# Design-Construction of Detroit Metropolitan Airport Air Traffic Control Tower

**Patrick McGuire, R.A.**
Project Architect
Leo A. Daly
Omaha, Nebraska

**Dennis Young, P.E.**
Structural Engineer
Leo A. Daly
Omaha, Nebraska

**John Ciulis, P.E.**
Vice President
National Precast, Inc.
Roseville, Michigan

**Charles E. Mayer**
President
Precast Services, Inc.
Twinsburg, Ohio

*Precast concrete was used as the principal structural loadbearing element, with an exposed architectural finish, in the new $10 million, 232 ft (71 m) tall, air traffic control tower for the Detroit Metropolitan Airport. This article describes the design-construction highlights of the project from the viewpoint of the architect, structural engineer, precaster and erector.*

The Detroit Metropolitan Wayne County Airport Traffic Control Tower is the second constructed example of a standard tower design completed for the Department of Transportation, Federal Aviation Administration (FAA). The tower structure design was completed by Leo A. Daly in 1988. Although the $10.3 million project includes the Air Traffic Control Tower (ATCT), an associated base building with a connecting link to the tower and an auxiliary utility building, all clad in precast concrete (see Photo 1), the emphasis of this article is on the tower.

The ATCT design represents a creative combination of the structural qualities of precast concrete with its natural aesthetics and the inherent economy of plant-cast production and erection. A taller version of the same design is currently under construction in Denver, Colorado. Also, two similar towers are now under construction at Dallas/Fort Worth Airport. The same structural precast concrete system was used earlier at Hopkins International Airport in Cleveland, Ohio, although the tower design requirements, and thus the resulting structure, were less dramatic than the Detroit ATCT.

The design is termed a Major Activity Level Airport Traffic Control Tower by the FAA. The clean, upward-soaring tower is built with precast concrete to satisfy a requirement for minimal maintenance. The shape of the tower was de-

Photo 1. East elevation of completed air traffic control tower and base building.

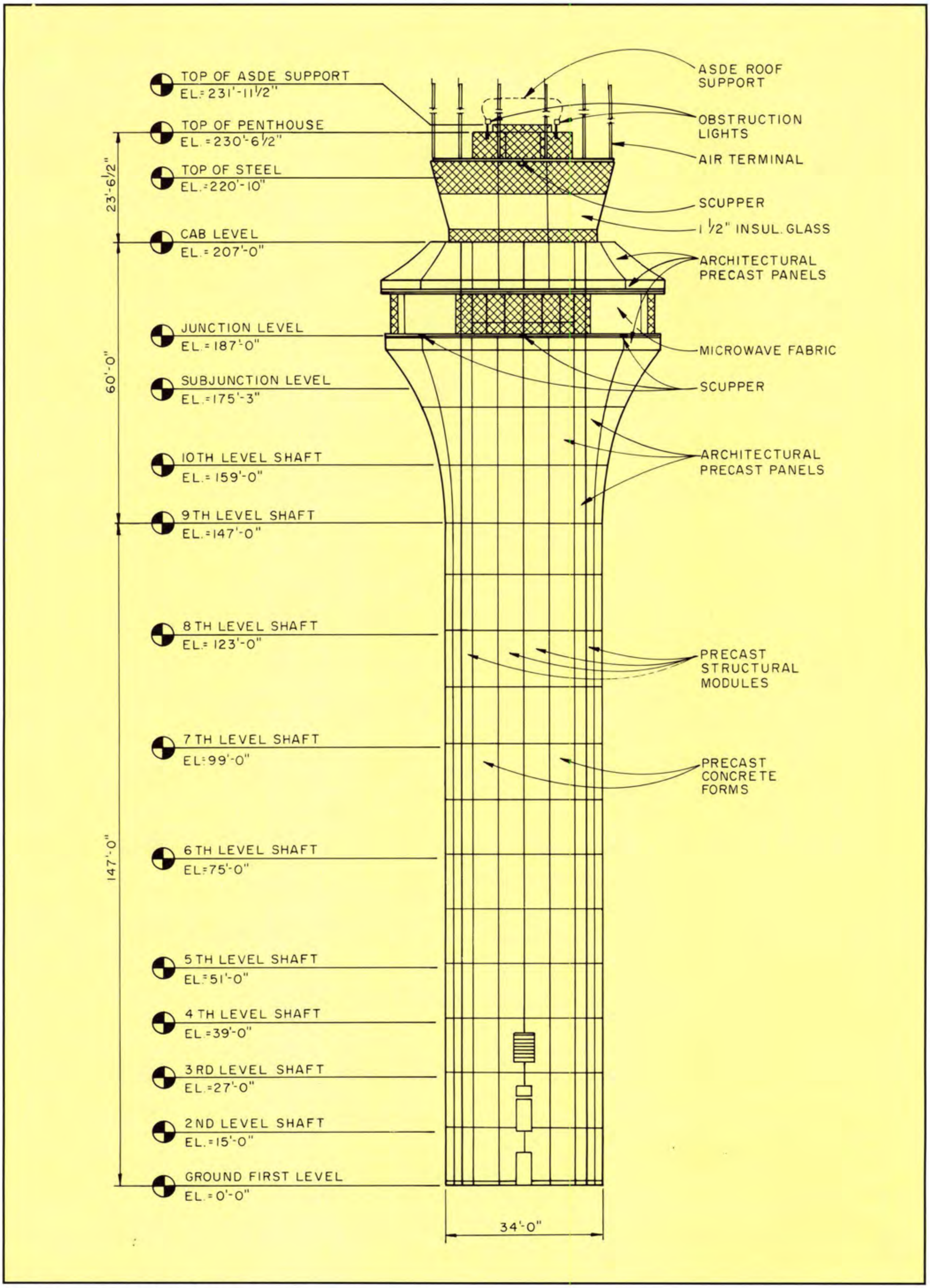


Fig. 1. Elevation of air traffic control tower.

