Architectural and Structural Precast/Prestressed Concrete Renovates Landmark Ohio Stadium

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After 75 years of service, the "Horseshoe," The Ohio State University's historic landmark stadium, was badly in need of restoration, code-mandated modifications and expanded seating capacity. This high-visibility, $195 million project called for a structural system that could meet the dual challenge of preserving the original classical architecture while providing uninterrupted stadium use for three football seasons during construction. Architectural precast concrete enhanced the aesthetics of the arched motif shell, giving the stadium its powerfully arcaded form. Structural and architectural precast elements composed the new lower and upper deck levels. The renovations to the entire stadium were possible only with the production predictability and design flexibility of precast/prestressed concrete components, including raker beams, triple risers and large curved architectural precast panels. This article explains how the precast concrete construction provided a highly successful, owner pleasing renovation solution.

Home to the "Buckeyes" football team of The Ohio State University, this horseshoe-shaped stadium on the banks of the Olentangy River in Columbus, Ohio, has been one of the best-known landmarks of collegiate sports since 1922. After more than 75 years of service, the Ohio Stadium, the "Horseshoe" or "Shoe" as it is commonly known, was badly in need of repair, restoration, and additional spectator seating.

Fig. 1. The renovated "Horseshoe" retains the classical appearance of the original stadium.

The spring of 1998 marked the first time major renovations were made to this football icon, a structure listed in the National Registry of Historic Places as one of the first college stadiums in the United States to be constructed of cast-in-place concrete. Built at an original cost of $1.6 million in the early 1920s, the Ohio Stadium was also the first to use lines of site to determine its geometry.

The two critical concerns of the owner, Ohio State University (OSU), were to preserve the classical appearance of the Horseshoe (see Fig. 1) and to ensure that the football schedule would continue without interruption during the entire renovation period. Precast concrete construction was the only viable system that would meet the University's absolute mandate that the stadium be usable for every home football game during the four-year construction period and guarantee that the number of seats available would never be less than the 90,000 that existed at the start of the project (see Table 1).

Table 1. Details of the construction timetable.

Construction element	Start date	Completion date
45 ft (13.4 m) deep slurry wall	December 1998*	August 1999
Lower the field 14 ft (4.3 m)	November 1999*	August 2000
East and west precast AA Deck	November 1999	August 2000
East Upper C Deck	November 1999	August 2000
East architectural precast wall	April 2000	August 2000
South end zone and scoreboard structure	November 1999	August 2000
West architectural precast wall with press box	November 2000	August 2001
Camera deck	February 2001	August 2001
West Upper C Deck	November 2000	August 2001

*Construction began immediately after football season.

Fig. 2. Original north rotunda blends gracefully with new architectural precast out-build.

Table 2. Architectural precast contract.

Architectural precast out-build and south end zone	Contract amount
Combined plant price	$4,044,538
Combined delivery price	$382,535
Combined installation price	$1,256,172
Total	$5,683,245

Table 3. Quantities of architectural precast components for stadium out-build and south end zone structure.

Stadium out-build		South end zone	
Component	Number of components	Component	Number of components
Curved panels	524	Architectural panels (CTI)	284
Entrance portal panels	72		
OSU locker room	11	Structural panels and stairs (Rinker)	181
Camera deck panels	16		
Total	623	Total	465

SYSTEM SELECTION

The owner's mandate required that the selected structural solution had to guarantee construction flexibility, schedule predictability and speed of erection – as well as the ability to achieve the classical architectural design for which the historic structure is known. In addition to over 30 prime contractors and numerous subcontractors working on a restricted jobsite, the limited construction access to both the infield and the stadium's exterior called for a structural system with production and erection versatility. The architect/engineer convinced the owner that architectural and structural precast/prestressed concrete components were the best choice to ensure timely construction, meet the historical architectural criteria, and keep the stadium fully functional.

Precast architectural panels for the exterior cladding formed the smooth, curved shape using three different design radii, resulting in some very complex geometry. With the production of very large panels, the erector was able to enclose the structure quickly and provide an acceptable completion deadline to the university.

ARCHITECTURAL PRECAST CONSTRUCTION

Concrete Technology, Inc., of Springboro, Ohio, was the manufacturer of the exterior architectural precast concrete, serving as the prime contractor for the stadium out-build construction and subcontractor for the south end zone construction. The combined contract amount for this work totaled over $5.6 million (see Table 2). The out-build precast design and shop drawings were prepared by H. Wilden & Associates, Inc., of Allentown, Pennsylvania, with the precast erection handled by SOFCO Erectors, Inc., of Columbus, Ohio. The south end zone precast concrete was designed by McNutt Engineering, Inc., of Dayton, Ohio and erected by Precast Services, Inc., of Columbus, Ohio.

Architectural Precast Shell

A new external architectural precast shell for the east and west sides of the stadium was designed to emulate and improve upon the arched motif that gave Ohio Stadium its classic arcaded appearance. Architectural precast panels achieve the Romanesque geometry

Fig. 3. Original stadium showing cornerstone towers and temporary bleachers at south end zone.

