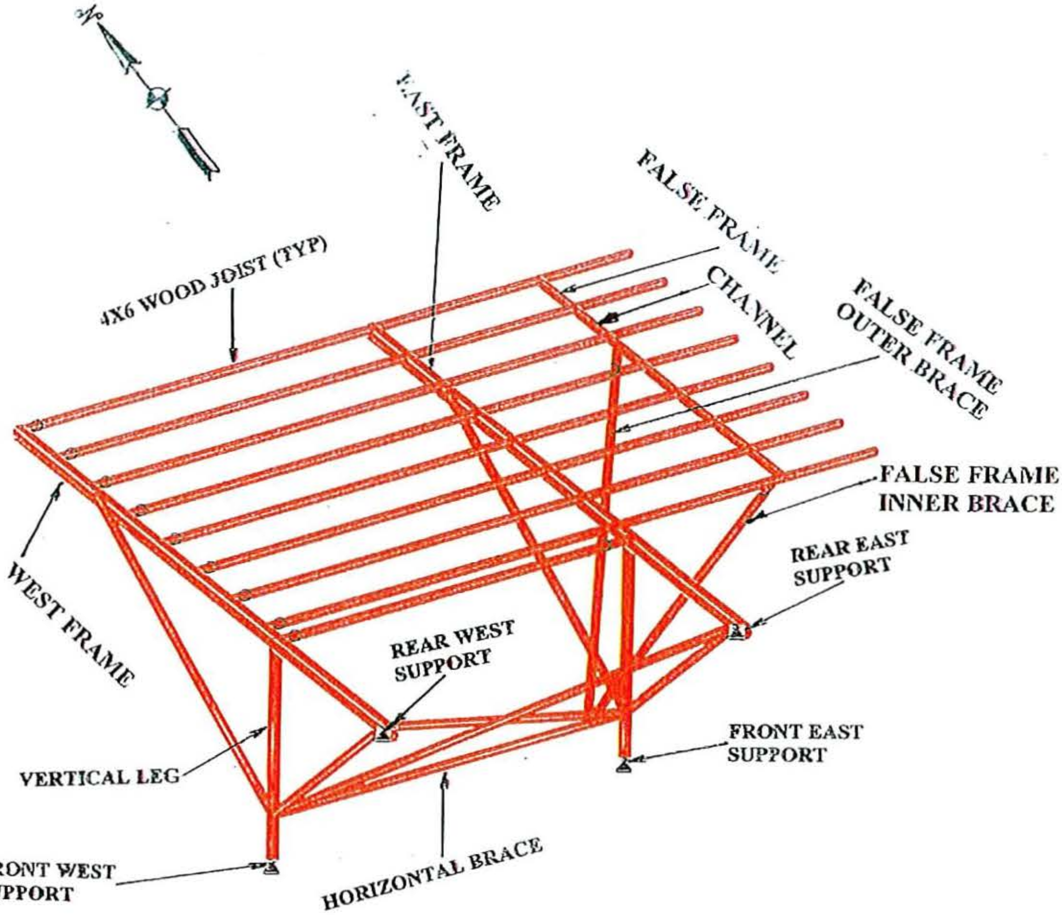
SUMMARY OF FORCES UNDER DEAD + LIVE LOAD							
Loading condition	Support condition	Vertical reactions in pounds units					
		File	Front west support @ base	Front east support @ base	Rear west support @ top	Rear east support @ top	False frame outer brace▲
1. Dead load	4 pinned supports (STAAD.Pro run)	OUTINORD-2	2167 (C)	5956 (C)	-316 UP	-3343 UP	-576 (C)
2. DL + 5 employees, each weighing 200 pounds Plus 50 pounds for equipment placed starting on most exterior joist over channel	4 pinned supports by STAAD.Pro run	OUTINORD-2R	1752 (C)	9477 (C)	730 DOWN	-6245 UP	-1965 (C)
	3 pinned supports with outer fixed brace (STAAD.Pro run)	OUTINORD-3R	878 (C)	10,598 (C)	Pin removed	-5713 UP	-1377 (C)
	3 pinned supports with outer pinned brace (STAAD.Pro run)	OUTINORD-3RR	899 (C)	10,599 (C)	Pin removed	-5784 UP	-1375 (C)
3. DL + 5 employees, each weighing 200 + 50 pounds on the outer east edge	3 pinned supports with outer pinned brace (STAAD.Pro run)	OUTINORD-3RRR Horizontal Fx Horizontal Fz	1129 (C) Fx = 1197* Fz = 822*	10878 (C)	Pin removed	-6294 UP	-2148 (C)
	Support 2 & 19 pinned, support 1 on roller, Support 7 removed	OUTINORD-3RRRR Horizontal Fx Horizontal Fz	120 (C) Fx = 0 Fz = 0	10946 (C)	Pin removed	-5352 (UP)	-2155 (C)
4. DL + 5 employees, each weighing 250 pounds Ψ, 3 on ext. N-E joist, 2 on int. N-E joist	3 pinned supports with outer pinned brace (STAAD.Pro run)	OUTINORD-3RRR" Horizontal Fx Horizontal Fz	1025 (C) Fx = 944* Fz = 632*	11288 (C)	Pin removed	-6599 UP	**-2405▲ (C)Ψ**
5. DL + 3 employees, each weighing 250 pounds on outer edge	Support 2 & 19 pinned, support 1 on roller, Support 7 removed	OUTINORD-3RRRRR Horizontal Fx Horizontal Fz	487 Fx = 0 Fz = 0	9540 (C)	Pin removed	-4813 (up)	-1554 (C)

