The Early Phrygian Gate at Gordion, Turkey

An Investigation of Dry Laid Masonry in Seismic Regions

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First excavated in the 1950s by a team of archaeologists from the University of Pennsylvania Museum of Archaeology and Anthropology, the Early Phrygian Gate is the largest extant masonry gate to survive from the Iron Age in the Middle East. However, its dry laid construction (built without the use of mortar) leaves it vulnerable to the region’s high seismic activity. Constructed around 900 BCE, the Early Phrygian Gate served only briefly as the main entryway to the citadel. Successive periods of occupation within the citadel mound resulted in further building campaigns which utilized the earlier structures as foundations for new construction. The changing load patterns produced by the new structures caused a series of visible conditions—most notably cracking and displacement—discovered upon excavation. Although cracking occurred historically from the additional loads of the later city walls, displacement continues to be an active condition. From 2006-2010, the University of Pennsylvania’s Architectural Conservation Laboratory (ACL) has conducted a detailed program to document, monitor and assess the gate’s overall structural stability and determine the condition of its limestone and rhyolite walls.

CONDITION

Only partially exposed during excavation, the gate’s South Court retains the original expansive clay construction fill in its interior—the result of the subsequent Phrygian building campaign. The clay fill, in addition to the settlement of core material, has contributed to several areas of displacement. Since its exposure to the environment approximately six decades ago, the gate has been subjected to several localized reconstructions, as well as a gravity injection grouting program to address movement and stabilize the ancient walls. Although the gate has largely maintained its original aesthetic, areas receiving these interventions exhibit variations in chinking technique and, in some cases, stone type. Concrete capping, like the grouting program, has been implemented as a reactive measure to inhibit water ingress and prevent further bulging; however, a more diagnostic approach was necessary to respond to ongoing displacement and possible collapse, which may result from future seismic activity.

DOCUMENTATION

Starting in 2006, the ACL developed an extensive documentation program, which included a digitized condition survey of each exposed elevation to record spalls, open joints, missing chinking stones and bulging, and in 2009 conducted high-density laser imaging with a mid-range Trimble VX100 laser scanner.

Results of the documentation process indicate that many visible conditions occurred historically. Comparisons made between images taken during the 1950s excavation and the 2006 condition survey show a correlation between the additional Middle Phrygian building load and the innumerable compression cracks found below extant Middle Phrygian courses. However, the 1950s images reveal that the greatest degree of displacement—visible by the large, central bulge of the South Court elevation—occurred more recently. A method to quantify displacement in this potentially unstable region has recently been implemented through a joint effort between Middle East Technical University and the Architectural Conservation Laboratory. The monitoring program, which will determine whether bulging is resulting from constant incremental movement or only displacing during seismic events, is critical to the design and execution of a stabilization program for the gate structure.