Erecting the Staggered-truss System: A View from the Field

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The staggered-steel truss system has been used as the major supporting element for many years. Projects using this truss system are economical, easy to fabricate and erect, and as a result beat out all other framing systems. This paper deals with a building recently completed which used the staggered-steel truss system. The project is the Resorts International Hotel in Atlantic City, N.J.

FABRICATION

Fabrication of this type of structure can readily be accomplished by any shop engaged in structural steel fabrication, provided they possess certified welders and are welding-oriented. In addition, the building must contain overhead cranes capable of lifting 10 to 15-ton trusses and columns for projects up to 20 stories.

Fabrication involves the following components: (1) Columns, (2) Spandrel Beams, (3) Trusses, (4) Secondary Columns and Beams and (5) Floor System.

1—Columns

Column fabrication is not complicated for buildings up to 20-stories high. They will be rolled wide-flange sections up to W14 × 720 with the longest being approximately 25 ft in length and with a total weight of 9 to 10 tons each (base plates are shipped loose).

Columns contained in buildings from 20 to 30 stories will probably be reinforced with flange plates as in Fig. 1. Above 30 stories will be built-up type columns consisting of three plates of varying thickness. On the Resorts International Hotel project, we had to fabricate (Fig. 2) columns with 8-in. thick flange plates and 6-in. thick web plates. This type of column requires more sophisticated fabrication equipment such as preheat devices, submerged arc welding equipment and heavy lifting capacity of 25 to 40 tons. In

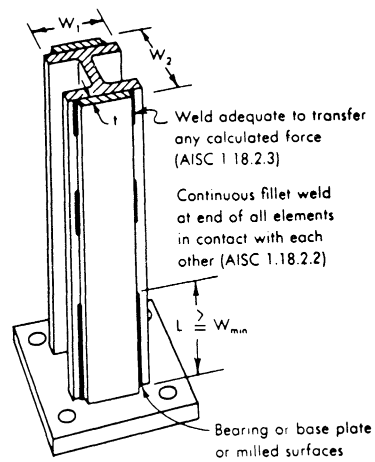

Figure 1

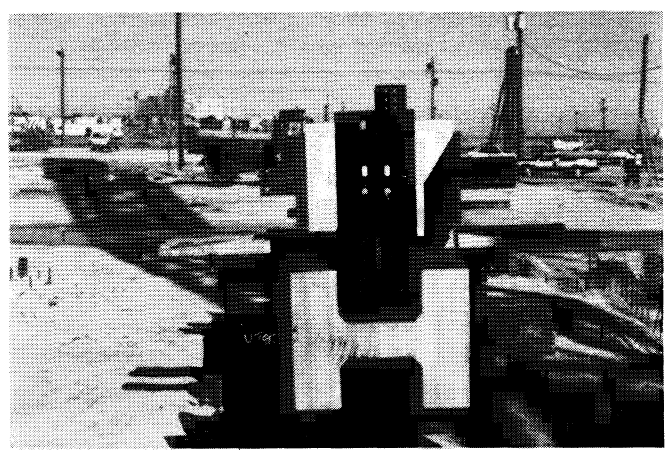

Figure 2

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other words, shops having the capacity to handle heavy plates and plate fabrication.

As in Fig. 3, these columns can also contain heavy bracing connections in the bottom tier which transfers the wind load to the concrete foundation. As an alternate for transfer of this wind stress, a bracing truss (Fig. 4) can be used at the bottom if architectural features are not obstructed.

2—Spandrel Beams

Spandrel beams are designed to resist the wind moment imposed on the end walls in the longitudinal direction (Figs. 5, 6). To resist this force, they can be steel beams moment-connected (Fig. 7) either by end plate connections or flange plates top and bottom with a web-shear plate. Fabrication of this type of beam presents no problem. However, due to rolling tolerances, the matching holes on the column flange plates or the flange width dimension when using end plates will have to be checked and matched with the beam to insure correct center-to-center of columns. This beam controls the total length of the building. In a building with 9 or 10 bays a deviation of + ¼ in. per bay (within the rolling tolerance) increases the overall length by 2 to 2½ in. The beam will also require a 2-hour fire rating (spray on) in accordance with most building codes.