▲ The false frame outer brace buckles under DL + 5 employees weight due to a maximum axial compressive force of 2405 pounds greater than failure load of 1891 pounds.

Ψ When the weight of each employee was reduced from 250 to 200 pounds, inclusive of equipment weight, the compressive force on the false frame outer brace was 1924 pounds, still greater than failure load of 1891 pounds.

* Front west support at base is modeled as a roller in the next run OUTINORD-3RRRR

Outer channel beam do not satisfy OSHA's requirement CFR 1926.451(a)(1) to resist dead load + 4 times of intended live load of five employees.



<u>**THREE DIMENSIONAL OUTINORD STRIPPING PLATFORM FRAMING**</u>

FIGURE 1

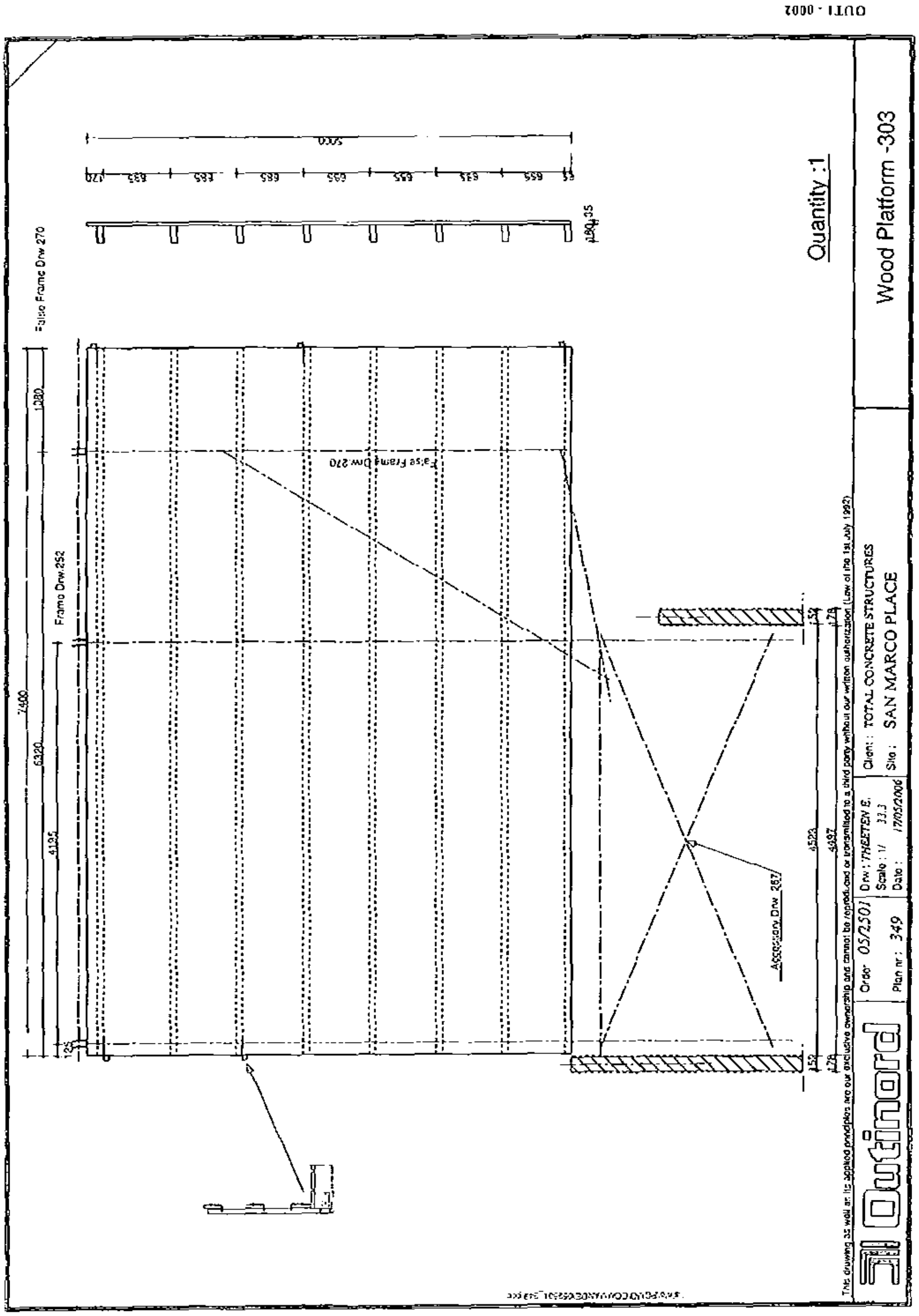

Wood Platform -303
Quantity :1
Client : TOTAL CONCRETE STRUCTURES
Site : SAN MARCO PLACE
Outinord
False Frame Drw 270
Frame Drw 252
Accessory Drw 287