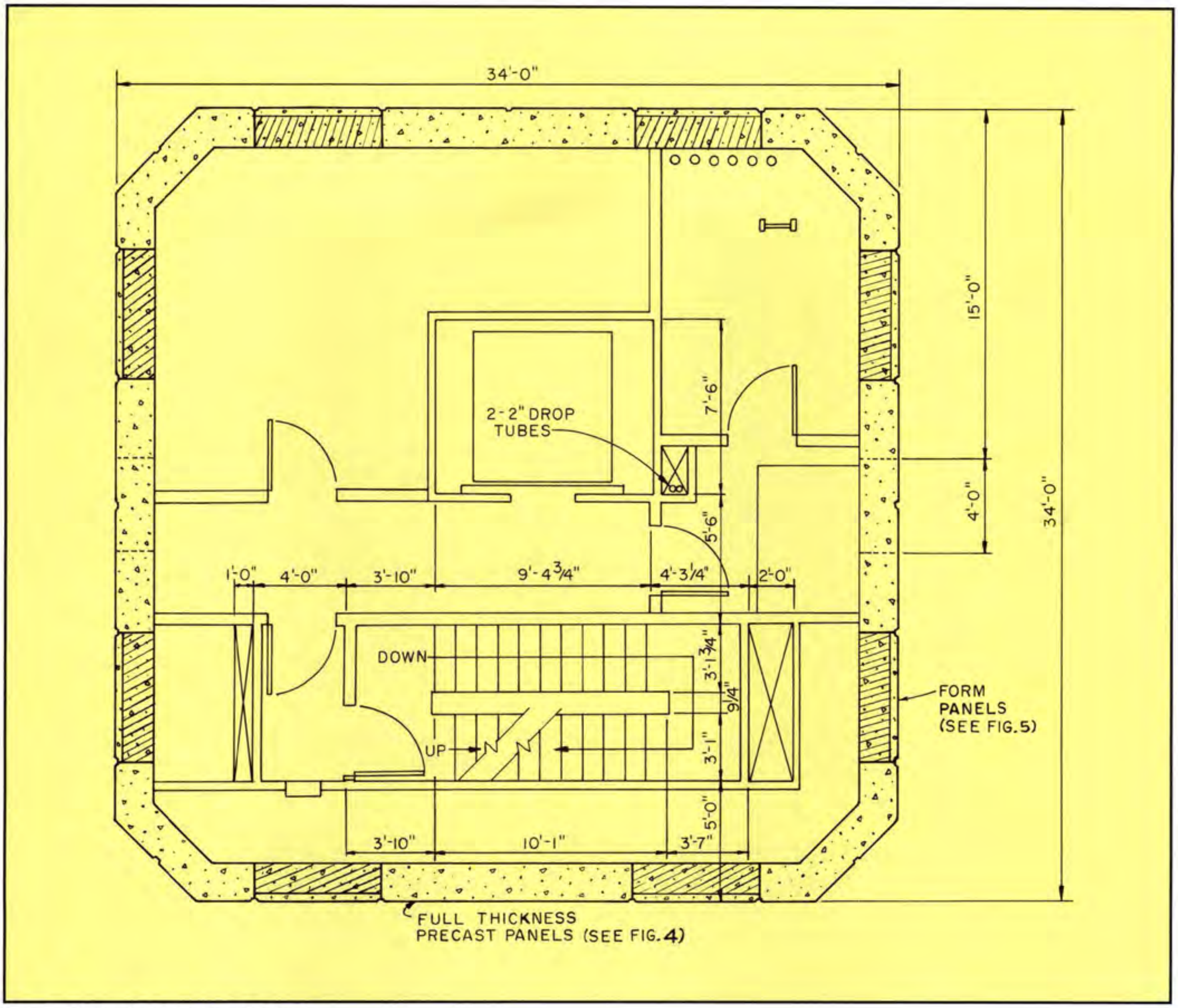


Fig. 2. Typical shaft plan of tower.

veloped from the architectural concept to:

- Minimize the area required for unoccupied shaft areas.
- Locate the occupied areas as close to the control cab as possible.
- Enlarge the cab to meet the increased demand for air travel.
- Respond to current building code requirements.
- Provide an aesthetically pleasing, symbolic representation of the FAA commitment to successfully meet today's challenges, as well as future demands placed upon it.

The standard ATCT design can be adapted to four optional heights, i.e., either 300, 276, 252 or 204 ft (91, 84, 77 or 62 m), depending on the specific requirements of the site. The height adaptation is accomplished by subtracting 24 ft (7.3 m) modules from the unoccupied shaft structure (see Fig. 1). The Detroit ATCT is the 204 ft (62 m) option modified further by adding 3 ft (0.91 m) to the base module, resulting in a height of 207 ft (63 m) measured to the cab floor level. The extra base module height facilitates interfacing with the adjoining base building through a two-story enclosed link with extra plenum space for mechanical, power and communications services.