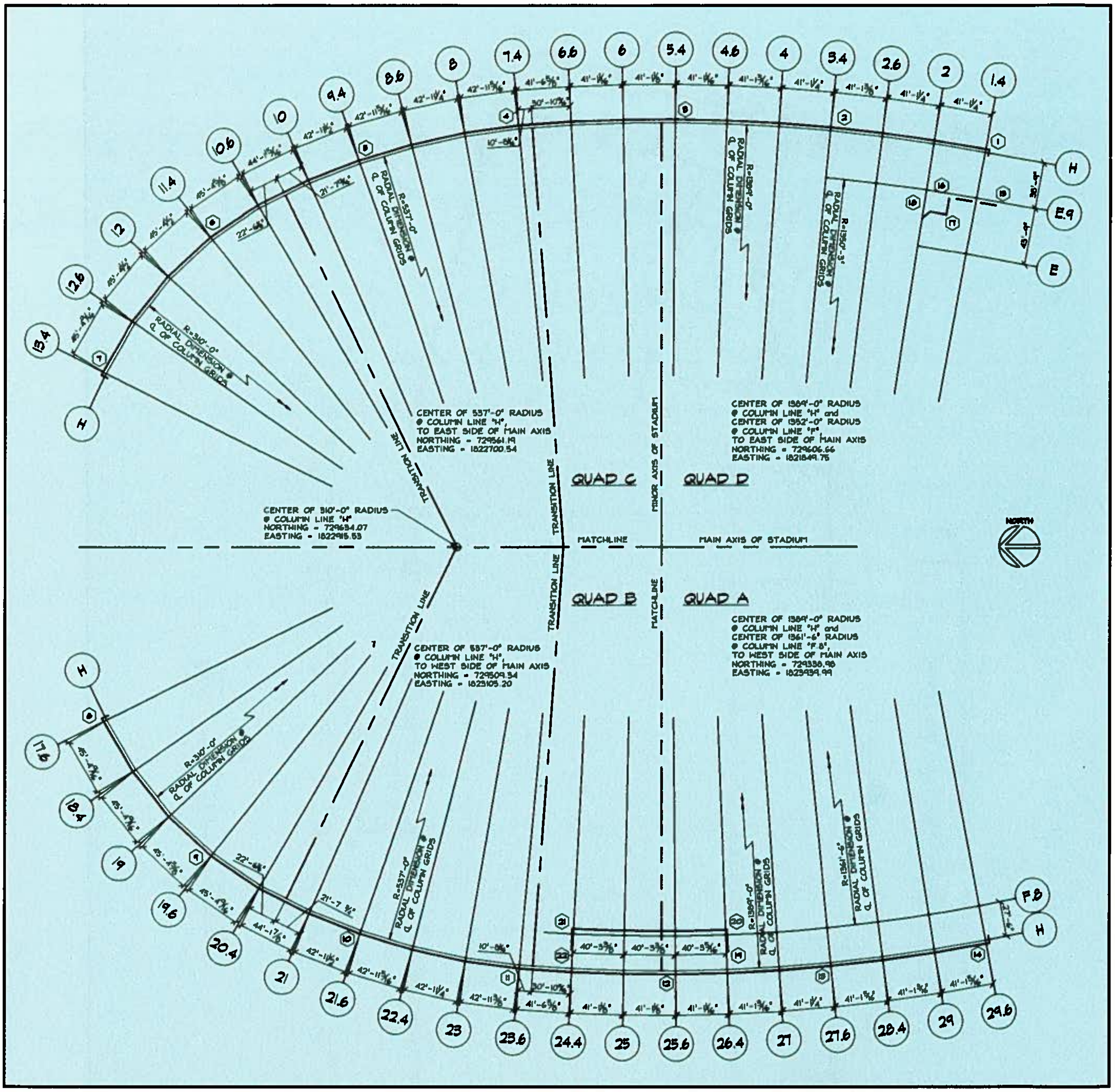

Fig. 4. Plan view of stadium. Three different radii were used for the architectural precast curved shell panels.

and the solid-to-void ratio that complements the original design intent. The new precast façade provides the important visual link between the new and old designs as the sandblasted precast finish clads the entire out-build structure that forms the stadium surround. The north rotunda and four cornerstone towers were retained from the original structure with appropriate restoration and repair (see Figs. 2 and 3).

Curved architectural precast panels were produced to follow the existing oval footprint (see Fig. 4), incorporating the ornately detailed wainscoting and entrance portal design of the original stadium. Renovations expanded the east and west sides of the Horseshoe by 42 ft (13 m) and provided structural support for the addition of 19 new rows to the upper deck. Quantities of the architectural precast components are provided in Table 3.

South End Zone Structure

The overriding owner concern was the preservation of the geometric integrity of the stadium's historic horseshoe shape. To accomplish this, the new construction in the south end zone establishes a visual break, or opening, at the south ends of the existing east and west sides of the stadium, leaving the horseshoe footprint intact. These openings function as entrance ramps to bring the players down from the existing grade to the new lowered playing field. Architectural precast panels, with similar historical detail as the main stadium, clad the exterior of the south end zone structure (see Figs. 5, 6, and 7). Quantities of components for the south end zone structure are provided in Table 3.