FIGURE 2

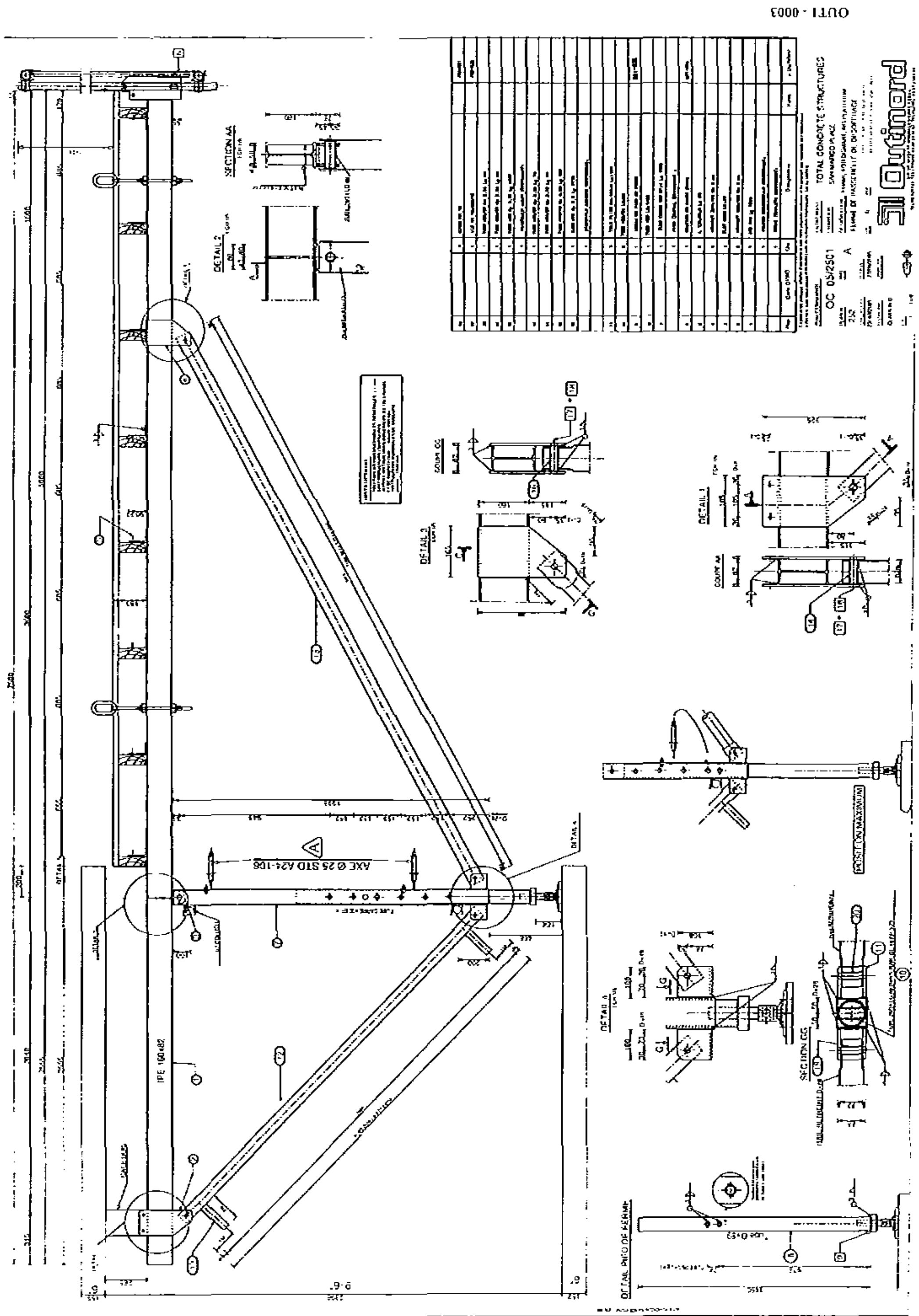

OUTI - 0003
TOTAL CONCRETE STRUCTURES
OC 05/2501
IPE 160x82
AXE Ø 25 STD A24-1DS
POSITION MAXIMUM
SECTION AA
DETAIL 2
DETAIL 3
DETAIL 1
DETAIL 4
SECTION GG
Outinord