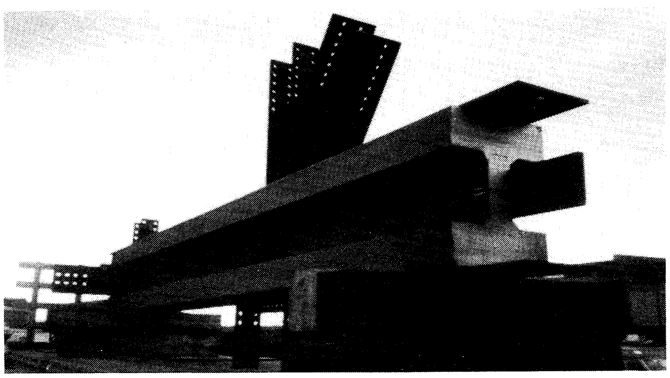
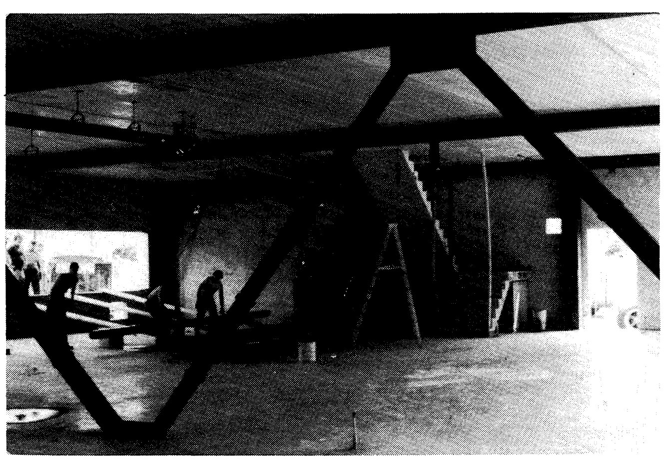


Figure 3



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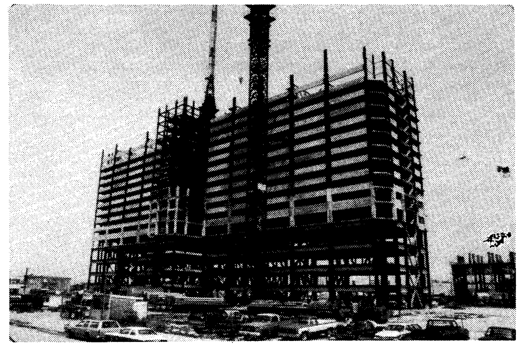


