Research Report
KTC-07-13/KH 55-07-1F

KENTUCKY TRANSPORTATION CENTER

DRY STONE MASONRY CULVERT RESTORATION

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Dry Stone Masonry Culvert Restoration

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16. Abstract
A damaged dry stone masonry culvert on KY 1268 Jessamine County was restored by the Kentucky Transportation Cabinet. The work was performed by the Dry Stone Conservancy, a non-profit agency promoting dry stone masonry. The work included replacement of a retaining wall and widening of the culvert. The project also included a partnering effort to improve the skills of local stone masons.

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BACKGROUND

In October 2006, the Kentucky Transportation Cabinet (KYTC) awarded a contract to the Kentucky Transportation Center (KTC) for repairing a stone culvert and retaining wall located on KY 1268 in Jessamine County, Ky. The culvert had sustained considerable damage when a large truck ran off the roadway and into the south side of the culvert (Figure 1). The original culvert employed a mix of wet and dry stone construction.

The culvert could have been replaced with a conventional concrete unit. However, KTYC chose to repair the existing culvert to preserve its historic character. There are several other unique dry and wet (mortared) stone culverts and bridges along KY 1268 and preservation of the culvert was in keeping with the other significant stonework along the road. KYTC also wished to provide training for locals to create a larger pool of stone masons bidding on future projects. KTC subsequently awarded the field work and training to the Dry Stone Conservancy (DSC). The DSC is a nonprofit agency whose mission is to revive and promote the ancient craft of dry stone masonry and to preserve existing dry stone structures. KTC was to monitor the project and document it in this report.

This mutually-beneficial training and restoration partnership was created to:

- Provide advanced on-the-job training opportunities for certified drystone masons as relates to drystone arch and roadway retaining wall construction techniques;
- Increase the availability of advanced drystone craft skills in the Commonwealth for future restoration efforts involving dry-laid stone masonry; and to
- Rebuild the historic culvert and retaining walls utilizing authentic construction techniques in prevalent use at the time they were first built (yet rarely available today).

Partnering arrangements between DSC and KYTC date back to the 1990s when they began to train workers on the dry stone building techniques as part of the reconstruction work on Paris Pike (US 62) between Lexington and Frankfort. The DSC trained about 30 stone masons and built approximately 3 miles of dry stone walls on that project.

Work on the dry stone culvert & retaining wall included:

1. Removal of approximately 8 linear feet of mortared double-barrel dry stone culvert replacing it with authentic dry-laid stone to match the remaining historic dry stone culvert, including adequate tie-ins to the existing stonework;
2. Provision and installation of 5 additional linear feet of double-barrel dry stone culvert to extend the culvert upstream (southward), including barrels, abutments, piers and spandrels to match the existing stonework;
3. Replacement of approximately 40 linear feet of gabion basket retaining wall with a dry stone retaining wall, varying in height from 18” to 7’-0”, including stepped foundations, tie-in to the adjacent dry stone culvert and a wall head;

4. Provision and installation of approximately 68 linear feet of continuous cap course and approximately 20 linear feet of stone brush curb to match the stone curb on the opposite side of the roadway, including securing the curb with dowels.

The work also included packing and backfilling as needed for the dry stone work, but did not include final grades, engineered fill, filter fabric, drainage structures or asphalt for the roadway or re-establishment of cover vegetation.

The DSC provided an expert dry stone mason (master craftsman) along with a crew of 11 DSC-certified master craftsmen, journeyman masons, and dry stone masons. The DSC provided project oversight, design, restoration methodology and training. During the culvert repair, workers in the crew received "hands-on" practical training from the DSC to improve their stone masonry skills and provide experience necessary for raising their job classifications.

PROJECT OVERVIEW

DSC work began at the job site on November 20, 2006. KY 1268 was closed during the culvert restoration. The crew size on the project varied over the course of the project due to other DCS commitments, manpower requirements during the different phases of work and the availability of masons.

The DSC crew began by establishing a staging and preparation area in an abandoned quarry located adjacent to the culvert. Work performed in this area centered on preparation (shaping & sizing) of stones used as the construction material in the culvert and retaining wall. Large stone slabs were obtained from a nearby source and delivered to the staging area. Although those slabs did not come from the abandoned quarry (that probably provided stone for the existing culvert) they were from the same rock strata providing a visual/structural match with the existing culvert stones (Figure 2).

