2012 Outstanding Infrastructure Project

California Memorial Stadium

By Nur Kasdi and Larry Totten

Fig. 1: Overview of the existing historic walls during demolition and excavation. A layer of shotcrete was later applied over the existing walls in various thicknesses from 5 to 36 in. (127 to 914 mm)

Fig. 2: Type 1 preconstruction test panel was composed of three curtains of No. 10 (No. 32M) and No. 9 (No. 29M) reinforcing steel with additional boundary reinforcing bar elements

Since 1923, California (Cal) Memorial Stadium in Berkeley, CA, has been the home of the University of California (UC) Berkeley's football team. Modeled after the Roman engineering marvel of the Colosseum, the oval stadium is situated above the surrounding landscape on Berkeley's hillside and features panoramic views of the San Francisco Bay Area. Due to its age and historical significance, in November 2006, Cal Memorial Stadium was included on the National Register of Historic Places.[1]

While the stadium seemingly disregarded almost a century of time and remains in remarkable condition for its age, the seismicity risks in the area are a constant concern. Positioned directly on top of the active Hayward Earthquake Fault, which runs roughly from end zone to end zone, the stadium is subjected to annual horizontal fault "creep" of up to 0.20 in. (5 mm). During significant seismic events, the ground along the fault could displace up to 6 ft (1.82 m) horizontally and 2 ft (0.61 m) vertically—with potential catastrophic impacts on the structure.[2]

Cal Memorial Stadium was in critical need of not only a seismic retrofit but also an upgrade to modern standards. In late 2010, UC Berkeley responded by apportioning $321 million for the Memorial Stadium improvements, with work scheduled to start in January 2011. In preparation, the California Golden Bears football team was temporarily moved to the AT&T Park in San Francisco for the duration of the 2011 football season. The stadium reopened in fall 2012.

Work Scope

A unique feature to the project was that while the majority of the existing structure was demolished and reconstructed, the outer perimeter wall had to remain in place to preserve the historic landmark.

Johnson Western Gunite (JWG), a Superior Gunite Company, was assigned the task to install a heavily reinforced shotcrete layer over the historic wall for seismic strengthening. The shotcrete overlay varied in thicknesses from 5 to 36 in. (127 to 914 mm). Because the majority of the wall surfaces were exposed, a steel trowel finish was required. The base contract volume was approximately 4000 yd^3 (3058 m^3).

In coordination with the concrete general contractor, JWG presented the owner with value engineering proposals for the majority of the new vertical cast-in-place concrete walls on the project. By substituting the cast-in-place method with the shotcrete method, the owner attained significant cost savings while maintaining both quality and project schedule activity durations.

As a result, the shotcrete scope doubled in volume through the addition of the following work: retaining walls, shear walls, miscellaneous interior walls, and a new loading dock building structure adjacent to the existing stadium.

Project Challenges

Like other shotcrete seismic retrofits, there were several challenges to the high-profile Cal Memorial Stadium retrofit project. First, because the project had a tight deadline schedule with a 6-day work week and double work shifts, the stadium was split into three work areas. Consequently, JWG had to coordinate multiple shotcrete crews working simultaneously in each area.

Second, the mixture design composition was especially unique for a Bay Area shotcrete project. After testing the concrete material, JWG had to make some modifications to customize it specifically for project application.

Third, the dense steel configuration in the shotcrete walls required close observation and quality control in the field. Preconstruction testing exemplified these congested areas to demonstrate that the nozzlemen were capable of performing the work.

Mixture Design Troubleshoot

The shotcrete mixture design was specified as a 7000 psi (48.3 MPa) mixture at 28 days. The original concrete mixture had a composition of 940 lb (426 kg) of cementitious materials with 15% fly ash content (equivalent to 10 sacks of cement) and 30 to 70% coarse-to-fine-aggregate ratio. The slump was 3.5 in. (89 mm). After analyzing laboratory trial results and conducting preconstruction testing, JWG adjusted the mixture design to tailor it to the work at the stadium.

When lab trial results proved that the mixture far surpassed the design strength, JWG was confident that the effects of a "hot mixture" could be reduced while still meeting the design strength. Thus, the cement content was reduced to 893 lb (405 kg), or 9.5 cement sacks.

During preconstruction testing, the JWG crew found difficulty in achieving the required steel trowel finish. As the finishers were "working" the substrate, the fine sand in the mixture kept emerging to the surface. This resulted in the surface exhibiting an aesthetically unpleasing "dimpling" finish. After investigating the issue, JWG determined that the root of the problem was the high content of fine sands. Subsequently, the mixture design was altered to include a blend of fine sands and fine aggregates, which increased the fineness modulus and created a more desirable aggregate gradation. Throughout the duration of the project, no further finishing issues were encountered.