Figure 5

Figure 6

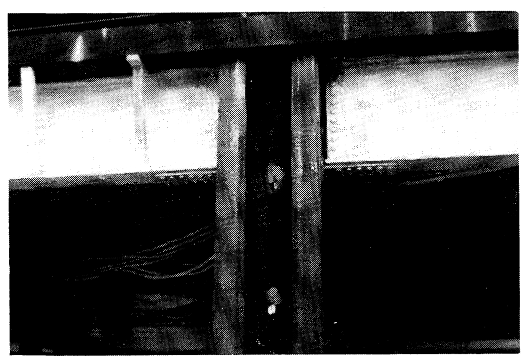


Figure 7

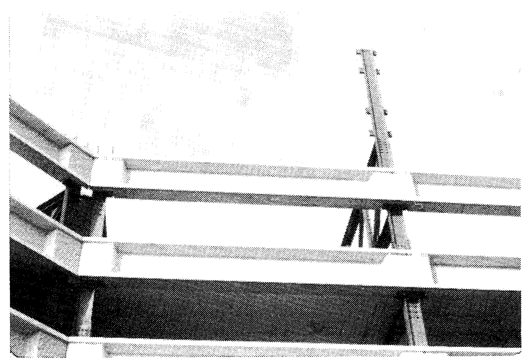


Figure 8

As a result of this, and with the imput of the architect on the projects we have completed, a concrete spandrel beam was developed (Fig. 8) to not only provide an increased lever arm to resist the applied moment, but also to eliminate fireproofing and at the same time serve as part of the exterior facade. This distance between connections on the column produced a considerable decrease in the quantity of field bolts. In addition, by using concrete, the beam can also function as part of the exterior facade. For the Resorts Hotel this beam was a structural component only and contained inserts to secure the window wall facade. However, it did eliminate field-applied fireproofing.

Shop work was not eliminated by this substitution of concrete for steel. To insure the accurate fit, as previously discussed, it was decided to develop a spandrel rebar cage to be fabricated in the shop and shipped to a precast contractor, who would set them in a steel form containing a shop supplied steel jig designed to maintain tolerances only a steel fabricator could provide.

3—Trusses

The weight of a truss is determined by gravity loads, wind loads, penetrations due to corridor, doors, pipes and/or window openings (Fig. 9). The truss weight will vary from 10,000 lbs. in a 4-story building to 36 tons in a 43-story building on the Resort project. Truss fabrication is not difficult. They should be set up on jugs to maintain correct overall dimensions. However, qualified welders are required to follow a quality assurance program (Fig. 10).

4—Secondary Supporting Structures

Secondary supporting structures are those necessary to support stair openings, elevator shafts and other framed openings required by the architectural design. This is important to overall costs. If the architect recognizes this type of structural solution will be used, he can design within its constraints and avoid unnecessary additional framing. (Figs. 11 and 12).

The Resorts project and the Towers on the Park project (Figs. 13 and 14) require additional support steel due to architectural configurations. The added steel framing can be designed as conventional (i.e., simple shear-connected) or to resist applied wind moments requiring partial moment connections. This type of framing is familiar to most fabrication shops.

5—Floor Systems

Floor systems can be the following types, however all must be designed to deliver the wind load as a diaphram (shear load) to the supporting trusses. For the steel fabricator they pose no problems. Architecturally, depth of construction and mechanical requirements can and will dictate the type of system to be used. As an example, the 8-in. hollow core floor deck provides a floor-to-floor height equal to a flat-