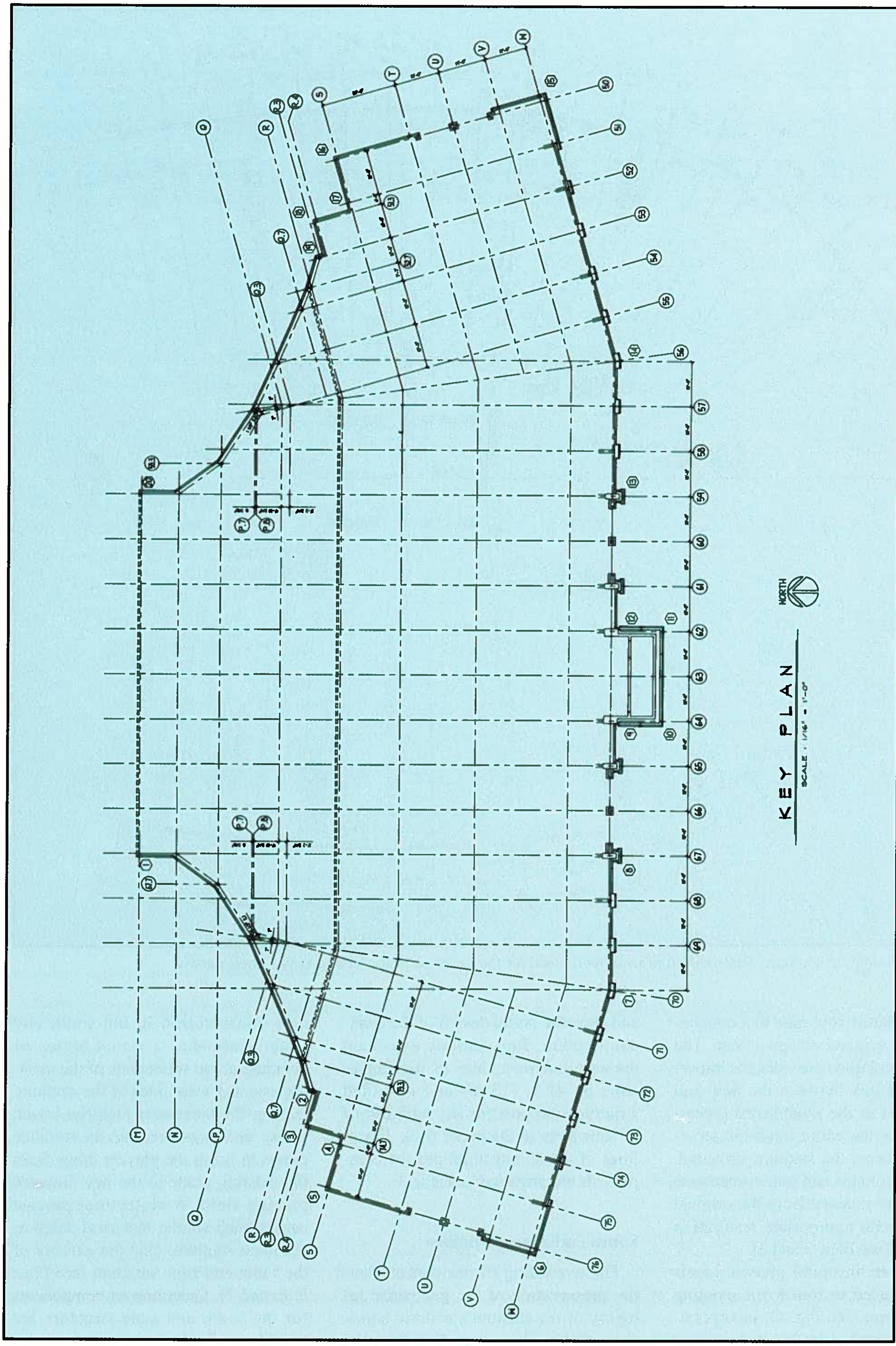

Fig. 5. Plan view of the south end zone expansion.

Fig. 6. The Horseshoe's original footprint is retained via an architectural break at the opening to the south end zone. (Photograph © 2002 Brad Feinknopf, Feinknopf Photography)

STRUCTURAL PRECAST INFIELD CONSTRUCTION

Infield precast concrete work was performed by the Prestress Division of Rinker Materials.* Rinker was responsible for all precast layouts, sections, and component shop drawings in-house. FRP, Inc., a local Indianapolis structural engineering firm, executed precast concrete member and connection designs. The total contract for the infield precast concrete was $6.4 million. Table 4 shows the different components that were used on the project, and Table 5 outlines the production and erection timetable.

Lower AA Deck Construction

Placing spectators closer to the action, the new Lower AA Deck was constructed entirely of structural and architectural precast components. Before installation of the new lower level precast seating, the playing field was excavated and lowered 14 ft (4.3 m). This included the removal of the Jesse

* The original company, American Precast Concrete, Inc., was purchased by CRS American in 1999, becoming CRS American Precast Concrete. The name changed to Rinker Materials in 2002.

Fig. 7. Aerial view of the Ohio Stadium, looking west to the Olentangy River and showing south end zone entrance ramps and the narrow erection access on the east side of the stadium.

Table 4. Concrete components for infield and upper deck.

Component	Number of components	Weight, tons (Mg)
Upper risers	224	2651 (2404)
Lower field risers	797	2972 (2696)
Tub units	92	302 (274)
Upper raker beams	21	512 (464)
Upper edge beams	14	204 (185)
Lower support walls	70	646 (586)
Walls and railings	243	1043 (946)
South end zone panels	117	390 (354)
South end zone stair units	50	179 (162)
Total	1628	8899 (8071)

Note: 1 ton = 0.91 Mg.

Table 5. Infield and upper deck precast production and erection schedule.

Production and erection schedule	Start date	Completion date
First phase production	December 1999	May 2000
First phase erection	March 2000	June 2000
Second phase production	December 2000	February 2001
Second phase erection	January 2001	March 2001

Fig. 8. Erection of the structural precast concrete raker beams at the excavated Lower AA Deck.

Fig. 9. Precast concrete erection moves simultaneously down from the north end zone.

Owens Track that encircled the playing field and ran underneath the existing portable south end grandstands. (The Jesse Owens Track was rebuilt in a new campus facility.)

Excavation began immediately after the last home football game in 1999, with removal of the goalposts, as earth-moving equipment began round-the-clock excavation. The lower infield walls and a significant portion of the existing lower seat deck was demolished, allowing room for the placement of the new precast walls, vomitories, and risers.

The designers reconfigured the seating geometry to improve sight lines for fans at all seating deck levels — namely, the new precast concrete lower deck, the new precast concrete intermediate level (replacing the existing lower deck), and the existing deck above. Precast concrete work began at the north end zone, or the closed end of the Horseshoe, and proceeded southward with both an eastside and westside crane, to speed the installation (see Figs. 8 and 9).

Because the new field level would be about 6 ft (2 m) below the existing groundwater table, a slurry wall had to be constructed immediately in front of the existing seating (outer edge of the running track). The 45 ft (14 m) deep wall made a complete oval inside the stadium, a subgrade barrier wall 2009 ft (612 m) long, going down to bedrock. (See Slurry Wall Construction sidebar, p. 58.)

With the completion of the slurry wall, demolition and cleanup crews carried out their work, and precast erection proceeded rapidly down both sides of the stadium simultaneously from the north to meet tight schedule deadlines. As precast erection proceeded, work on the engineered turf system could begin. Due to the drainage piping and turf system, no construction equipment or trucks were allowed beyond the point of the advancing precast erection (see Figs. 10 and 11).

Inside and immediately infield of the now-exposed upper slurry wall, the new precast risers were supported on precast walls. To reduce schedule time, trenches were dug for foundations and the walls were then erected by shimming on top of concrete masonry units. With the walls temporarily braced, concrete was placed around and under the base of these walls for permanent support. Riser erection proceeded quickly behind the footer pours (see Fig. 12).

Jobsite access was very restricted. Bound by the slurry wall, front precast field wall, and precast risers above, the only access to the area under the risers was from the one construction opening at the far north end of the stadium. Because of the lack of adequate ventilation and for other safety reasons, welding was not allowed on the underside of these risers. Most riser connections were performed from the top side.