The typical shaft modules are unoccupied in the sense that they contain vertical mechanical and electrical shafts, an elevator, an exit stair designed as a smokeproof enclosure, and some unassigned areas. The occupied areas of the tower, located at the top of the shaft, or mushroomed portion of the tower, are the same regardless of tower height. These include mechanical and communications equipment areas, administrative and personnel support spaces, and a cable access level just below the cab.

The cab for the standard design was enlarged over previous FAA requirements and enlarged further after the project was originally bid to 850 sq ft (79 $m^2$). A walkway around the cab perimeter allows for maintenance of the cab exterior. A penthouse on top of the cab has been designed to accommodate air surface detection equipment. The top of the penthouse is 232 ft (71 m) above ground level (see Fig. 1). A typical plan of the tower shaft is shown in Fig. 2.

The purpose of this article is to present the architectural features of the

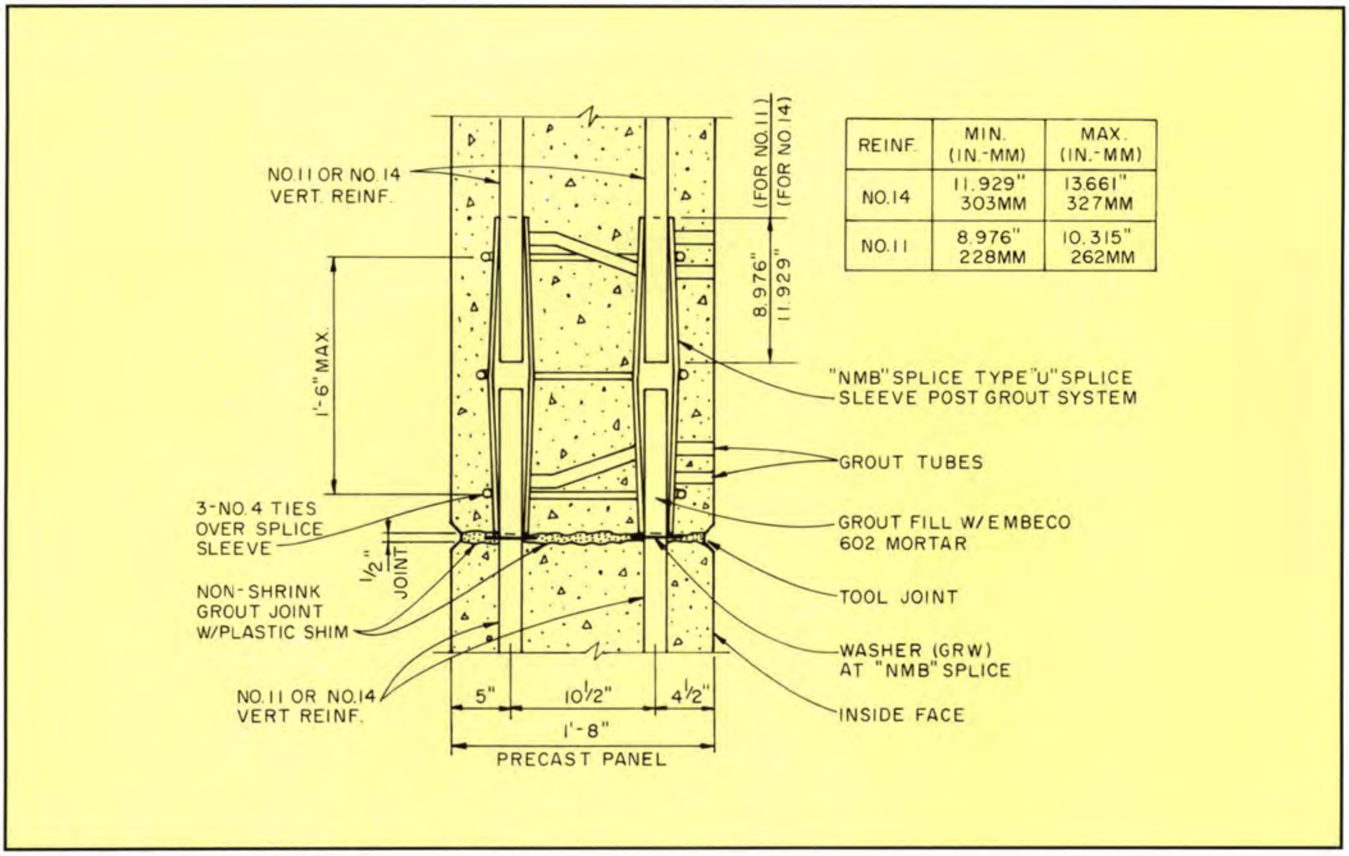


Fig. 3. Typical precast panel splice.

ATCT facility, discuss the structural considerations employed in designing the tower and then highlight the production, transportation and erection of the precast concrete components that enabled the structure to be completed on schedule.

## Architectural Features

The mushroomed portion of the upper tower is accented by a dark bronze horizontal band consisting of glass curtainwall at the administrative/support spaces level on three sides and mechanical louvers on the fourth side. The corners are chamfered and contain microwave equipment balconies designed to provide 360 degree transmitting capability.

The balconies are enclosed with a special microwave transparent fabric, of a color matching the curtainwall, which shields the dishes from sight and provides some protection from the weather. The control cab and penthouse, perched like a crown above the flared levels, are also clad with bronze metal panels and insulating glass.

