Located in Eugene, Oregon, Autzen Stadium at the University of Oregon is one of the premier collegiate football venues in the United States and home of the Oregon Ducks. The continued success of the football program impelled the University to upgrade the stadium facilities to meet the demands of a top-level competitor in NCAA Division I athletics. In less than nine months, over 25,000 lineal ft (7600 m) of seating, 32 new luxury suites, and a private 3000-seat club and lounge level were created. The use of a precast concrete system allowed completion of the stadium expansion and renovation work in record time without interruption to the scheduled athletic program. This article explains how project design challenges and high production levels were achieved within an unremitting construction timetable.

Autzen Stadium is one of the premier collegiate football venues in the United States. Located on a 90-acre (36 ha) site on the University of Oregon campus, just north of the picturesque Willamette River in Eugene, Oregon, Autzen Stadium was originally constructed in 1967 at a cost of $2.5 million. The old stadium consisted of an earth-filled bowl with a cantilever roof designed to protect 1000 people, most of whom were stadium sponsors.

In recent years, the continued success of the college’s football program fueled the University’s desire to significantly upgrade and expand the stadium facilities to meet the demands of a top-level competitor of NCAA Division I athletics. Home to the University of Oregon Ducks football
team, Autzen Stadium is noted as being one of the nation’s most intimidating collegiate stadiums (see Fig. 1).

Two main ideas were essential for the successful realization of the University’s vision for this project. First, the stadium’s architecture had to make a bold visual statement while maximizing functionality. Second, stadium construction could not adversely affect the current or upcoming football seasons. The owner’s mandate for fast-track project delivery required all demolition and on-site construction to be carried out between the last game of the 2001 season on December 2 and the first game of the 2002 season on August 27. The use of precast concrete building components allowed both criteria to be met.

The three-year design and documentation process, led by the architectural firm of Ellerbe Becket of Kansas City, Missouri, produced an expansion and renovation solution that added 12,000 seats and renovated 18,000 of the original stadium’s 42,000 seating capacity. A private, elevated club level was also constructed to support enhanced concession services and a 20,000 sq ft (1858 m²) public lounge, as well as spectacular views of the Willamette River Valley. Two levels in the new press tower contain 32 private suites, while the topmost level is dedicated to supporting media operations (see Fig. 2).

At a finished height of 170.25 ft (51.9 m), the completed structure stands almost 14 stories tall. Over 15,000 cu yd (11,470 m³) of concrete and 1612 precast concrete pieces were used in the stadium expansion project.
The total project cost for demolition, renovation, and expansion of the Autzen Stadium was about $90 million. The precast concrete portion of the contract was $6.9 million. Tables 1 and 2 list the precast concrete components and project schedule.

### Table 1. Type and number of precast concrete components.

<table>
<thead>
<tr>
<th>Precast component</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns</td>
<td>59</td>
</tr>
<tr>
<td>Y-columns</td>
<td>28</td>
</tr>
<tr>
<td>Raker beams</td>
<td>68</td>
</tr>
<tr>
<td>Stairs</td>
<td>32</td>
</tr>
<tr>
<td>Risers</td>
<td>432</td>
</tr>
<tr>
<td>Wall panels</td>
<td>119</td>
</tr>
<tr>
<td>Vomitory panels</td>
<td>113</td>
</tr>
<tr>
<td>Beams</td>
<td>120</td>
</tr>
<tr>
<td>8 in. hollow-core slabs</td>
<td>74</td>
</tr>
<tr>
<td>12 in. hollow-core slabs</td>
<td>393</td>
</tr>
<tr>
<td>Spandrels</td>
<td>57</td>
</tr>
<tr>
<td>Miscellaneous components</td>
<td>117</td>
</tr>
<tr>
<td>Total number</td>
<td>1612</td>
</tr>
</tbody>
</table>

Note: 1 in. = 25.4 mm.