Scheduling did not allow for field verification between demolition and infield precast erection. The structural drawings included an *x-y* coordinate system for existing columns and walls. Renovations to an existing structure, especially an old historic one, can be challenging, since as-built drawings are not always available for reference. Extra tolerances were allowed around the slurry wall for the precast support walls.

The short raker beams that support precast risers outside the slurry wall had to line up with the existing columns so that new lower vomitory walls could be erected in correct locations. Riser joints on the new precast raker beams were not always perfectly centered on existing beams, but the overall fit-up was very good and erection proceeded quickly. Both east and west sections of the lower deck precast construction were installed in just 12 weeks.

Fig. 10. New playing surface, excavated down 14 ft (4.3 m), places the playing field almost 6 ft (2 m) below the groundwater table.

Fig. 11. Once the initial construction for the engineered turf drainage system began, no construction equipment was permitted on the stadium infield.

UPPER C DECK CONSTRUCTION

For the new 19 rows of seats on the east and west sides, cast-in-place concrete was used for the construction of columns and platform to the top of the existing stadium. Above this platform, precast "stepped" raker beams and triple risers were used. The upper deck was erected on the elevated cast-in-place platform. For the press box, constructed of steel framing, transverse trusses were assembled on the ground and lifted as one piece.

Erection of precast elements at the press box area on the west side proved to be a challenge. Some of the longitudinal steel bracing members had to be temporarily left out to allow for crane lines for erection of the precast risers. Balancing the necessary amount of longitudinal bracing with erector requirements was a delicate operation (see Figs. 13 and 14).

Triple Precast Risers

The precaster chose to use triple risers instead of double risers for the upper decks (see Fig. 15). Typical riser span was 40 to 45 ft (12 to 14 m) long. Based on the good experience on a previous job using triple risers, the precaster felt that using precast raker beams allowed good control of the bearing surfaces for more accurate and even support to all legs. The oval shape of the stadium meant that all the column lines fan outward radially. Therefore, all risers had skewed ends with many risers presenting different skew angles at opposite ends of the same riser.

The advantages of using triple risers included reductions in the required amount of joint caulking and number of riser-to-riser connections, faster erection, and one-third fewer component truckloads to transport to the site. Shipping permits allowed only one-

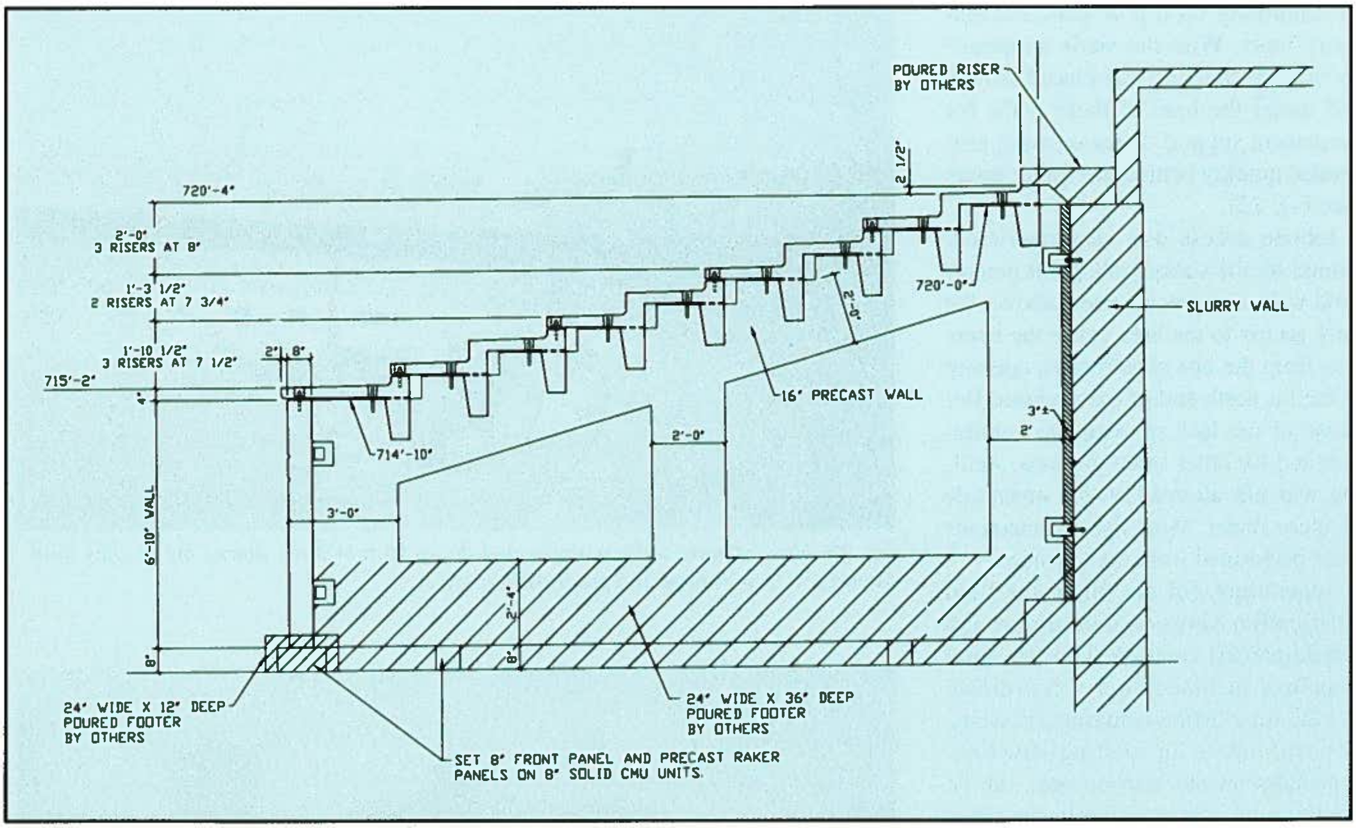

Fig. 12. Section through Lower AA Deck, showing the slurry wall.