FIGURE 3

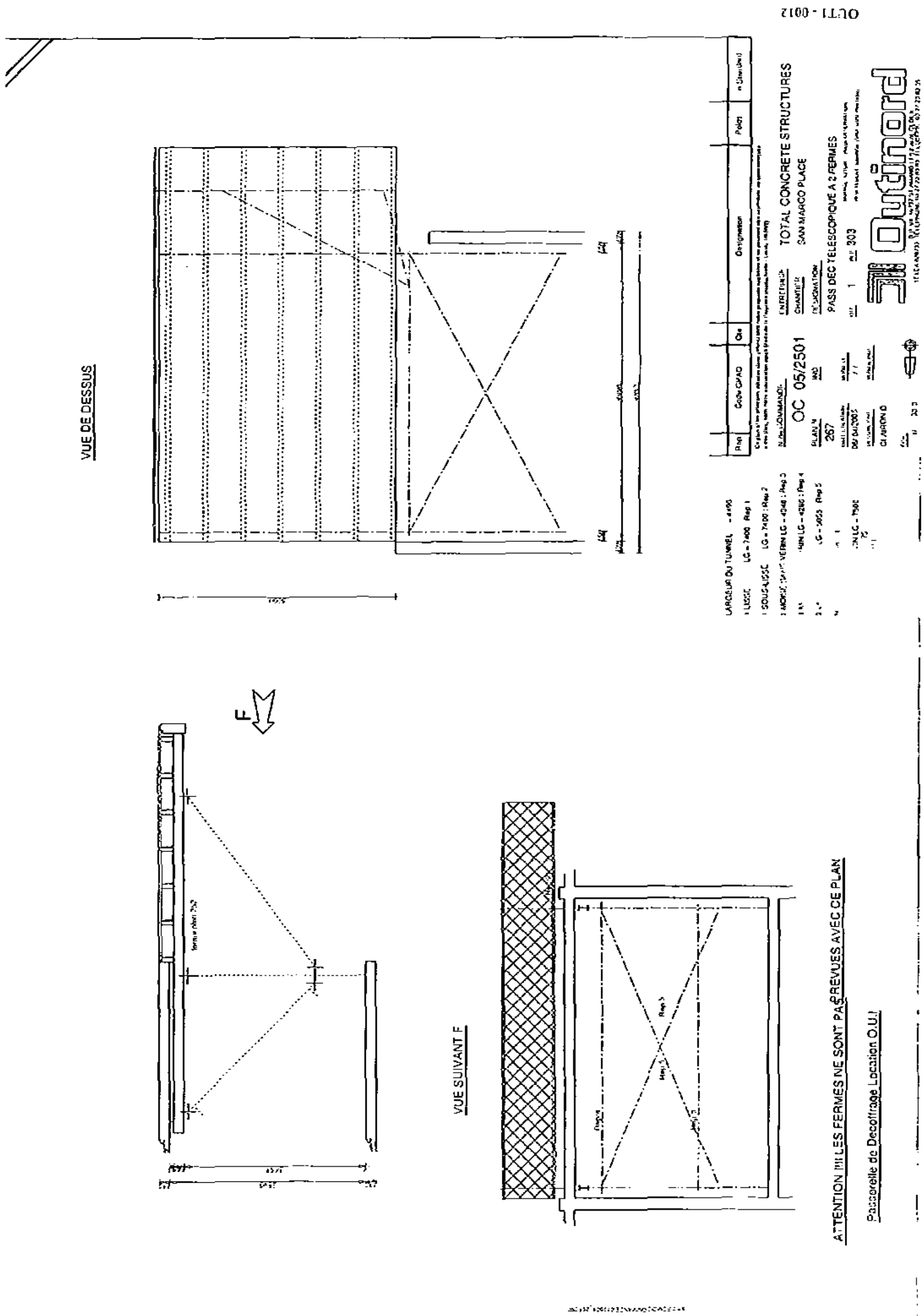

VUE DE DESSUS
VUE SUIVANT F
F
ATTENTION !!! LES FERMES NE SONT PAS PREVUES AVEC CE PLAN
Passerelle de Decoffrage Location O.U.I
TOTAL CONCRETE STRUCTURES
SAN MARCO PLACE
PASS DEC TELESCOPIQUE A 2 FERMES
OC 05/2501
267
Outinord
OUTI - 0012