The finish for the precast concrete was specified to be a medium sandblast with transparent damp-proofing to match the FAA resident engineer's sample. The standard design includes an option for staining or use of colored concrete. At the Detroit airport, a desire to coordinate the finish of this project with that of other construction projects led to the requirement for buff-colored cement and limestone aggregate in the face mix.

Photo 2. Erection of first level panels looking from west.

## Structural Design Considerations

Tall airport traffic control towers challenge designers to create a slender

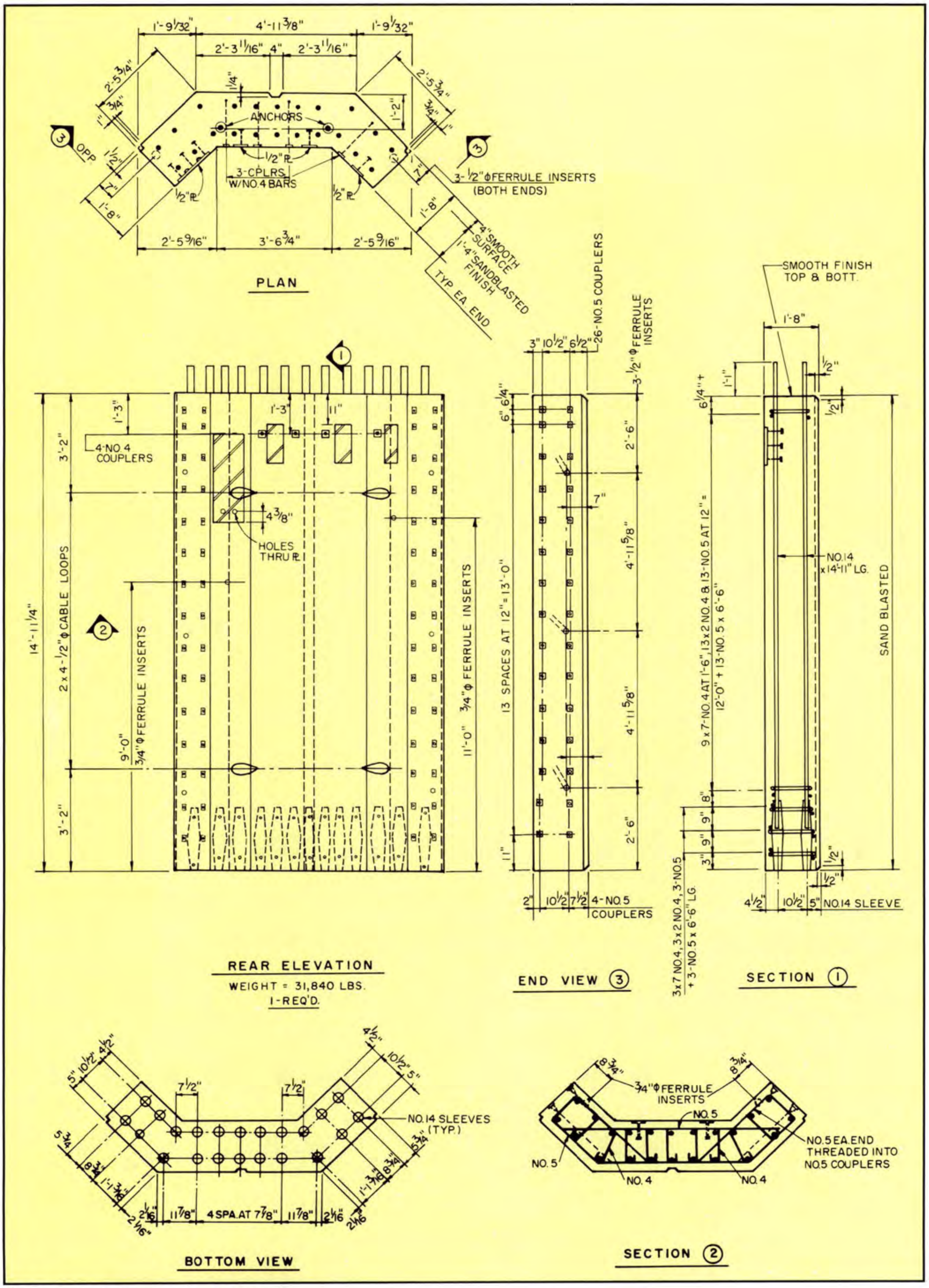


Fig. 4. Typical chamfered corner panel.