SLURRY WALL CONSTRUCTION

Lowering the field by 14 ft (4.3 m) between the 1999 and 2000 seasons was the most technically challenging aspect of the stadium renovation and expansion, a technique not previously used in Columbus, Ohio. Because the Olentangy River historically flowed through the current site and was diverted for the original stadium construction, the underground sand and gravel layer continued to allow groundwater to flow under the stadium just 6 ft (2 m) below the old playing surface.

The slurry wall extended from its surface grade elevation down to bedrock and formed a barrier surrounding the field. Construction involved digging a 2009 ft (612 m) long trench 2 ft (0.6 m) wide by 45 ft (14 m) deep around the entire inside field where the Jesse Owens Track was removed. The trench was dug in alternating 19 ft (5.8 m) sections by cranes using narrow clamshell buckets.

In order to keep the trench from caving in, it was filled with a mud-like slurry mixture of bentonite clay and water, which equalized the pressure in the trench and stabilized the earth on either side. Once the excavation keyed 1 ft (0.3 m) into bedrock, a cage of steel reinforcing bars was lowered into the bentonite slurry, after which concrete was pumped down into the bottom of the trench. The heavier concrete filled the trench from the bottom and displaced the slurry out of the top, where it was pumped into tanks for de-sanding and reuse in the next wall section.

The cutoff wall was completed during the summer of 1999, and that fall marked the last football season played on the elevated field. Immediately after the last game in November, the water trapped underground inside the cutoff wall was pumped out and the field excavated down 14 ft (4.3 m) to its new lower level. The new drainage systems, turf, and new precast AA Deck seating were installed in less than 6 months for the start of the 2000 season.

piece loads to be overweight, and since two double risers would have been too heavy, they would have had to be shipped as two separate loads.

The 19 rows for the east side upper deck seating were installed in seven weeks, with the exterior architectural fascia panel crew following right behind. Use of the precast triple risers saved critical schedule time and erection and transportation costs.

DESIGN ELEMENTS

The major precast concrete components used on this project are described in this section.

Infield Precast Construction

All risers were prestressed for deflection and crack control. Most risers maintained the L-shape at the end bearings, but had heels added to increase structural depth for load capacity and vibration control. The new Lower AA Deck both increases the stadium's seating capacity and gives the home team a more competitive edge by drawing the fans closer to the action.

Buckeye Logo

One of the most attractive and owner-pleasing elements of the precast panels that make up the inner perimeter fascia walls is the OSU traditional "Block O" logo cast into the pieces at every column line (see Figs. 16 and 17).

Out-Build Precast Construction

To create entrance and egress points every 20 ft (8 m) along all elevations, the original archways were carried to grade level, a major improvement for stadium traffic and pedestrian patterns. (These multiple pedestrian portals were a classical design from the Roman Coliseum used by the original architect.) As on the original wall, the new architectural precast wall presents a horizontal intermediate cornice, or belt course, that breaks up the massiveness and verticality of the wall.

Old Versus New Look

The materials, textures, and finishes of the architectural precast façade achieve a monolithic, simple character similar to that of the original Romanesque exterior. The new construction intentionally does not match the original, so that the difference between old and new is clearly apparent (see Fig. 18).

The south end zone structure, in particular, was of a different architectural design to avoid a massive appearance that would compete with or overshadow the character and style of the original stadium. The design of the south structure maximizes the views of the trademark Horseshoe walls and corner towers (see Fig. 19).

The slenderness of the new precast concrete wall – 6 to 16 in. (152 to 406 mm) – contrasts with the massiveness of the cast-in-place concrete of the original structure. By intent, the new precast elements are contemporary in design and serve to complement, rather than compete with, the old construction; there were no attempts to make the new precast exterior look "old" or weathered.

Exterior Precast Finish

Entrance portals received a "bush-hammered" finish to match the same design appearance as the existing façade. The outer precast walls were sandblasted to blend with the existing concrete. The textured, bush-hammered precast finish works particularly well with the original historic look of the north rotunda (see Figs. 20 and 21).

Fig. 13. Cast-in-place concrete columns and platforms provide structural support for precast expansion for the new Upper C Deck.

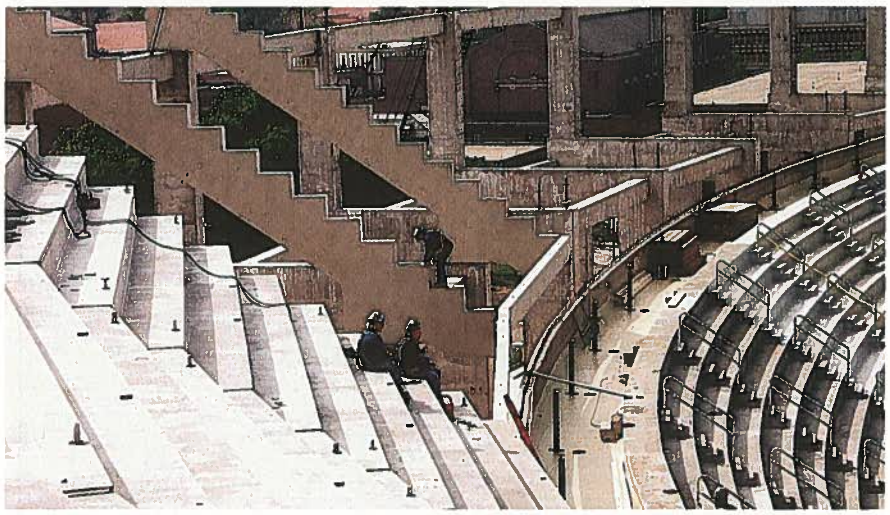

Fig. 14. Triple precast structural concrete risers provided erection efficiency and cost savings in the construction of the added 19 stadium rows.

Design Code

The structural system is a dual system with ordinary moment frame analysis for reinforced concrete and shear walls. The seismic values used for design were hazard exposure Group II and performance Category B. Wind code values used in architectural precast elements of the Ohio Stadium renovation and expansion project were for a basic wind speed of 80 mph (130 km/h) and a design pressure of 16.4 psf (90 kg/m^2). All loading was in accordance with the 1998 Ohio Basic Building Code.

CONSTRUCTION HIGHLIGHTS

Access to the site by construction equipment was severely limited in two ways. First, only one of the down ramps or openings on either side of the south end zone structure was permitted for construction traffic. Over 30 contractors were restricted to this one infield access point.