### Table 2. Project schedule for the construction.

<table>
<thead>
<tr>
<th>Construction element</th>
<th>Start date</th>
<th>Completion date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>March 1999</td>
<td>March 2001</td>
</tr>
<tr>
<td>Excavation work</td>
<td>November 2001</td>
<td>December 2001</td>
</tr>
<tr>
<td>Precast production</td>
<td>September 2001</td>
<td>March 2002</td>
</tr>
<tr>
<td>Precast erection</td>
<td>January 2002</td>
<td>April 2002</td>
</tr>
<tr>
<td>Demolition</td>
<td>November 2001</td>
<td>January 2002</td>
</tr>
<tr>
<td>Construction</td>
<td>December 2001</td>
<td>August 2002</td>
</tr>
</tbody>
</table>

Fig. 3. The original stadium, circa 1967. The plan mimicked the Oregon “O” logo and the cantilever roof canopy protected approximately 1000 stadium sponsors.

The existing structure had an unusual geometric plan; when seen from above, the plan mimicked the standard “O” logo used by the University as an identifier (see Fig. 3). The architectural design of the new Autzen Stadium needed to accommodate significant expansion – a capacity increase of almost 30 percent – and at the same time produce bold lines and dynamic original forms. The final design needed to create a venue with increased seating capacity, yet retain the stadium’s original sense of intimacy with the gridiron action.

Because of the massive scale of the proposed structure and its projected service and upkeep requirements, materials for the expansion were selected with an eye towards creating a facility that could be easily and economically maintained for many seasons to come. The exposed structure of the seating bowl is fabricated of structural and architectural precast concrete, forming a graceful curve that effectively extends the existing seating bowl configuration while preserving the intimate feel of the original single-bowl concept.

### Engineering and Analysis

Ellerbe Becket’s engineers and architects carried the project through the design and development phase, and presented various preliminary schemes to the University. Haris Engineering of Overland Park, Kansas, assumed responsibility for the structural engineering and provided the engineer of record after the design and development phase was completed. The firm continued to oversee the project through the completion of construction.

A complete three-dimensional structural analysis and design was performed for the side structures and center tower using the STAAD 3 general analysis and design program. Because the project inherited plan and geometric irregularities induced by the original stadium configuration, the spectral dynamic analysis that was used followed the State of Oregon Structural Specialty Code, which is based on the 1997 edition of the Uniform Building Code (UBC). The geotechnical study for the site revealed that the site-specific acceleration response spectrum was smaller than the UBC spectrum for the local soil type in Seismic Zone 3.

The UBC spectrum was used for the
elastic dynamic analysis. Nearly 100 vibration modes were included in the analysis to capture 90 percent of the participating mass of the structure in calculating the response for each principal horizontal axis. Basic loads included gravity dead and live loads, wind loads, seismic dynamic loads, and thermal change effects.

Two sets of load combinations were created for the design. One set for the LRFD steel design included a special load combination for the steel column design with amplified seismic loads. The second load combination was used for the concrete member design. The seismic loading was the major load governing the design of most members, both steel and concrete, along with the dead and live loads.

The precast concrete seating units were modeled as shell elements, and the resulting diaphragm’s shear forces were used to design the connections between the precast concrete units and the support rakers. The concrete columns and rakers were initially sized based on a simplified gravity analysis for the model’s input data.

Based on the results of the analysis, the members were redesigned in order to arrive at realistic cross-sectional dimensions, and then the model’s input data were updated. Several iterations were performed to determine the final precast concrete member sizes. The dynamic analysis was sensitive to column and raker dimensions with respect to both stiffness and mass changes.

Additional mathematical models were produced for the vibration analysis under live loads. Once the final sizes of the concrete and steel members had been determined, SAP 2000 Models were produced for plane frames, with lumped masses at several joints along each member. Dynamic (forcing) function coupled with a live load of 32 psf (156 kg/m²) were used for the excitation dynamic analysis according to the 1990 National Building Code of Canada (NBCC) and AISC Steel Design Guide No. 11.