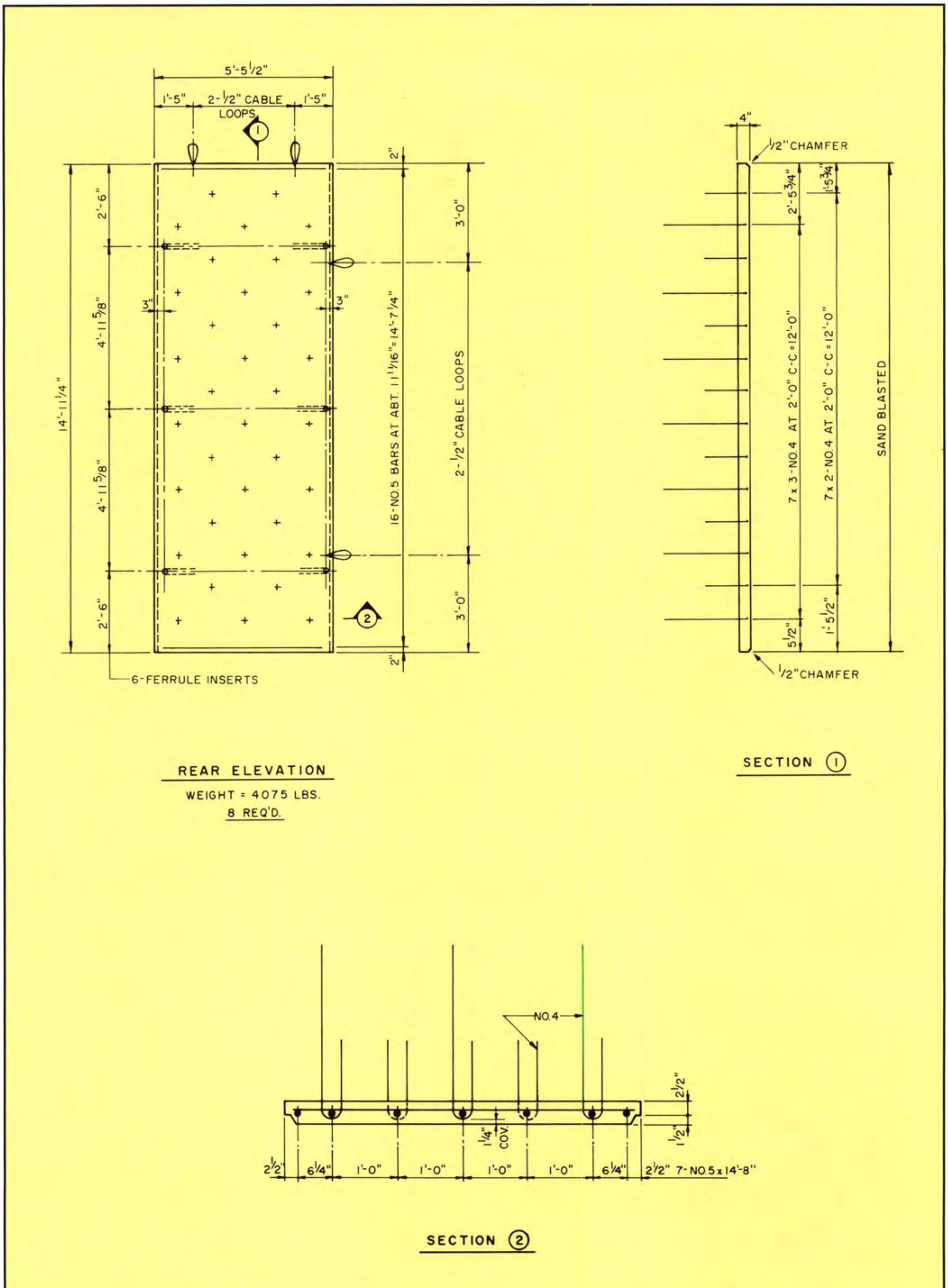


Fig. 5. Typical 4 in. (102 mm) thick precast architectural panel.

Photo 3. First level panels looking from east. Exterior scaffolding was used in grouting horizontal joints and splice sleeves.


Photo 4. Rubber gasket around perimeter of horizontal joints.

structure that will resist wind or seismic forces. The precast concrete tower lends itself well to using precast concrete panels as both solid structural members and as forms for the cast-in-place sections. These sections serve as places to tie the structural precast concrete panels together.

For this particular design, wind loads exceeded the Seismic Zone 2 load requirements. The wind loads at each level were obtained from wind tunnel tests and resulted in maximum uniform pressures of up to 55 psi (2.63 kPa). The precast concrete panel system easily satisfied both the wind load requirements and seismic design provisions.

Structural precast concrete provided a rigid shear wall design, an attractive maintenance-free exterior finish, and a rapid construction sequence. The tower has a 34 ft (10.4 m) square base plan with chamfered corners to reduce the overall effect of the wind loading. This shape was specially designed to resist the dynamic effects of vortex shedding which produces strong crosswind forces as determined by wind tunnel testing. These forces create internal stresses on the panels that the sleeve-joined reinforcing bars help resist.

The precast concrete shaft rises from a 66 ft (20 m) square x 5 ft (1.52 m) thick reinforced concrete foundation mat. The side panels of the shaft are typically 12 ft (3.66 m) high x 11 ft (3.35 m) wide and are 20 in. (508 mm) thick (see Photo 4). They weigh approximately 33,000 lb (147 kN). The panels forming the chamfered corners are the same thickness and slightly smaller, weighing approximately 26,000 lb (116 kN). Two strips on each elevation are infilled with 12 ft (3.66 m) high x 5.5 ft (1.68 m) wide x 4 in. (102 mm) thick panels to complete the perimeter. Eleven levels were constructed in this manner.

The 20 in. (508 mm) thick panels are stacked vertically and rigidly connected to each other using the NMB Splice Sleeve System (see Fig. 3). These splice sleeves are cast into the bottom end of each panel and connect to the vertical panel reinforcement. When the panels are joined on site, the reinforcing bar protruding from a precast panel slides into the sleeve above and the sleeve is filled with a high strength non-shrink grout.

The grout expands slightly as it hardens to a minimum specified compressive strength of 9300 psi (64 MPa), and locks the reinforcing bars together. The panels are then able to act together as if they are continuously re-

Photo 5. Grouted horizontal panel joint ready to receive panel above it.