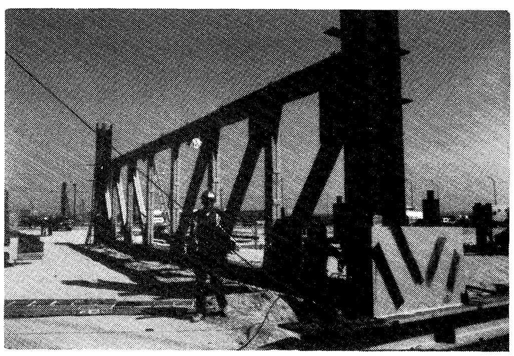


Figure 9

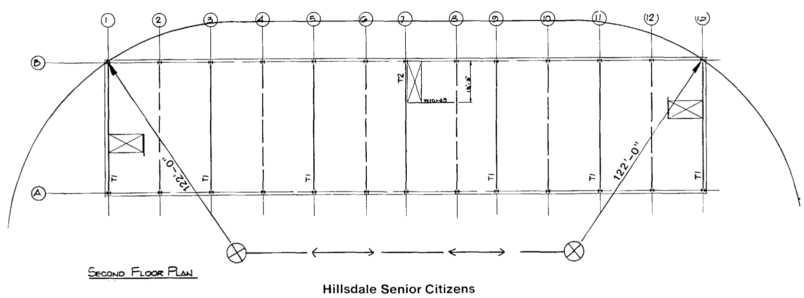


Figure 11

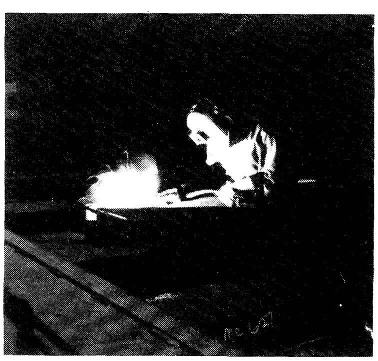


Figure 10

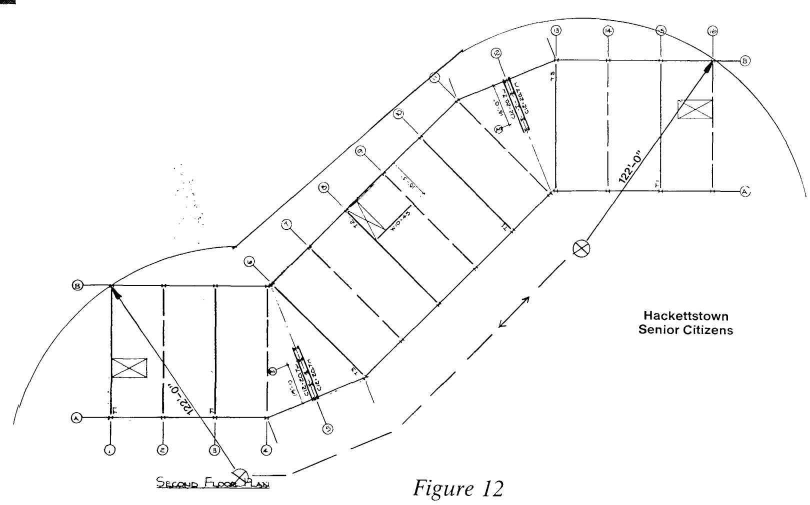


Figure 12

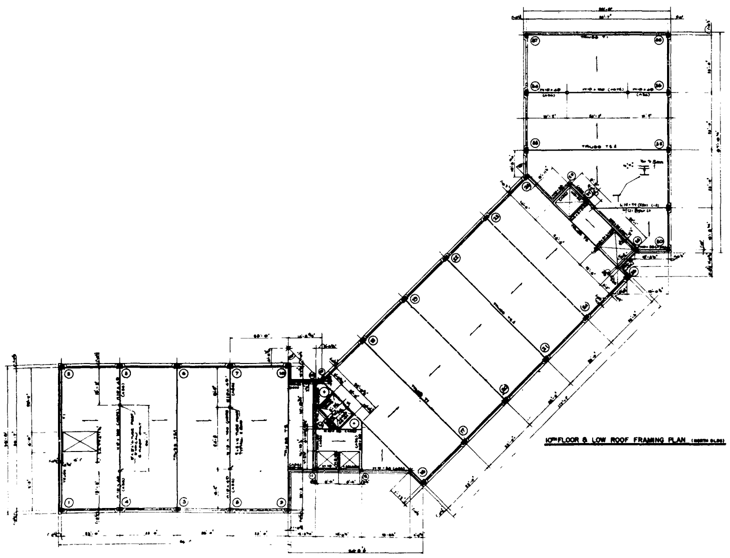


Figure 13

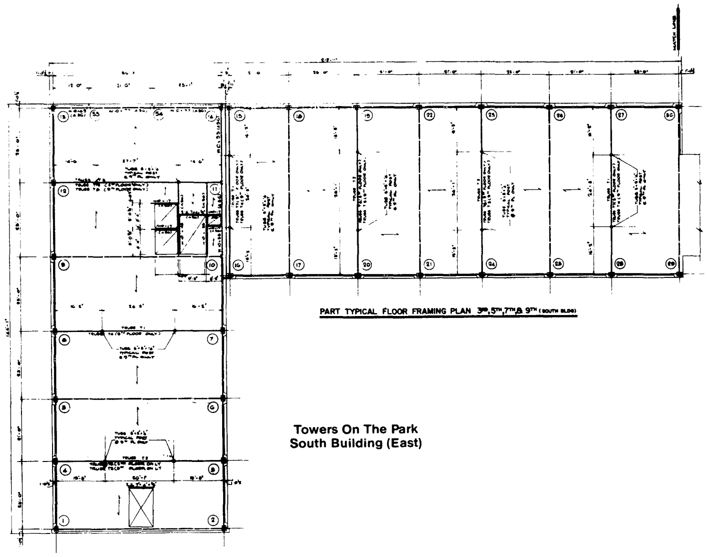


Figure 14

plate concrete system. Therefore, total height of the building will not be affected.

FIELD ERECTION

This type of structure has to be erected on a floor-by-floor sequence because of the instability caused by a floor system not in place. Also, depending on the height of the building, a tower crane has to be used to reach over the spandrel beams. Therefore, a crane must have the range (reach) and capacity (picking load) to cover the entire floor area if the building is to remain stable. Using guy cables or temporary bracing interferes with the erection process. Guy derricks (those attached to and climbing up on columns) and internal climbing cranes (supported on the floor structure) cannot be used, unless the design provides support areas—such as an elevator core which can be reinforced to support the additional loads.

For buildings up to about 20 stories with a floor height of 8 ft-9 in. (a total height of about 190 ft, a tower crane, self-supported, truck or cat-mounted (similar to a Manitowoc 4100W), can be used. Above 20 stories, use an external climbing crane (similar to Link Belt TG-1900) supported on steel tower units and connected to the structure at intervals of 75 ft, with the initial tie-in at 160 ft. Figures 15, 16, 17 and 18 show crane location, range etc. for erection of Hillsdale Senior Citizens Building, Hackettstown Senior Citizens Building and Towers on the Park respectively.

The erection sequence is important because of the previously mentioned stability of the structure. It should proceed as follows:

1. Set columns
2. Set spandrel beams to tie columns along strong axis
3. Set trusses

   Note: Connection of the bottom chord should be bolted tight after the dead load is imposed from the floor system. The bottom chord should be shortened approximately $3/16$ in. to allow for camber reduction and subsequent chord lengthening)

4. Bolt up and torque high-tension bolts
5. The 8-in. hollow-core planks are bolted (in lieu of weld plates) to the truss (Fig. 19). This provides an immediate bracing system, working platform etc. between trusses. However, grouting the key joints must proceed to provide the shear distribution previously mentioned.

   Note: Due to the inherent stiffness of the trusses, concrete spandrel beams and hollow-core floor planks, these structures can safely be erected for about 8–10 floors before grouting has to be in place. During extreme weather conditions—cold, rain etc.—erection can proceed even though concrete cannot be poured.