Fig. 3: Cores retrieved from Type 1 preconstruction test panel

Fig. 4: Existing historic wall prior to shotcrete overlay application

Fig. 5: Application of 40 ft (12.2 m) tall shotcrete layer 36 in. (914 mm) thick over the existing historic perimeter wall

Fig. 6: Existing historic wall after shotcrete overlay application

Fig. 7: Shotcrete shear wall after the forms were stripped. The right side of the wall is the stripped form side. The left side is the shotcrete steel trowel finish side

Preconstruction Testing

Each nozzleman had to shoot a set of four preconstruction test panels that demonstrated the most challenging reinforcing steel configurations in the project. A mean grade of 2.0 was required to pass, with no single core having a core grade exceeding 3.0. Seven of the eight nozzlemen successfully passed the test. The engineer selected the following test panel conditions:

- Type 1: A historic wall shotcrete overlay intersected with a shear wall, with three curtains of No. 10 (No. 32M) and No. 9 (No. 29M) reinforcing steel with additional boundary reinforcing bar elements each 24 in. (610 mm) thick. Refer to Fig. 1 through 3.
- Type 2: A historic wall shotcrete overlay intersected with a shear wall with an existing pilaster obstruction and three curtains of No. 10 (No. 32M) and No. 9 (No. 29M) reinforcing steel with additional boundary reinforcing bar elements each 18 in. (457 mm) thick.
- Type 3: A historic wall shotcrete overlay with an embedded existing pilaster with reinforcing steel cages 20 in. (508 mm) thick.
- Type 4: A miscellaneous interior wall with an embedded column 12 in. (305 mm) thick.

Work Production

Shotcrete work occurred from May 2011 to February 2012 with a 6-day work week. As many as two to three shotcrete crews were on the job site each work day. The average pumping distance on the project was about 300 to 400 ft (91 to 122 m) from the shotcrete pump to the work location.

The dense steel configuration motivated the JWG crew to take an unconventional approach to shotcrete application. At some locations, the actual field measurements for the historic wall overlays were over 36 in. (914 mm) thick and required full height installation of up to 40 ft (12.2 m; refer to Fig. 4 through 6). To address this problem, shotcrete was applied in 12 ft (305 mm) tall lifts. Once the concrete material set up, the next shotcrete lift was installed. Consequently, there were no major voids as a result of poor consolidation reported on the project.

The walls were applied in one layer of scratch coat from the bottom to the top, and then the final finish coat from the top down was later applied (refer to Fig. 7). By taking this approach, JWG was able to ensure a uniform steel trowel finish. A unique experience at this project was that JWG found that the use of additional water-reducing admixture was actually detrimental to work production. As a result, JWG used a low dosage when applying a scratch finish so more concrete material could be stacked on the wall. The dosage was increased when applying the final coat finish, which accommodated extra time for the finishers to complete their work before the concrete set.

Summary

The California Memorial Stadium was undoubtedly one of the most unique seismic retrofit projects for JWG. The following were the keys for achieving this successful shotcrete project:

- Selection and modification of the high-strength concrete mixture design to streamline the shotcrete application process;
- Tight coordination in the field to stay on track with the fast-paced schedule; and
- Unconventional shotcrete application approach to deliver a high-quality shotcrete product.

References

1. "California Memorial Stadium," Cal Athletics, Berkeley, CA, 2010, http://stadium.berkeley.edu. (last accessed July 20, 2012)

2. Cardno, C. A., "Retrofit of Stadium Straddling Active Fault Moves Forward," *Civil Engineering*, ASCE, July 2010, pp. 12-14.

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Project Name
California Memorial Stadium

Project Location
Berkeley, CA

Shotcrete Contractor
Superior Gunite Company*

General Contractor
Webcor Concrete

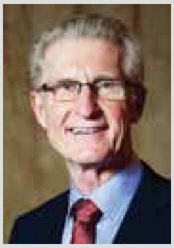
Architect/Engineer
HNTB/Studios Architecture

Material Supplier/Manufacturer
Cemex

Project Owner
University of California, Berkeley

*Corporate Member of the American Shotcrete Association

***Nur Kasdi** is currently the Project Engineer for Johnson Western Gunite, a Superior Gunite Company. Kasdi has been with the company since 2006 after receiving her BS in civil engineering from UC Berkeley. She provides estimating and technical support for various shotcrete projects across the United States. Her notable projects include the City Creek Center in Salt Lake City, UT; the Caldecott Fourth Bore Tunnel in Oakland, CA; and the SR 99 Tunnel in Seattle, WA. She is a licensed P.E. civil engineer in California and is a certified LEED Green Associate. Superior Gunite is a Corporate member of ASA.*



***Larry Totten** is currently the COO of Superior Gunite Company and the President of Johnson Western Gunite Company. He has also served as a Project Manager and Chief Estimator in his 36 years with the company. He received his BS and MS in civil engineering and is a member of ASA, the American Society of Civil Engineers (ASCE), the American Concrete Institute (ACI), and the Associated General Contractors of America (AGC). He holds contractors' licenses in several states and is licensed professional engineer in California. He is current Chair of ACI Committee 506, Shotcreting; past Chair of the Northern California Laborers Trust Fund; a past Director and a Past President of ASA; and an Approved ASA Trainer for the ACI Shotcrete Nozzleman Certification Program.*