FIGURE 4

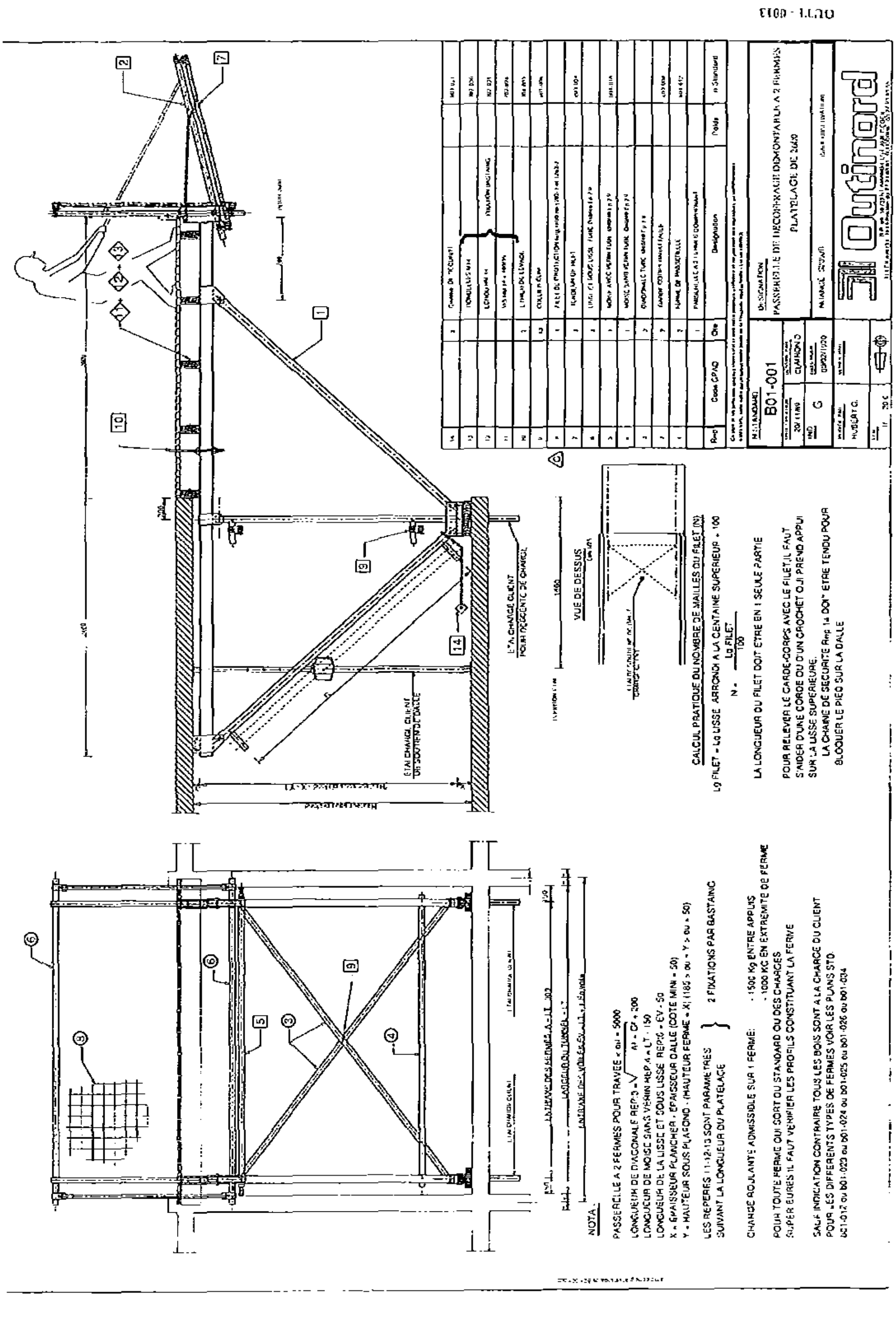


FIGURE 5

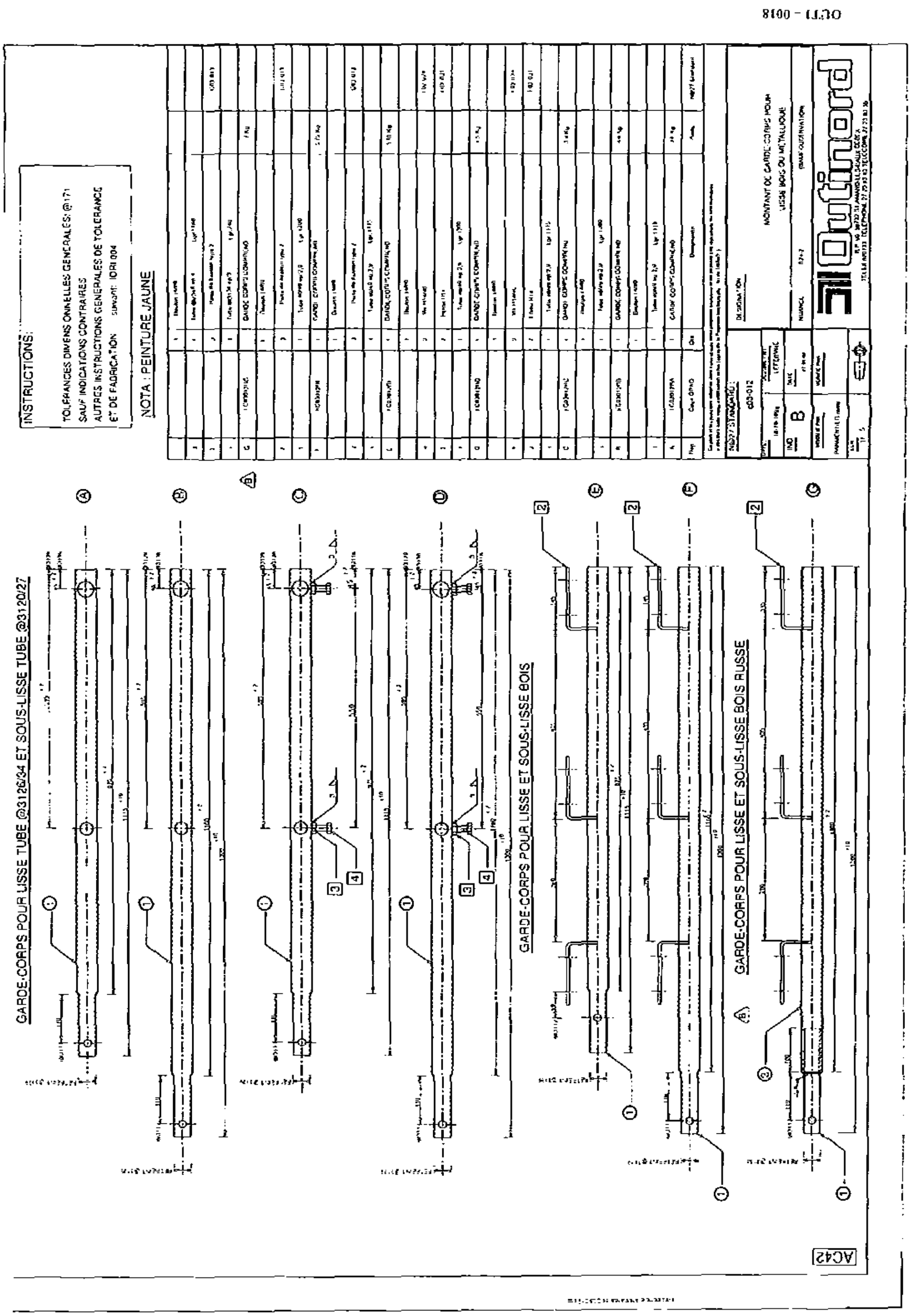

OUTI - 0018
INSTRUCTIONS:
NOTA : PEINTURE JAUNE