In addition, the end of the steel cantilevers at the suites and press levels, the back of the cantilever precast concrete rakers, and the midspan of the rakers were analyzed for vertical acceleration caused by spectators’ rhythmic excitation movements during a sporting event. The acceleration results were kept below the maximum values recommended by NBCC; these results equaled 5 percent of the ground acceleration.

Columns and Architectural Design

Precast concrete elements fabricated for the project include the entire seating bowl assembly, as well as the base of the press tower structure. The seating bowl is composed of a series of el-
egant Y-shaped precast concrete columns spaced around the circumference of the facility, braced by galvanized steel tubes supporting stepped seating units spanning up to 40 ft (12 m) between the columns (see Figs. 4 and 5).

The exterior backside of the seating bowl is enveloped in a continuous ribbon of 8 in. (203 mm) thick architectural precast concrete panels that rises gracefully with the height of the bowl, and flanks the towering press tower structure at the center. Architectural precast façade panels simulating “buff limestone” in color and texture clad the south façade of the press tower and the exit stairs. All structural precast concrete elements exposed to weather are treated with a 100 percent penetrating silane sealer to provide protection from the typically moist environment and rainy conditions of the Pacific Northwest.

**PRECAST CONCRETE SYSTEM**

Precast concrete was the only option that would address the needs of the tight construction schedule, structural challenges, and architectural effects required for the expansion of the University’s stadium. Precast concrete component design and construction were the assigned responsibility of Morse Bros., Inc., of Harrisburg, Oregon, the precast concrete supplier.

Morse Bros. retained The Consulting Engineers Group, Inc., of San Antonio, Texas, to design and detail all precast pieces. The engineer of record for the project, Haris Engineering, supplied the connection forces.

The geometry of the stadium’s original plan complicated not only the contract documents with regard to dimensions, but also the verification of those actual dimensions at the site (see Figs. 3 and 6). The architect created some additional design and fabrication challenges by specifying that the precast concrete connections be hidden from view for reasons of aesthetics, durability, and ease of maintenance.

Two expansion joints were utilized to reduce the thermal effects. Expansion joints near the goal lines created three independent lateral load resisting systems. Lateral resistance in the end sections was provided by precast concrete frames in one direction and a combination of precast and cast-in-place (CIP) shear walls in the opposite direction. The center section relied on a CIP shear wall for lateral resistance, with precast framing providing vertical support.

Fig. 7 shows a typical frame used in the end sections. This innovative system utilized the stiffness of the Y-shaped columns, with the sloped geometry of the raker beams to provide lateral resistance. As many as 27 post-tensioned strands, \( \frac{1}{2} \) in. (12.7 mm) in diameter, were used along the length of the rakers to transfer axial tension and bending moments across the joints. Temporary bolted connections were used to allow the erection of seating units before the grouting of raker joints and post-tensioning operations (see Figs. 8 and 9). Dead end an-
chors were cast into the back raker, and all post-tensioning was performed from the lower front end. Access holes cut into the precast panels in front of the rakers allowed for stressing operations after erection.

To minimize conditions conducive to rust formation, column-to-foundation connections were made with reinforcing bar dowels projecting from the base of the column; these dowels slipped into corrugated sleeves embedded in the foundation. Rakers were attached to columns using a combination of reinforcing bar splice sleeves and Dywidag bars. The Dywidag bars were placed into sleeves running vertically through the raker beams and threaded into couplers at the top of the columns. The sleeves were fully grouted to prevent corrosion.

**PRODUCTION AND CONSTRUCTION**

A very tight construction schedule for the Autzen Stadium expansion was crucial for the success of the project. Originally, November 19, 2001, was set as the date for demolition of the south side press and suite levels, the upper portion of the concrete treads and risers, and the south middle section of the concrete seating area. The demolition was delayed two weeks to allow the traditional Oregon versus Oregon State football game to be nationally televised.

The big push to construct Autzen Stadium began hours after the conclusion of that contest in early December. On the following Sunday, the stadium seating and concessions equipment were removed and structural demolition began. The mass excavation of 65,000 cu yd (49,700 m³) of earth started five days later (see Fig. 1).