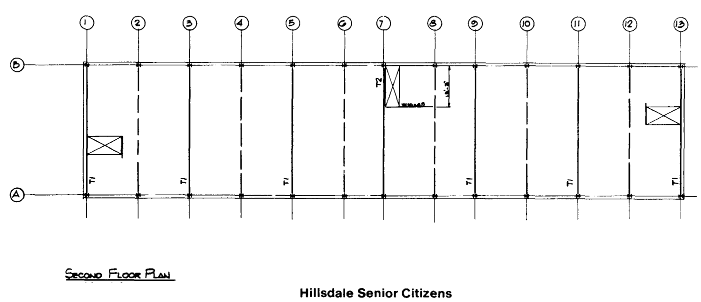


Figure 15

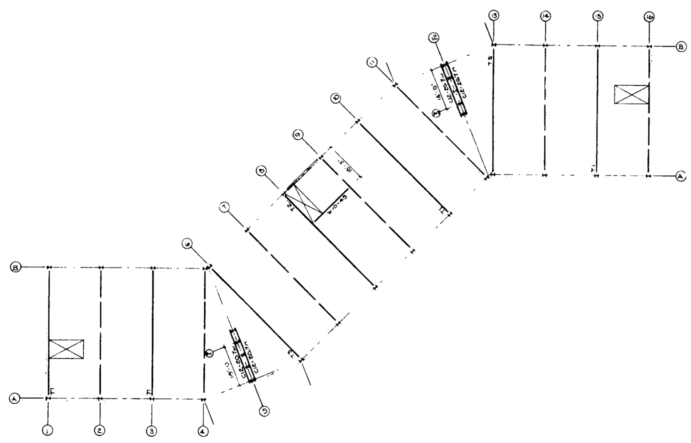


Figure 16

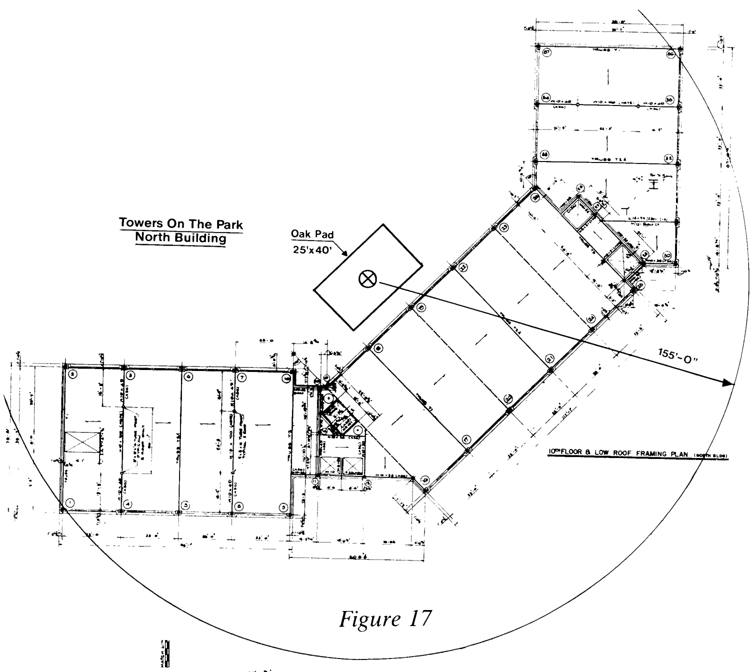
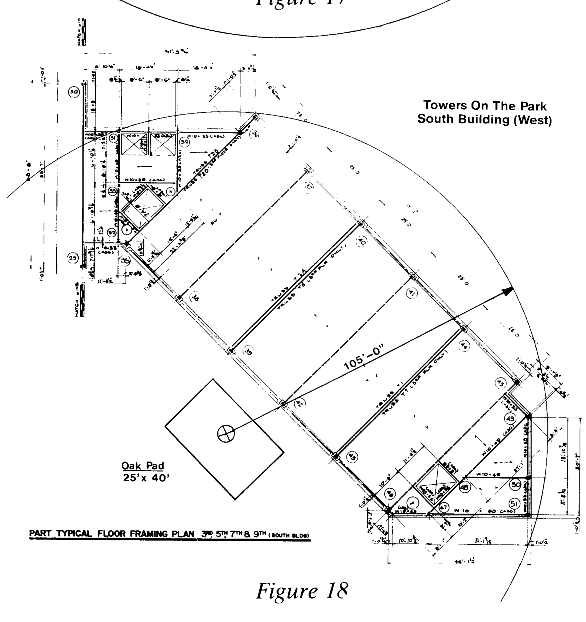


