Elephant Lands

By John Fulford

Controversy surrounding keeping large mammals in zoos has recently increased in the zoological community. The Oregon Zoo responded strongly and positively to this challenge by dedicating six acres (24,000 m^2) of their facility to the most ambitious and largest exhibit built in their 128-year history: "Elephant Lands." With the health and welfare of the Portland community's beloved elephants as the guiding principle, a world-class exhibit was constructed over the course of 3 years, all while the popular herd was kept on view to the public through a complicated series of construction phases. The result is a robust habitat that keeps the six elephants of the Oregon Zoo's herd mentally and physically active with abundant behavioral enrichment opportunities (such as mud wallows and a 160,000 gal. [605,000 L^3] pool for swimming and cavorting) while providing the public with an exciting and enriching experience that honors these magnificent animals.

This $57 million project was designed by CLR, a Philadelphia-based architectural firm that is widely known and highly regarded in the zoo construction industry. The innovative engineering of the project's shotcrete elements was performed by Armour Unsderfer Engineering, and the General Contractor/Construction Manager for the project was Lease Crutcher Lewis, one of the Pacific Northwest's premier builders.

The Turnstone Construction, Inc., crew had the pleasure of building the previous home for these elephants back in 1992, and so we were happily aware of some of the habits and personalities of these behemoths. We knew that Packy, the 54-year-old patriarch, enjoyed rubbing his belly on rocks with striated rib-like textures at about 4 ft (1.2 m) above grade. We also knew that the removal of the existing work to make way for the new exhibit would entail patience and heavy equipment. We happily left that work to a demolition contractor who exclaimed, "We had no idea concrete could get that hard," as they spent weeks breaking apart the old shotcrete rockwork and pool. Shotcrete structures held up to their notoriety as the strongest concrete in the zoo!

Fig. 1: Clay models were developed to show mass and scale of the shotcrete elements of the exhibit

This was the fourth elephant exhibit Turnstone had constructed, which allowed us to participate in preconstruction meetings with the zoo's animal management staff and the architectural and engineering team. We knew that the concrete surface textures needed to have high compressive strengths to withstand the rubbing of an elephant's leathery skin and at the same time be easy for them to walk on, and that walls had to be engineered to withstand the same impacts as a highway guardrail (a long-used standard).

Our staff also brought construction options to the design process that used shotcrete's sustainability advantages. As an example, we promoted top-down soil nail construction techniques to help save many of the trees in the areas that abutted the exhibit's containment walls. This was an important success because modern zoo design is based on the concept of habitat immersion—creating a sense of timelessness to help zoo visitors realize the importance of preserving the world's natural habitats. Being able to save large, mature trees in the background of these large mammals is particularly important to this illusion. It is also important to note that the substantially reduced excavation required by the shotcrete-based method provided multiple benefits, from less disruption to the animals and the public, environmental advantages (saved emissions and lowered fuel use), substantial cost savings, and schedule enhancement. Thousands of yd^3 (m^3) of soil remained in place due to this approach.

The construction process began with carefully shaped clay models of the exhibit and three-dimensional samples of each texture we would be sculpting. This was an important means of communicating to the owner and design team how we were interpreting a very subjectively judged scope of work. We requested an interactive workshop to develop the clay forms and review the samples so that we would not have to reconfigure our shotcrete during the construction process—clay being a much easier material to re-sculpt

Fig. 2: Earthen textures with embedded cobbles, roots, integral pigments, and topical stains

Fig. 3: Three-dimensional samples displaying the different textures were prepared for approval prior to production

Fig. 4: Shotcrete finishing for bedrock textures

than hard shotcrete. This stage of the project built strong team dynamics and trust that positioned us to work through the challenges of a complex construction project.

The construction schedule was particularly interesting because the elephants were to remain on view throughout, which required safe and secure areas while the other sections of the new yard were being built. Every day counted as we choreographed a ballet of large animals moving between enclosures. Shotcrete as a method of construction contributed to schedule enhancement in multiple ways. As an example, the conventional concrete construction of the deepest life support vault of the project's pool would have required closing the main access road to the site. However, using temporary shotcrete walls constructed with top-down soil nail techniques kept this from occurring, saving weeks on the overall schedule. Animal management staff worked closely with the construction team to develop the phasing strategy and reported that the changes in location kept the elephants mentally and physically active while they were moved between spaces.