Photo 6. Tower shaft showing structural precast panels shored in place. Base building at right is clad with architectural panels.

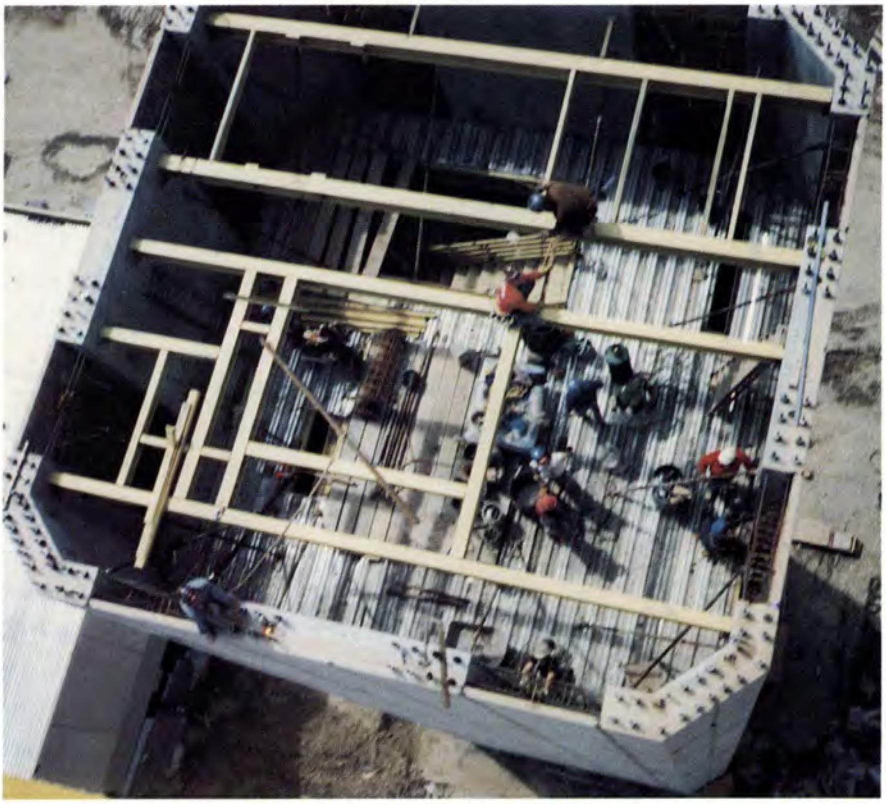

Photo 7. Overhead view of tower shaft showing structural precast panels alternating with thin veneer precast panels. Note that veneer panels act as a stay-in-place form for cast-in-place concrete.

inforced concrete sections. The splice develops at least 125 percent of specified reinforcing bar yield strength, satisfying both the ACI Building Code and Uniform Building Code requirements for connection strength.

Cast-in-place concrete is used to tie all the precast concrete panels together horizontally. The thin veneer architectural precast panels act as the exterior form, providing the same exterior finish. Reinforcement projections from the sides of the thicker panels, which are actually reinforcing bars screwed into dowel bar splicers, anchor the adjacent thick panel together horizontally.

Floor level framing in the shaft consists of steel beams connected to the structural precast concrete at embedded plates. Where the tower begins to mushroom out, the structure changes to steel framing and the precast panels become facing panels only. The tower includes 283 precast concrete panels combining structure, function, aesthetics, and both speed and economy of construction.

The sleeve connectors and structural precast concrete system allowed savings in construction time and costs. The simplicity of the splice sleeve connector, originally invented by Alfred A. Yee of Leo A. Daly and first used to connect integrally placed beam-to-column units in a Honolulu hotel, reduces the need for an additional construction subcontractor to be on site during erection. In the past, post-tensioning of the precast concrete panels was required. This system allows the local precast erector to complete the installation with his own workers.

## Production of Precast Components

The 20 in. (508 mm) structural panels are typically 12 ft (3.66 m) in height and extend from the base of the structure to an approximate elevation of 150 ft (46 m) above ground. The panels were produced with a 6000 psi (4 MPa) concrete mix. At each horizontal joint, the panels were connected to each other using splice sleeves, as mentioned earlier. The chamfered corner panels each have 22 sleeves while the flat intermediate panels use only 16 sleeves. Each connector is capable of accommodating one #14 reinforcing bar.

As with any project utilizing the Splice Sleeve System, tolerances in locating the sleeves are important to maintain. Making the project even more challenging, the corner pieces were designed with an exaggerated chamfer. Thus, the normal one and two-dimensional tolerance requirements were amplified when projected to a three-dimensional scale. The management team knew that we had to devise a system that would make it physically impossible for the splice sleeves to be improperly placed.

The fabrication drawing for panel mark A-1 (see Fig. 4) indicates how the 22 continuous length #14 reinforcing bars extended from the splice sleeve that was securely fastened to the bottom header of the form and extended 13 in. (330 mm) through the top header. The top end steel header was made in three pieces which were bolted together to eliminate any oversizing of the holes for the reinforcing bar and thus accommodate stripping while maintaining the tolerance requirements. In addition, a second steel header was placed at the end of the projecting reinforcing bar to ensure that the bars were not skewed.

Achieving uniformity of the medium sandblast architectural finish of the buff cement and limestone face mix presented another challenge due to the amount of reinforcement in the panels. In addition to the 22 longitudinal #14 reinforcing bars, numerous #5 stirrups and #4 hairpins were spaced at 12 in. (305 mm) on center, leaving little room to ensure proper vibration of the concrete.