The reconstructed culvert was to replicate the original appearance of the historic dry-laid stonework as closely as possible, guided by the original stone sizes, shapes, colors and patterns of workmanship. New stone was shaped to match the historic stone as closely as possible to achieve a uniform final appearance

The stone slabs were split into strips by drilling and use a technique termed "plugs-and-feathers". Masons would drill holes 6" to 8" apart penetrating to a depth of about 2/3 of the slab thickness (Figure 3). Then, they would place feathers into the holes and incrementally drive plugs (wedges) in the holes, hammering the plugs until the rock slabs would split into smaller strips (Figure 4). Those rough-cut pieces were taken to a *Mason-50 Hydraulic Rock Breaker* and broken into near-final-dimension sizes (Figure 5). The stones were finished (dressed) using manual and powered chisels that used compressed air (Figure 6).

The smaller stones used to form the culvert barrel arches (vaults) were laid out on the ground in courses of the same thickness. Then they were tapered by chiseling to fit a template of the culvert barrel (Figure 7). The surfaces of the tapered stones had a rough finish to promote friction between mating surfaces and thereby inhibit sliding. Waste generated during stone cutting and tapering was saved to be used for packing and fill material inside the culvert. Larger blocks were used for the pier and abutments.

The mortared section of the culvert was carefully dismantled down to structurally sound existing stonework or stable footing just below grade (Figure 8). Rotten, severely weathered and mortar-encased stones were discarded.

Once the stone preparation began at the staging site, work started on dismantling the gabion retaining wall. It was subsequently replaced with a dry laid stone retaining wall along the existing alignment (Figure 9). The replacement wall had a 1:6 (horizontal to vertical) batter that transitioned into the culvert abutment. Tie stones were incorporated at regular intervals to tie the wall face to the core packing behind it. A stepped foundation with a 4-inch projecting foundation course was installed followed by a drystone cover course.

Larger stones blocks were prepared and placed at the base of the culvert to extend the width of the culvert pier and abutments (Figure 10). With the pier and abutments extended, wooden falsework (centering) for the vaults (arches, barrels) were built and placed in alignment with the existing culvert vaults (Figure 11). Masons proceeded to lay and dress the stones forming the arches at precise angles around the falsework (Figures 12-16). This work was complicated slightly due to the different sizes of the two barrels. The north barrel had an arch radius of 56 inches and a span of 101 inches and the south barrel had an arch radius of 49 inches and a span of 92 inches.

As work progressed on the culvert, the barrel arches and culvert walls were completed. Wall capstones were subsequently placed with their tops level to the proposed road grade (Figure 17). Thick stone slabs are cut, shaped and dressed and set atop the culvert vaults to be used as brush curbs. Two of those curb stones were from the original culvert. They had been pushed into the stream during the crash and were retrieved for reuse. The space created by the vaults and walls was carefully hand packed and filled with stone rubble generated during stone preparation and topped with a gravel road base in preparation for asphalt (Figure 18). Large stone slabs were temporarily placed over the culvert vaults to help seat them (Figure 19). Once the culvert stone work had been completed (Figure 20), the falsework inside the culvert vaults was removed and carried away to be dismantled (Figures 21 and 23). Inspection inside the culvert vaults showed that the stonework in the vaults was properly consolidated (Figures 22 and 24).

One lane of the roadway that was not damaged was re-opened to the public when the stonework was completed during the first week of March. The abandoned quarry was returned to its original state prior to the DSC leaving the job site. Paving work in the previously damaged area over the culvert (from the wall capstones to the original road) was completed on May 8, 2007 (Figures 25 and 26)

SUMMARY

The project was completed at the original contract price of $98,175. The DSC absorbed some additional training costs for the 11 stone masons that amounted to about $40,000.

The DSC was on site for approximately 70 days for a total of approximately 2,070 man-hours of labor, training and project oversight. Approximately 109 tons of stone were used on the project at a cost of $100/ton. The stone was purchased at a private quarry in Mercer County, Kentucky approximately 7 miles from the job site.

The project was originally scheduled for completion by December 31, 2006. Due to delays and a three-week shut down during Christmas holidays, it was not completed until March 12, 2007. During the project, the DSC spent some time providing training to masons at the job site.

This project is an excellent example of KYTC environmental stewardship and context sensitivity. It preserved a unique structure of similar construction to other culverts/bridges in the area and maintained the historic character of the route and area. Hopefully, this exemplary project will receive significant local and national recognition for which it is truly worthy. It also represents a mutually beneficial partnership between a state transportation and a key stakeholder, the DSC, which resulted in cost sharing by both parties to achieve mutually supportive goals. For its benefit, the DSC was able to: preserve another unique dry stone structure, provide training to a cadre of stone masons, and support continued KYTC implementation of projects involving dry stone masonry by ensuring an adequate number of qualified stone masons in the future.