Within only a few weeks, soil excavation, formwork, reinforcing bar installation and the concrete foundations for the south side of the stadium were underway. Construction and erection crews worked ten hours a day, six days a week, and continued with this demanding schedule until the newly expanded stadium was ready for the opening of the following football season. Most of the Autzen Stadium expansion and renovation project was completed in just nine months between the 2001 and 2002 football seasons.

**Intense precast production schedule** – The Autzen Stadium expansion project presented many initial challenges for the precaster, Morse Bros. Each of the 1612 precast concrete pieces had to be carefully planned, issues surrounding the intense production schedule had to be addressed, fabrication questions remained to be answered, and transportation issues awaited resolution (see Table 1).

Because a majority of the project’s success was dependent upon timely
delivery of precast products within a narrow window for construction, Morse Bros. was brought on board up front, during the design phase. Involving the precaster and the precast engineer in the design process proved to be very beneficial, as many connection issues were addressed early on, including difficulties with a major raker-beam connection.

Raker-beam connection details in the original structural drawings called for large embeds and a substantial number of welds. Morse Bros. design engineers suggested post-tensioning the raker beam sections together to create the connection-free look requested by the architect, while providing the required structural strength.

To meet the tight production schedule, Morse Bros. increased their plant personnel by 270 percent, from 60 to 160 employees. Schedules for most of the workers were increased from five days per week to six or seven days per week. Production conflicts with another project being produced concurrently required Morse Bros. to team up with Concrete Technology Corporation, a precast partner located in Tacoma, Washington, to ensure that the casting of the beams for this project remained on schedule.

Producing a large volume of products in such a short time was perhaps the most challenging aspect of the production process. Because of the time constraints, all casting forms had a one-day turnaround; this required the use of high range water reducers and concrete accelerators to ensure that the release strengths were reached the morning following casting operations.

The construction of Autzen Stadium actually began two months prior to the demolition phase with the production of the precast concrete components. Extensive use of structural and architectural precast concrete was incorporated into the stadium expansion in order to meet the project’s aggressive construction schedule. Since precast erection was slated to last only 12 weeks of the nine-month construction schedule, the 1612 precast components needed to be produced well ahead of time (see Tables 1 and 2). The first precast column was erected on January 28, 2002.
**Transportation constraints** – More than 1200 truckloads were required to ship the 1600-plus precast concrete pieces, resulting in a unique set of logistical hurdles for the precaster’s transportation department. Coordination between Morse Bros. transportation staff and the erection contractor was crucial, as two cranes at the job-site had to be continually supplied with components.

The large and heavy precast elements required special handling and were subject to restricted shipping conditions that permitted transport only during specified times of the day. Special tractor and trailer configurations were devised to accommodate the extra number of axles required to deliver the heavy loads to the project site (see Fig. 10). From 18 to 20 trucks per day made the 25 mile (40 km) trip from the precast facility to the construction site.

**Y-shaped columns** – One of the biggest project challenges for the precast team was the production, handling and erection of the Y-shaped columns (see Fig. 11). With lengths exceeding 57 ft (17.4 m), the columns were dimensionally too large to transport in one piece. The sloping profile of the stadium also varied the dimensions of the columns and raker beams along each side. A perfect fit was required between the leg of the “Y” and the main body, which was designed with protruding reinforcing bars. The precaster utilized a match cast system, using a form that could be jacked apart.

Advanced planning and cooperation between construction team members resulted in minor modifications to the Y-columns to allow the production of all pieces in one adjustable fabrication form. Match casting was used to split the Y-columns into two pieces for hauling with an invisible zero joint after reassembly in the field. Special temporary bracing and shear keys cast into the match joint facilitated fit-up, while an epoxied joint provided uniform transfer of compression forces (see Fig. 12).

Two rows of 24 in. (610 mm) diameter galvanized steel pipe braced the Y-columns about the weak axis while acting as a seismic tie strut to transfer seismic loads to end shear walls. The
struts were connected to the raker beams with through-bolts in sleeves which had been cast into the raker (see Figs. 13 and 14).