Second, near the east side of the stadium, there was barely enough room for one crane to set up next to the struc-

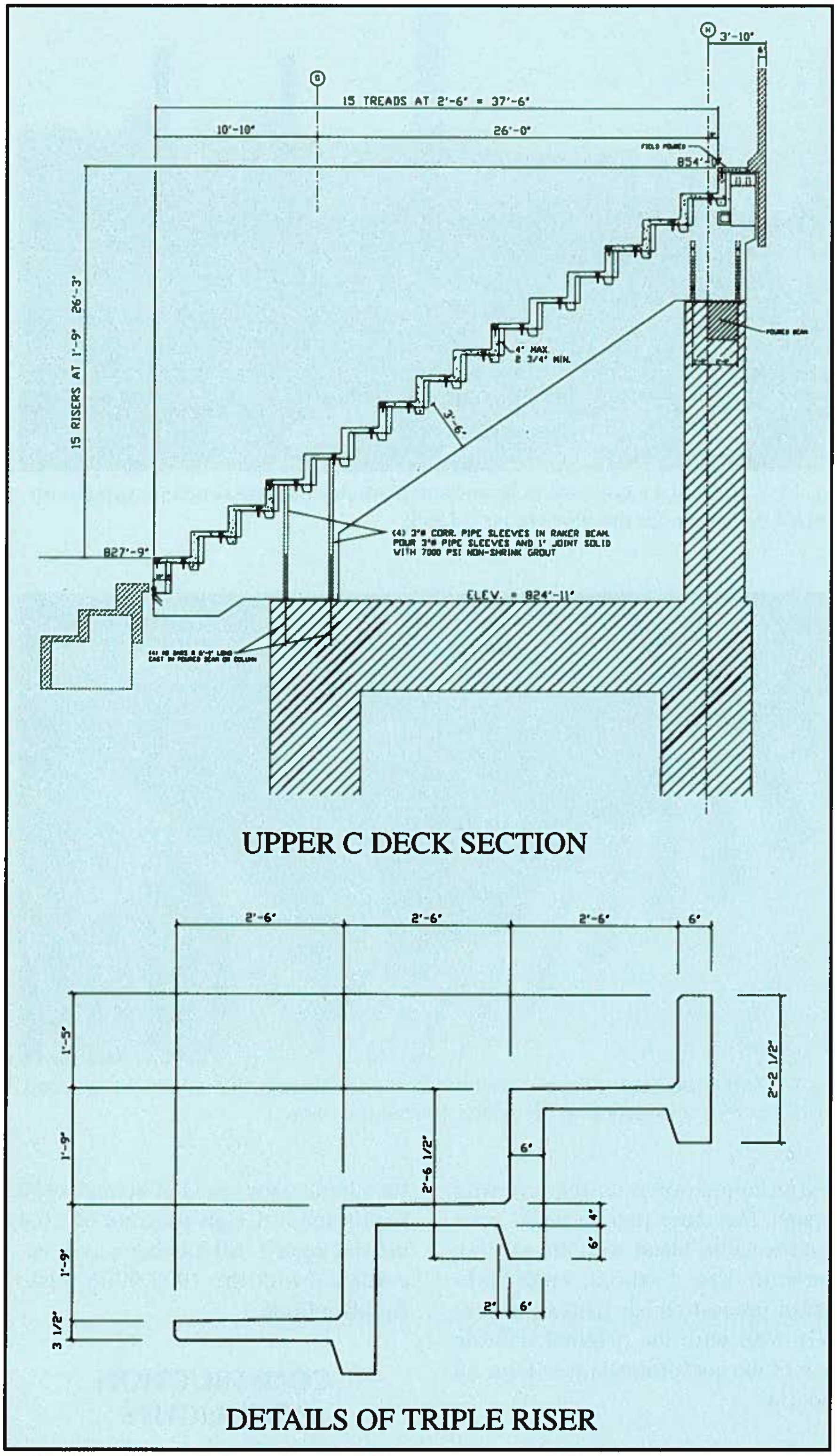

Fig. 15. Upper C Deck section (top) showing how triple risers provided erection efficiencies over original design with double risers.

ture. This meant that, due to the tight schedule of the upper seating and perimeter beam construction, the crane used by the structural precast erector and the crane used by the architectural precast erectors for the shell elements were both positioned in this limited area at the same time. The cast-in-place concrete contractor also had a crane set up in the limited east wall space. The cranes were unable to maneuver past one another during erection.

Restricted site access called for outstanding cooperation and scheduling by all contractors involved in the project. In addition, once the installation of the grass playing surface started, the remainder of the precast erection for both the out-build and the south end zone had to take place from outside of the stadium.

The tight schedule for completion of the initial phase of the contract had to be complete before the first home game in the fall of 2000. The overall schedule covers the activities of numerous trades and contractors. Successfully orchestrating the activities of this many contractors in a demanding and non-negotiable schedule was the accomplishment of Turner Construction Co., project construction managers, in conjunction with all of the prime contractors, particularly Kokosing/P.J. Dick (a joint venture), who was the prime contractor for the entire south end zone general trades package, and Kokosing/P.J. Dick/Baker (a joint venture), who was the prime contractor for the cast-in-place concrete for the main stadium. In the end, the owner was very pleased with the efforts of all involved on the project, and especially with the final result (see Fig. 22).

CONCLUDING REMARKS

The design process for the renovation and expansion of the Ohio Stadium was very complex because construction was phased over a number of football seasons, during which seating capacity and access could not be affected. In essence, this meant that specific structural construction sequences had to be developed to assure ongoing, in-use, structural stability as well as public safety during construction.

Lowering of the field by 14 ft (4.3 m) meant the playing surface would be below the Olentangy River, only 300 yd (275 m) away, and the surrounding water table, requiring construction of an extensive groundwater cutoff wall and drainage system. As a result of this initial work inside the stadium, subsequent construction equipment access and maneuvering room at the site was very limited. To compound the situation, the structural and architectural precast erection had to take place outside the stadium walls once the field

Fig. 16. Architectural precast concrete fascia walls at playing level provided owner-pleasing detailing of the OSU block "O" logo.