FIGURES

Figure 1. View of the damaged double-barrel stone culvert and the gabion retaining wall prior to onset of the project. *(Picture provided by the Dry Stone Conservancy)*

Figure 2. The DSC used abandoned quarry to store, cut and dress stones for the rebuilding of the culvert.

Figure 3. Large stone slabs were obtained for use in the culvert and retaining wall. This picture shows a mason drilling holes in a stone slab.

Figure 4. Masons hammered plugs (wedges) into the holes drilled in the stone slabs to split them into manageable sizes.

Figure 5. Masons used a *Mason-50 Hydraulic Rock Breaker* to break rough-cut pieces from the slabs into smaller ones approximating their final dimensions.

Figure 6. Once the stone pieces had been roughly cut, masons chiseled them to the final size and shape. Stones used for the culvert barrel arches had tapers chiseled on two opposing faces.

Figure 7. As the vault stones were shaped, they were placed around a arch template (the semi-circle plate) to assure the proper taper and fit.

Figure 8. View of site preparation work. The north vault was uncovered and the south vault and gabion retaining wall were dismantled.

Figure 9. Work on the retaining wall that replaced the gabions at the north end of the culvert.

Figure 10. The masons placed the newly cut stone block to re-form the demolished portions of the culvert center pier & abutments and to extend the culvert.

Figure 11. The DSC finished construction of the falsework on the south vault and began installing falsework for the north vault.

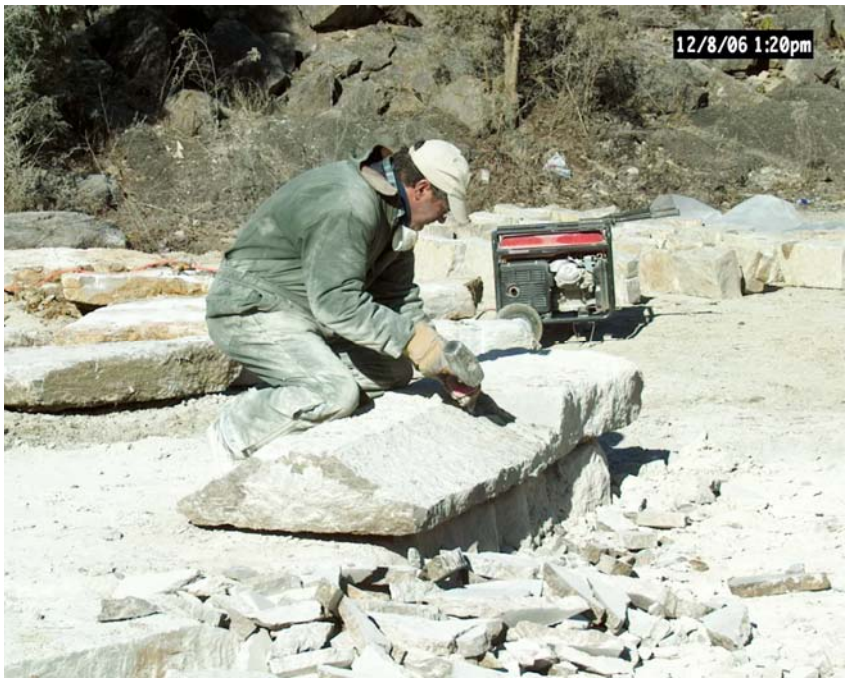

Figure 12. A mason is shown preparing a “springer” stone to cap the center pier. These stones formed the base for the vaults rising from the pier.

Figure 13. The center pier “springer” stones are shown after placement.

Figure 14. This view shows the abutments and pier looking into the west side of the culvert. Note that some smaller vault stones having been placed around the falsework.

Figure 15. The smaller stones, also known as “voussoir” stones, were laid in courses with all joints broken. Each “voussoir” stone received a final dressing to fit properly.

Figure 16. This view shows the dry stone retaining wall which is nearly completed. In the background, a mason is dressing the top of the center (keystone) course of the vault falsework.

Figure 17. Capstones were placed with tops level with proposed road grade (after paving).

Figure 18. Packing and road base material was added behind the culvert wall face level to the bottom of the capstones.

Figure 19. A view of the project before the falsework was removed.

Figure 20. A view of the completed stone work looking into the west face of the culvert..

Figure 21. The masons removed the falsework from the north vault.

Figure 22. This view shows the completed stone work in the north vault.

Figure 23. This photo shows the masons removing the falsework from the south vault.

Figure 24. A view of the restored culvert. *(Picture provided by the Dry Stone Conservancy)*

Figure 25. Paving work on the culvert deck.

Figure 26. The completed project on May 8, 2007 (except for paint striping on the roadway).

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