Connections and seating skews – Seating units were interconnected by a bolt thread that projected from the lower riser unit into a grouted hole in the tread of the unit above. Bolt spacings as tight as 24 in. (610 mm) on center were required in some areas to transfer the required seismic force. The seating units were attached to the rakers by threaded dowels field drilled and epoxied into the rakers through holes in the tread of the seating units that were later fully grouted. A compressible bond breaker was placed over the dowels at the expansion end to allow for longitudinal movement. Vomitory and bulkhead walls were attached at the base with projecting dowels grouted into holes in the CIP slabs (see Fig. 15).

Another potential connection problem involving the rakers was solved by the precast engineer. The original design called for large connection plates to pass through the rakers, each of which was to receive 24 in. (610 mm) diameter steel seismic struts. These plates required a 12-bolt pattern which could not physically be installed due to reinforcement congestion in the rakers. To resolve the problem, the precaster increased the size of the bolts and substituted a plate with an eight-bolt pattern.

At the top of the bowl, precast concrete spandrels were used to support the upper seating units as well as to provide an architectural band on the exterior of the structure. The southern stairwell walls were acid-washed to a buffed limestone finish (see Fig. 16). The seating bowl elevations required 12 different rise-and-run configurations for the precast seating units. Detailing and production of the units were complicated by the variety of skews required in the structural layout, which ranged from 4 to 75 degrees. Seating units were handled with coil inserts cast into the face of the risers (see Fig. 17). Morse Bros. solved the skewing problem by utilizing four variable riser forms.

Three-dimensional detailing was utilized at skewed stepped areas to obtain...
proper support beam profiles and stepped bearing dimensions. A steel frame interfaced with precast concrete at the club level provided the structural support for the skybox levels, the press level, and the massive cantilever roof.

As mandated by the University of Oregon, the stadium expansion project was completed in the summer of 2002, in time for the start of the fall football program.

**CONCLUSION**

Charlene Lindsay, project manager for the University of Oregon, explained that despite the challenges of the unremitting schedule, the precaster delivered “a very high quality product on time and on budget.” The Autzen Stadium Project “has been a great success for the University and its athletic program,” Lindsay claims, thanks to the “precast seating bowl design that made it possible to start fabrication long before the site was ready for the first seating risers.”

Precast concrete was a natural choice for a project of this scale, level of complexity, and short construction time frame. A precast concrete system incorporated both structural and architectural concrete elements into the conceptual design. The end result is a

---

Fig. 18. The completed Autzen Stadium is an example of the versatility and beauty of precast concrete systems.

Fig. 19. Aerial photograph of the south entrance shows the completely renovated Autzen Stadium receiving football fans prior to game time.
stadium facility possessing strength and long-term durability, while providing the owner with ease of maintenance in a bold design with an awe-inspiring appearance.

The entire Autzen Stadium design provides the University of Oregon with one of the most magnificent college football stadiums in the United States. University alumni, students, and fans can be proud to host their football rivals at Autzen Stadium for many seasons to come (see Figs. 18, 19 and 20).

**ACKNOWLEDGMENT**

The authors extend their appreciation to Charlene Lindsay, Project Manager, and Steve McBride, Associate Athletic Director, at the University of Oregon for their contribution in making the Autzen Stadium expansion and renovation a success.

**CREDITS**

Owner: The University of Oregon, Eugene, Oregon

Architectural and Structural Engineers: Ellerbe-Becket, Kansas City, Missouri

General Contractor: Hunt-Wildish JV, Phoenix, Arizona

Engineer of Record: Haris Engineering, Inc., Overland Park, Kansas

Precaster: Morse Bros., Inc., Harrisburg, Oregon

Hollow-Core Precast Producer: Morse Bros., Inc., Harrisburg, Oregon

Specialty Precast Engineer: The Consulting Engineers Group, Inc., San Antonio, Texas