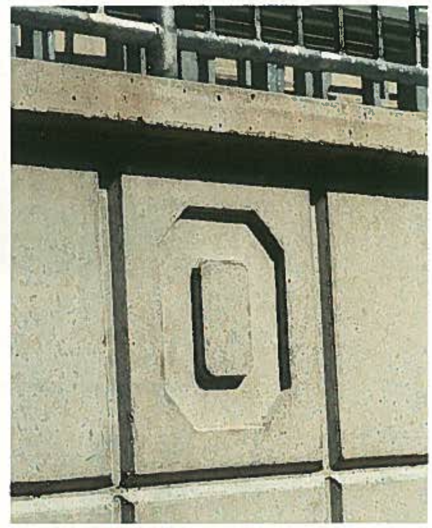

Fig. 17. Close-up detail of team logo letter on infield architectural precast fascia wall.

surface installation began.

The production and erection advantages along with the design flexibility of precast/prestressed concrete ensured that the integrity of the Horseshoe was protected while the project was completed on schedule – all without disruption to the OSU football season or mandated seating capacity – for over three years of construction.

The restoration effort of the Ohio Stadium has been recognized by the International Concrete Repair Institute (ICRI) as the project of the year for 2001.

HORSESHOE FACTS

The original Ohio Stadium was built in the early 1920s at a cost of $1.6 million. At that time, the most popular spectator sport was track and field. Because the 220 yard (200 m) dash was run in a straight line, the south end of the stadium was left open.

Howard Dwight Smith, an OSU graduate architect and stadium designer, spent several years in Greece, and the influence of his experience with the power and line in classical design are evident in the architecture of the stadium's arcaded forms.

The "Horseshoe" was the first collegiate stadium to adapt "lines of sight" in the curved sides for spectator seating, much like the Coliseum in Rome. The double-deck feature allows fans to be closer to the action in the cantilevered upper deck, with the under-deck space used for student activities.

The original walls were made to appear as a curved surface by forming 6 in. (150 mm) wide vertical, chordal concrete segments. The original façade had a smooth form finish.

Two of the four stadium towers flank the historic north rotunda, 100 ft (30 m) high and 72 ft (22 m) in diameter.

The original site required that the Olentangy River be rerouted 300 yd (270 m) westward and the ground dewatered before construction could begin.

The Horseshoe is listed on the National Register of Historic Places, as it was the first cast-in-place concrete stadium ever built and the first to consider sight lines in its design.

At completion of renovation, the Ohio Stadium will have a seating capacity of 101,568 (third highest of college-owned stadiums), ensuring its position as a premier venue for college football well into the 21st century. The University of Michigan and University of Tennessee rank first and second, respectively, in seating capacity at 107,000 and 106,000.

Funding for this $195 million project of renovation and expansion began in 1998 and involved no tax dollars or University monies. Funds from the sale of 82 hospitality suites and 2500 club seats paid for 80 percent of the work. Concession and ticket sales will make up the balance.

Compliance with the Americans with Disabilities Act (ADA), including widening of the aisles and adding restrooms and wheelchair access, meant the loss of approximately 13,000 seats, which was unacceptable to the University. This was the reason for the construction of a new lower and upper deck, which added approximately 20,000 seats to offset the seating loss due to the ADA.

The playing field was lowered 14 ft (4.3 m) to make room for the new Lower AA Deck. Using a slurry wall construction, a reinforced concrete wall, 2 ft (1.7 m) thick and over 45 ft (14 m) deep, and 2009 ft (612 m) long encircles the playing field down from the lower deck level into bedrock. In conjunction with an elaborate drainage and pumping system, this barrier keeps the high water table from entering the stadium substrata.

Fig. 18. New architectural precast wall panels blend the powerfully arcaded forms of the stadium expansion with the "old" architecture of the north rotunda.

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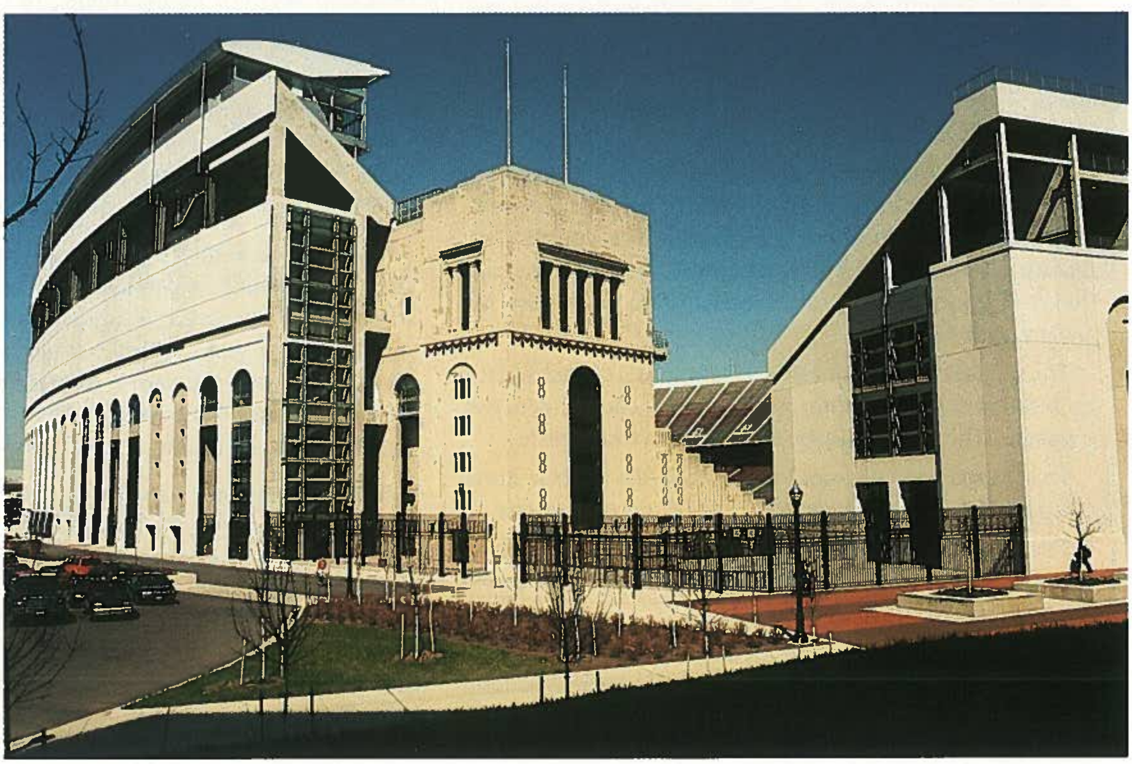

Fig. 19. View of the southwest tower. The new architectural precast south end zone building was designed to appear separate from the historic form of the original stadium.