Above the structural base of the tower, at elevation 150 ft (46 m), the tower mushroomed out to provide additional space for the control tower personnel and equipment. These panels brought the tower to its overall height of 232 ft (71 m) and were quite complicated with various radii and architectural features. These architectural panels were hung from the steel frame that was supported by the precast concrete structural tower base.

Fig. 5 shows the configuration of a typical 4 in. (102 mm) architectural precast panel.

Photo 8. Detail at structural precast panels showing horizontal reinforcing bars extending into void space where cast-in-place concrete tie panels together. Note that vertical reinforcing bars will extend into splice sleeves.

Photo 9. Interior elevation detail at tower shaft illustrates the back of veneer precast panels and exposed reinforcing bars of structural precast panels. This space will be filled with cast-in-place concrete.

Photo 10. Tower shaft at 199 and 186 ft (61 and 57 m) level showing flare of precast panels.

Photo 11. Erection of architectural precast panel at top of tower.

Photo 12. Erection of architectural precast panel next to in-place panels.

Overall, once the production team became familiar with the methods of achieving the required tolerances and other features of the project, production proceeded smoothly. The base of the tower was completed on schedule, with daily production consisting of one chamfered corner panel, one flat intermediate panel and three architectural form panels for the cast-in-place pour strip. Production started in mid-December of 1989 and finished in mid-February of 1990, about three weeks before erection was scheduled to begin.

## Transportation of Precast Components

The original contract drawings for the 20 in. (508 mm) structural corner and intermediate panels called for #5 bars [2 ft 6 in. (0.76 m) long], projecting out of each side of the panel into the cast-in-place pour strip. This requirement presented numerous challenges.

Firstly, this situation would require the bars to project through the side rails of the form, thus making the stripping of the side rail tedious, time-consuming and nearly impossible.

Secondly, the projecting bars would present a safety hazard during all phases of production and handling.

Lastly, the combination of the length of the bars, together with the

Photo 13. Aerial view of precast concrete tower with base building below it. The tower shaft is structural precast concrete while the upper flared portion and cap is architectural precast concrete.

Photo 14. Top portion of control tower. Architectural precast panels are clad on a steel frame. The remaining areas are enclosed with glass, metal insulated panels and microwave transparent fabric.

panel widths, made the panels wider than normal trailer widths, thus requiring special permits and escorts.

In consideration of these drawbacks, we proposed, and the architect/engineer accepted, the use of a #5 reinforcing bar splicer cast into the sides of the panels as a substitution, thus allowing the bars to be screwed in place once the panels arrived at the jobsite.

### Erection Highlights

Erection of the tower started on March 5, 1990. Photos 2 through 14 show various erection phases of the tower structure.

Because the precast concrete panels supported the stair and elevator framing and associated landings at each level, comprising about 460 tons (417 t) of steel total, the only way to make the project flow smoothly and minimize costs was to have one erector handle the erection of both the precast concrete and the structural steel.

Erection of the precast concrete preceded the steel erection by at least one level, and preferably two, in order to facilitate all the various operations. We started each level by erecting all the 20 in. (508 mm) structural panels on that level, bracing them back to the lower level metal pan landings. We would then erect the 4 in. (102 mm) architectural panels which bolted to the adjacent structural panels, thus forming the outside form of the cast-in-place pour strip (Photos 8 and 9).

The next procedure was to position the exterior scaffolding (see Photo 3) such that grouting of the splice sleeves could be performed as we were erecting the structural steel framing for the stairs, elevators and landings on the lower floor. Each such level took approximately four days to complete, with the general contractor staying three levels below us with the forming and pouring of the cast-in-place concrete strips.

Prior to erecting each of the 20 in. (508 mm) precast panels, a rubber gasket was glued to the perimeter of the top of the previous panel (see Photo 4). A cement grout was then placed within the confines for the gasket just prior to the erection of the panel (see Photo 5). As the panel was erected, it would compress the gasket and the grout down to the shim level. A 2 in. (51 mm) slot in the gasket was left open on each end adjacent to the cast-in-place pour strip to prevent any air pockets from forming and ensuring a perfect grout bed in the horizontal joints between panels.

Grouting of the splice sleeves and the horizontal joints was a very important part of the project, since a specified strength of the grout in both the sleeve and bedding was mandatory prior to erecting the next level, and thus much time was spent on coming up with a system that would not allow grouting to be a factor in the erection schedule. In addition to the 283 precast panels and the 460 tons (417 t) of steel, the erection scope of work included grouting 5800 linear ft (1768 m) of vertical and horizontal joints and 1800 splice sleeves (see Photos 6 through 9).

This process was repeated up through the eleventh level, which was completed on May 8, 1990. At that level, the method of constructing the tower changed as it mushroomed out to accommodate the necessary floor space required for the control room equipment and personnel. A structural steel frame was erected, supported by the structural precast concrete system.

After about four weeks, during which the general contractor formed and poured a series of cast-in-place concrete floors and beams, we were able to proceed with the completion of the architectural panels that hung from the steel frame (Photos 10 to 14).

There were a number of items that concerned us as we went into the erection of this structure; however, we found that with the cooperation of the design team members, careful planning and quality precast concrete panels, none of those fears materialized.

