

Advantages of Using Shotcrete for Arch Culverts

by Howard L. Robbins

Arch structures have been used in various forms of construction for thousands of years. The earliest arch structures date back to ancient times when crude arch prototypes were constructed by building a corbelled arch in which



projecting elements from a wall rose in steps to meet at the center. The Egyptians, Greeks, and Romans all used the arch for various types of structures, including sewers, aqueducts, bridges, and ornamental architectural buildings such as palaces and churches. The fact that many of these ancient structures are still standing today is a testament to the durability and structural integrity of this design. Fast-forward 2000 years to modern construction practices, and the benefits of the arch design are still as valuable, relevant, and practical as ever.

Various Uses for Arch Culverts

Among the many modern-day uses of arch culverts are culverts, storm drains, bridges, cut and cover tunnels, pedestrian and equestrian underpasses, golf cart crossings, underground vaults and reservoirs, and environmentally sensitive wash-crossing structures. These types of crossings can be constructed on spread footings and without concrete inverts, thereby maintaining the natural integrity of the wash bed. Detailed engineering studies have verified that arch culverts will have a similar life cycle to comparably reinforced concrete box culverts.

Benefits of Arch Culverts

The advantages of using shotcrete arch culverts over traditional formed and poured concrete box culverts, concrete pipe, and corrugated metal pipe are as follows.

- *Cost savings:* Due to the design advantages of soil-structure interaction, the backfill surrounding the arch acts in tandem with the surrounding soil to carry the imposed load. This allows for the design of thinner, exceptionally strong structures, resulting in a reduction of as much as 10 to 20% in the amount of concrete and reinforcing steel when compared with a traditionally reinforced concrete box culvert.
- *Accelerated construction schedule:* By using this advanced forming system, multiple 8 ft (2.44 m) form sections can be combined to rapidly construct structures of any length. After applying shotcrete, the forms can be moved within 24 to 48 h to be repositioned to continue production up to the desired length of the structure. Backfill can commence on previously placed shotcrete as well during this same time.



- *Greater hydraulic efficiency:* Arch culverts can span greater distances without the need for interior support walls typical in multi-barrel box culverts. This gives the arch culverts the ability to convey the same amount of runoff as multi-barreled structures with a more hydraulically efficient cross section. This design also allows for the flexibility to add pipe inlets and equalization ports as required.
- *Pleasing aesthetics:* The general appearance of the arch, as opposed to other structural alternatives, is more pleasing in appearance and also lends itself to many architectural treatments such as form liners, natural stone facing, and architectural shotcrete. This provides design flexibility to clients for whom appearance is a significant factor.
- *Design build advantage:* By using a design/build approach to the project, a firm can assume total control and responsibility providing the client with superior customer service and significant time savings.

The Corte Bella Project

Commercial Shotcrete, Inc. was approached by the Del Webb Corporation to consult on the design and, ultimately, the construction of a 48 ft (14.63 m) span shotcrete arch bridge structure that would also function as a golf cart underpass at an upscale residential development in Surprise, AZ. The project, named Corte Bella, is Del Webb's first active adult country club community. The bridge is 10 ft (3.05 m) high and 111 ft (33.82 m) long. This structure is the main entry feature into the community and the architectural focus of the landscape and hardscape design.

One of the primary concerns of the client was the construction schedule. The bridge needed to be completed prior to the third week in July 2003, in order to have the development ready for initial home sales. A comprehensive marketing program was developed to meet this deadline. Another vital concern was budget. Other bridge options were explored but were deemed excessively expensive and too time-consuming to construct. Additionally, the other design proposals considered were unable to accommodate certain Tuscan design features that the developer deemed important to the overall design theme for the project.

Commercial Shotcrete, Inc. began initial construction after the site excavation work had been completed by the developer. The invert area was fine graded, reinforcing steel was installed, tied, and inspected. Next, 185 yd³ (141.1 m³) of 3000 psi (20.7 MPa) concrete was placed, finished, and cured in a single placement. The next step in the process was the installation of the 48 ft (14.63 m) span metal forming system that was tied into the outside edges of the invert. The 8 ft (2.44 m) form



sections were bolted together in groupings of six sections. The reinforcing steel was then fabricated, placed, and tied in preparation for the placement of 4000 psi (27.6 MPa) structural shotcrete. Due to the hot weather conditions in the Phoenix area, all the shotcrete was placed between midnight and 7:00 a.m. This allowed for the most productive working environment for crew members, kept the steel form system cooler during placement, provided maximum workability of the shotcrete prior to the material hardening, and produced a high-quality finish when the forms were removed. This process was repeated a total of three times to complete the desired length of the structure. In total, 690 yd³ (527.5 m³) of shotcrete was placed. At the same time, head walls and wing walls were formed and shotcreted to complete the structure.

After form removal, the entire bridge underwent fog curing in addition to an application of a liquid

curing compound. The entire structure also received a waterproofing treatment consisting of a sprayed-on bituminous material and a geosynthetic drain system.

Finally, architectural retaining walls were constructed to complete the bridge infrastructure. Due to the exceptionally high quality of the interior finish left after form removal, no further interior finish was necessary. The bridge was then turned over to the developer for the installation of final hardscape and landscape materials.

Ultimately, the project was completed on schedule and within budget, saving the developer in excess of \$200,000 over the other designs proposed. Because Del Webb was so pleased with the quality of the structure, Commercial Shotcrete Inc. was awarded a contract to construct two additional 48 ft (14.63 m) long culverts at another new golf course development in Indio, CA.

Summary

Arch culverts have a history of providing durable construction over hundreds of years. Today these culverts continue to provide utility with aesthetic benefits. As demonstrated in this article, shotcrete provides these qualities with the economy and speed demanded in today's marketplace.



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Commercial Shotcrete, Inc. builds structural walls, sculpted architectural shotcrete features, canal and lake linings, and soil stabilization projects. Robbins has more than 18 years of experience in sales, marketing, construction management, and project management of commercial concrete and shotcrete projects in the Midwest and southwestern United States. For the past 9 years, he has been involved in the marketing and construction of arch culvert projects for the public and private sector markets in Arizona, California, Nevada, and New Mexico. He can be reached at (602) 290-0362 or via e-mail at hlobbins@earthlink.net.