Figure 17



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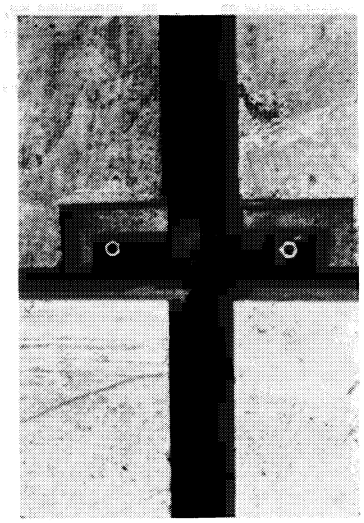

Figure 19

BUILDING COSTS

Using a building containing 13 supported levels, 9 bays @ 25 ft c. to c. long and 56 ft-1 in. c. to c. main building columns containing about 170,000 sq ft of supported area using 6-in. thick concrete spandrel beams acting also as the exterior facade and 4-in. thick precast end walls as an example, the following is the building cost:

Building Cost Breakdown

1. Structural steel
2. Precast concrete elements
3. Miscellaneous items
4. Erection
5. Unit price per sq ft

Item 1—Structural steel

Material costs	Weight (lbs.)
1. Anchor bolts	500
2. Columns & loose base plates	600,000
3. Trusses	580,000
4. Miscellaneous beams	
A. Elevator divider beams	
B. End spandrel beams	
C. Roof beams	
D. Penthouse & elevator mach. room beams	167,500
5. Field bolts	12,000
6. Paint (if required)	
7. Shipping	
Total cost: 1,360,000 @ \$.30/lb. average	1,360,000 lbs.
(8 lb./sq ft) =	\$ 408,000.

Note: No material discounts have been applied

Shop drafting—1,360 hrs. @ \$20/hr. =	27,200.
Shop labor—Shop labor averaged 15 hrs./ton 680 tons × 15 H/T = 10,200 hrs. @ \$15/hr. =	153,000.
Total item 1—steel furnished & delivered	\$ 588,200.

Item 2

Precast concrete components

1. Spandrel beams				
(a) Rebar cages 234 pcs. @ $400	=	$ 93,600		
(b) Casting 22,340 sq ft @ $9.50	=	212,230		
Total delivered price		$305,830	=	$ 350,830.
2. 4-in. precast end walls, 12,826 sq ft @ $6.50/sq ft			=	83,369.
3. 8-in. hollow-core plank, 165,000 sq ft @ $3.50/sq ft			=	577,500.
4. Connection angles, plank & spandrel ties, field bolts			=	10,000.
				$ 976,699.
5. Grout precast planks				
(a) Plank joints				
(b) Plank ends, 165,000 sq ft @ $.50/sq ft			=	82,500.
6. Caulking				
Exterior joints				
Interior plank joints			=	25,000.
Total Item 2—precast concrete				$1,084,199.

Item 3

Miscellaneous items

(a) Field expenses		
(b) Shop & field testing	=	25,000.

Item 4

Field labor—Equipment crane Manitowoc 4100W

(a) 1. Crane set up & removal		
2. Shipping to & from site		
3. 70-ton truck crane & crew to assemble	=	40,000.

Hoisting

(b) For this size building—should complete about 13,000 sq ft/floor in four days, includes a 10% down factor for weather and maintenance.

Crane—3 months rental

Crane crew	—2 men × 60 days =	120	man-days			
Hoist "	—6 men × 60 days =	360	"	"		
Bolt "	—6 men × 60 days =	360	"	"		
Stone "	—4 men × 60 days =	240	"	"		
Surveys	—1 man × 60 days =	60	"	"		
Super	—1 man × 60 days =	60	"	"		
Total		1,200	"	"	@ $315/day =	378,000.