Construction also kept us mentally and physically active while we deployed plans and methods that used the full range of shotcrete's versatility. On this site, we built tall, architecturally finished walls that provided containment for the elephants (this required that the walls were at least 9 ft [3 m] tall with an overhang). These were textured with embedded roots and real cobbles to simulate the aesthetic of eroding embankments in Asia. To make them as authentic in appearance as possible we searched for images from Asia so we could replicate specific features of the land. We manipulated our textures to display the stratigraphy of the soil lens, replicating various soil types, including clays and sandy loam. We stained the surface of integrally colored shotcrete to replicate the rich colors of Asian soils. In some areas, we purposefully showed the dynamic process of

slumping soil by building erosional remnants of the same soil in the area below the eroded section of wall—a subtle effect but one that strengthened the intended illusion and allowed further opportunities for the elephants to rub against different shotcrete textures.

The project included two water-containing structures—one being a large pool able to accommodate up to 10 mature elephants and deep enough to allow them to fully submerge. These watertight shotcrete structures were placed monolithically. Both pools accommodated complex support systems crucial to the elephants' health that required detailing our finishes around 40 pipe penetrations. The construction of these pools also entailed slab textures carefully detailed to be friendly to elephant feet. These water features have proven to be efficacious at inspiring play among members of the herd.

Other applications of the shotcrete method included the lagging for top-down shoring techniques that were used to tuck a large building up against a hillside to keep it out of the sightlines of the public, again while saving the mature landscape above. Shotcrete was also used to provide a permanent wall face over a mechanically stabilized earthen structure and over a soldier pile wall. Existing form-and-pour walls were overlaid with shotcrete that was then textured to appear as large sections of native bedrock. Cantilevered retaining walls were formed on one side and built with shotcrete. Two bridge abutments were installed using shotcrete that allowed viewers to walk over the elephants' space. In each case, the structural method was chosen for its cost effectiveness and schedule benefits, and in each case the shotcrete process was central to the method elected. Ultimately, these structures were camouflaged using naturally textured shotcrete, which allowed them to blend in as an element of the elephants' natural habitat. Shotcrete's superior adhesion qualities were important to many facets of the work.

The construction and finished result of Elephant Lands is a testament to the versatility of shotcrete. Over 1250 yd^3 (956 m^3) of shotcrete was placed with ACI Certified Nozzlemen in the exhibit scope of work, and five different mixture designs were created to meet the shotcrete requirements of the project, including waterproofing,

Fig. 5: Finished bedrock textures included painted lichens native to the Asian habitat

Fig. 7: Mother Rose-Tu and baby Lily cavorting in their new pool

Fig. 6: Part of the Oregon Zoo elephant herd traveling through their new exhibit

Fig. 8: The youngest member of the herd exploring her new habitat

structural strength, aesthetic finishing, and pumpability. Integral pigments were added to the textural mixture designs to help develop the organic palette of colors for the habitat. All the shotcrete material was supplied by the Cemex Corporation.

Building a home for such magnificent animals made the challenges along the way much easier to keep in perspective. At completion, it was exhilarating to witness the Oregon Zoo herd walking together over sustained distances in a large exhibit yard that appeared to be from the forests and savannas of Asia. This is particularly unusual for elephants in captivity. This feeling was only eclipsed by the joy of watching the youngest elephant, 4-year-old Lily, swim with exuberance while being carefully watched over by the older members of the herd!

THE OUTSTANDING ARCHITECTURE | NEW CONSTRUCTION PROJECT

Project Name
Elephant Lands, Oregon Zoo

Project Location
Portland, OR

Shotcrete Contractor
Turnstone Construction, Inc.*

General Contractor
Lease Crutcher Lewis

Architect/Engineer
CLR Design, Armour Unsderfer Engineering

Material Supplier/Manufacturer
CEMEX CEMENTO

Project Owner
Oregon Zoo

*Corporate Member of the American Shotcrete Association

This project won the 2016 Project of the Year Awards with both the *Daily Journal of Commerce* (Oregon) and the Oregon Concrete and Aggregates Producers Association. Special thanks to the Oregon Zoo, Lease Crutcher Lewis, AUE Engineering, CLR Architects, and the Cemex Corporation.

John Fulford *founded Turnstone Construction, Inc., in 1997. Based in the Pacific Northwest, Turnstone has been building unusual shotcrete structures ever since, including zoo and aquarium exhibits, complex water features, climbing walls, naturalistic hot spas, salmon spawning streams, Hobbit houses, and simulations of famous caves. Fulford has been involved in five zoological projects that have won the prestigious "Best Exhibit" award from the American Zoo and Aquarium Association.*

Fig. 9: The highlighted area shows the scale of the six-acre elephant exhibit in relation to the rest of the zoo