The erection of the project went as smoothly as anyone could have hoped. All the splice sleeve connectors fit properly, grouting of the splices went as scheduled, imbeds for attachment of the steel framing system were accurately positioned, and all other aspects of the system fell into place as planned.

Erection of the entire tower was completed on August 16, 1990. The contract value of the precast concrete, manufactured, delivered and installed, amounted to approximately $1.9 million for the entire structure.

The facility is now fully operational (see Photo 15). The owner and all parties involved in the project are pleased with the finished structure both from a functional and aesthetic viewpoint. Indeed, the control tower is now a distinguished landmark at the Detroit Metropolitan Wayne County Airport, visible to pilots flying above and admired by airline travelers motoring below.

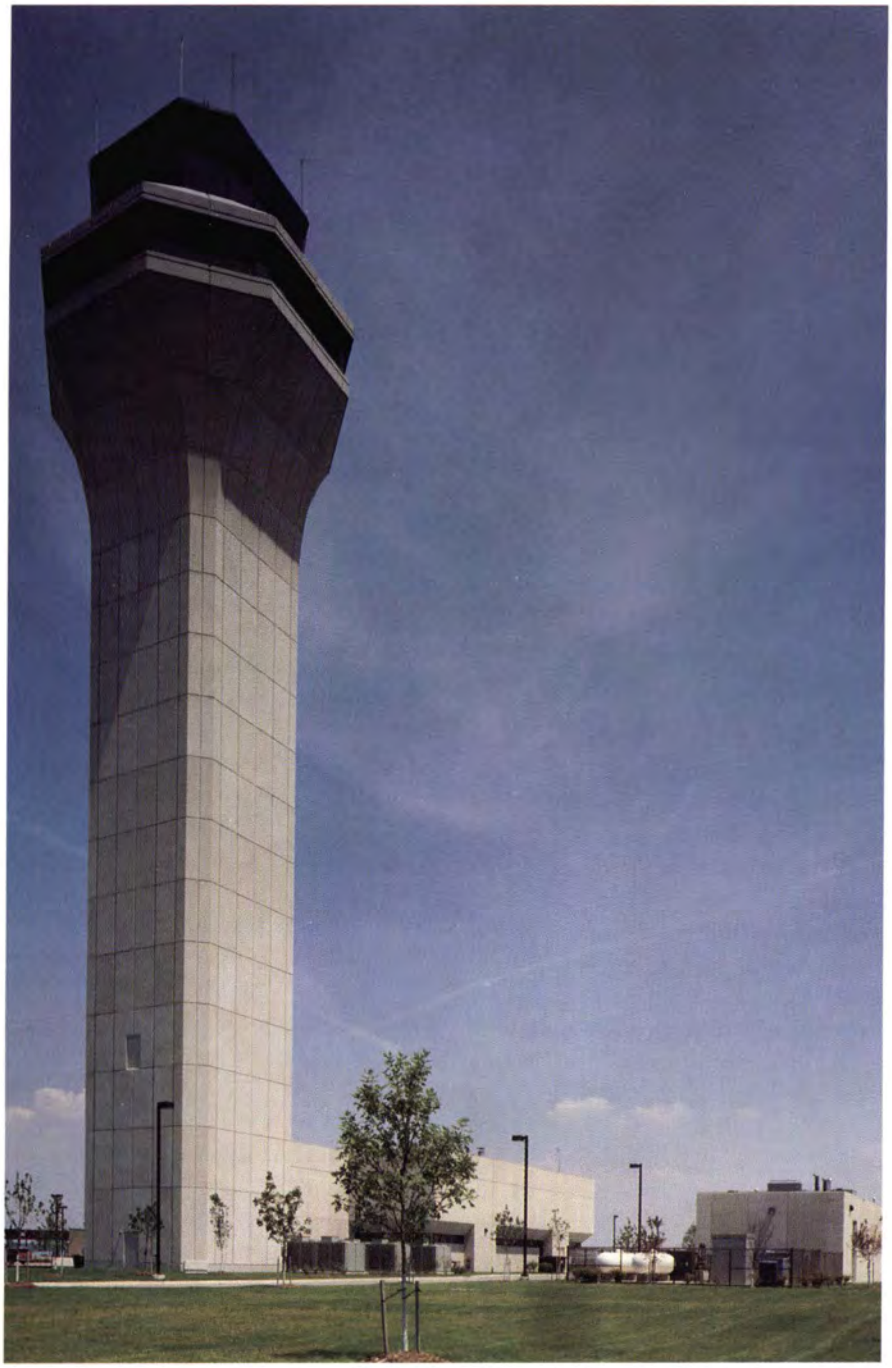

Photo 15. West elevation of completed air traffic control tower, base building and auxiliary utility building.

## Credits

Owner: Department of Transportation, FAA, Great Lakes Region, Des Plaines, Illinois
- Dennis Schwartz, project manger

Architect/Engineer: Leo A. Daly, Omaha, Nebraska.
- Paul E. Halverson, project manager
- Patrick McGuire, project architect
- Dennis Young, structural engineer
- Gary Ryba, mechanical engineer
- Jim Phillips, electrical engineer

General Contractor: DeMaria Building Company, Inc., Novi, Michigan
- Joe Lopez, project contractor

Precast Concrete Manufacturer: National Precast, Inc., Roseville, Michigan
- Ned Piccinini, president

Precast Concrete Erector: Precast Services, Inc., Twinsburg, Ohio
- Charles E. Mayer, president