GARDE-CORPS POUR LISSE TUBE @3126/34 ET SOUS-LISSE TUBE @3120/27
GARDE-CORPS POUR LISSE ET SOUS-LISSE BOIS
GARDE-CORPS POUR LISSE ET SOUS-LISSE BOIS RUSSE
AC42
Outinord

FIGURE 6

Figure 7

Figure 8.

Figure 9

Figure 10.

Figure 11

Figure 12

Figure 13

Figure 14

Figure 15

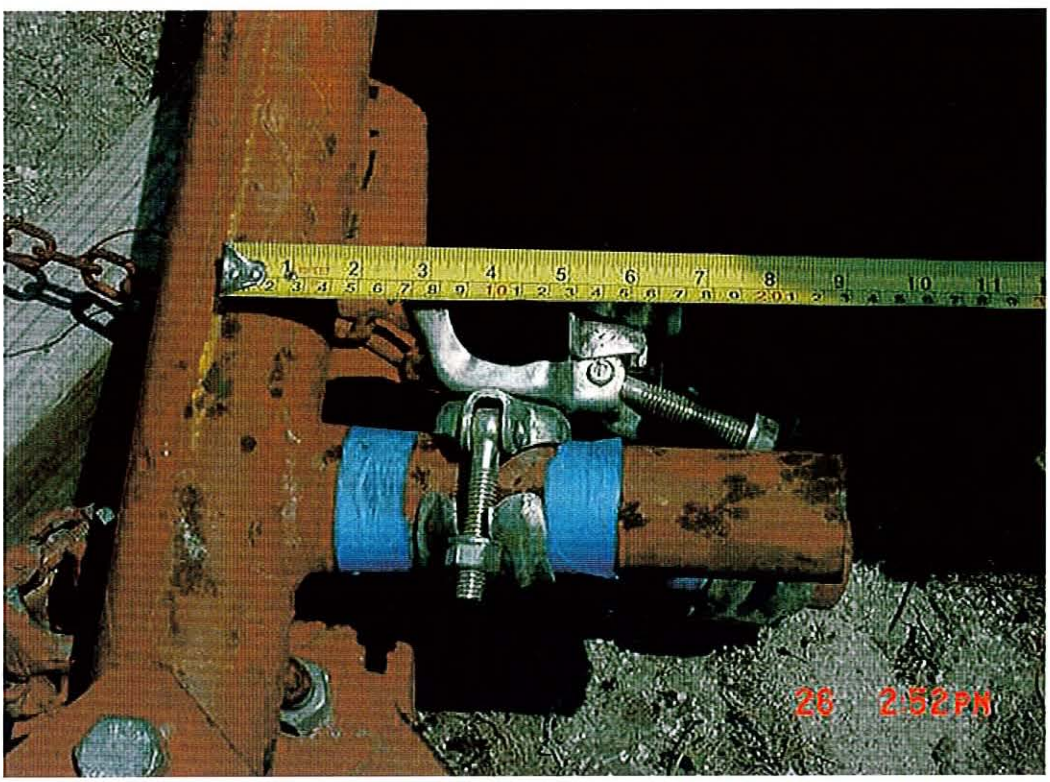


Figure 16

Figure 17

Figure 18