CREDITS

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University Architect: OSU Office of Facilities Planning and Development, Columbus, Ohio

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Associate Architect: Design Group, Columbus, Ohio

Construction Manager: Turner Construction Company, Worthington, Ohio

Architectural Precast Contractor/Producer: Concrete Technology, Inc. (CTI), Springboro, Ohio

Structural Precast Contractor/Producer: Rinker Materials Prestress Indianapolis Plant, Indianapolis, Indiana

Prime Contractor: Kokosing/P.J. Dick, a Joint Venture: Kokosing Construction Co., Fredricktown, Ohio; P.J. Dick Inc., Pittsburgh, Pennsylvania

Hollowcore Precast Producer: Hollowcore, Inc., Detroit, Michigan

Fig. 20. Entrance portals were given a bush-hammered finish to work in aesthetic harmony with the older existing cast-in-place concrete.

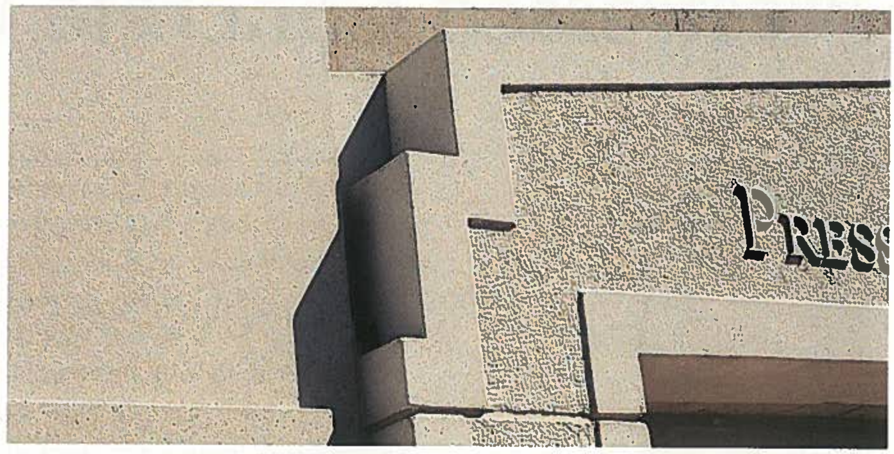

Fig. 21. Bush-hammering finish detail at the press entrance to the stadium.

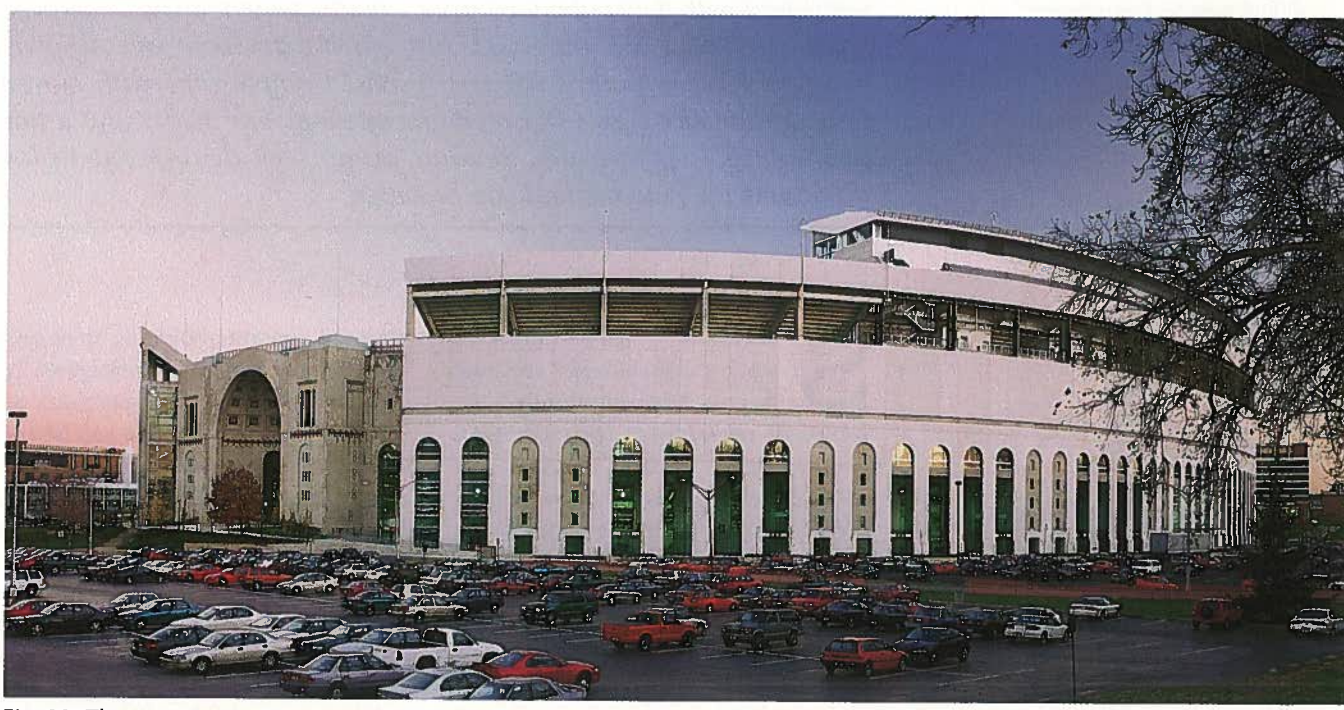

Fig. 22. The new precast exterior serves to complement, rather than compete with, the existing construction. (Photograph © 2002 Brad Feinknopf, Feinknopf Photography)