Total Item 4—Field labor		418,000.
Total Items 1, 2, 3, 4	Total cost	$2,115,399.
	× O&P 15%	317,310.
	Total	$2,432,709.
	+ Sales tax if required	

Item 5

Unit price per square foot

(a) Structural frame consisting of:
1. Structural steel
2. Concrete spandrel beams
3. 8-in. hollow-core plank, including grouting

(b) Architectural component
1. 4-in. Precast end walls, including caulking

(c)

1. Total cost of the supported frame	=	$2,284,343	=	$13.44 sq ft
2. " " " " exterior facade	=	148,266	=	.87
Total		$2,432,609	=	$14.31 sq ft

Erection allowance—approx. $31,760

COST FOR FRAMING THE RESORTS INTERNATIONAL HOTEL

Building Description

As previously shown, this building contained 43 supported levels approx. 1,116,000 sq ft; 420 ft high.

Center (elev. core) — 35 ft × 114 ft
Two adjacent wings — 68 ft × 157 ft-6 in.
Total steel weight — 13,700 tons, 24.6 lbs./sq ft

Total cost of this project, based on a contract price of $22,100,000 (including performance bond and sales tax), amounted to $19.80/sq ft.

Notes:

1. Field erection commenced on March 18, 1985, with the final lift on March 31, 1986. Project was estimated to take one year using two cranes, and including holidays, weather and down time.
2. The structure is plumb within ⅝ in. from top floor to ground level—quite an achievement (Fig. 20).

SUMMARY

It has been shown the use of this system for apartments and hotels is fast and economical. A structural frame, including the exterior facade, can be completed as shown in two months for a cost equal to what would provide only a structural support frame, such as flat-plate concrete. Material costs are basically the same throughout the country. However, they can vary due to mill discounts, freight etc. The cost of shop production and field labor can vary considerably due to factors such as union vs. non-union, fringe benefits, insurance etc. To analyze the impact of this system locally, care should be exercised in converting to local wages.

Resorts International Atlantic City, New Jersey

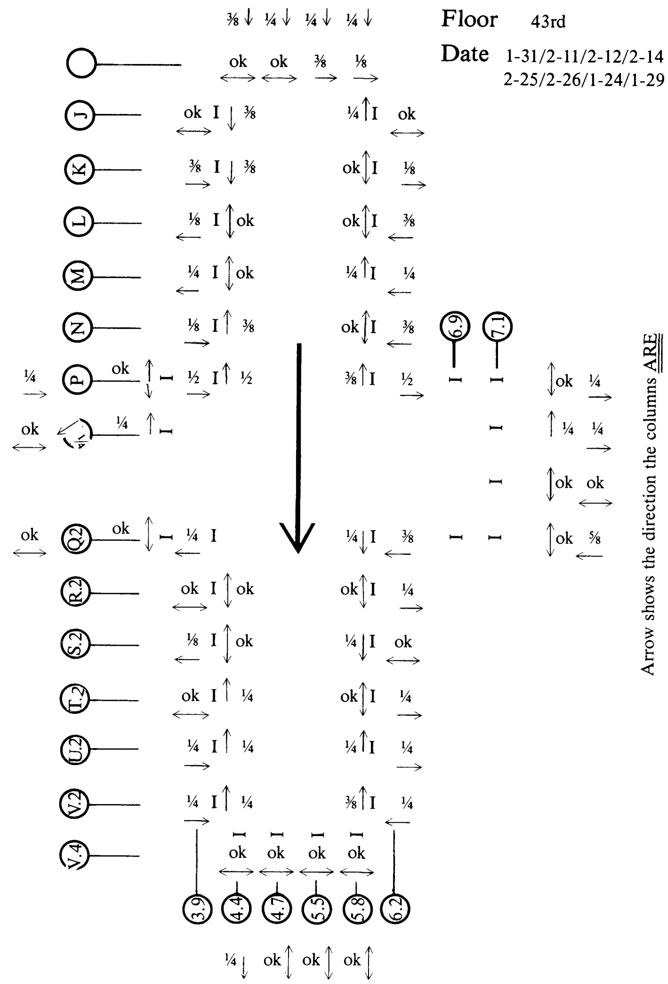

Figure 20