Twenty-one experiments were conducted on a metal box culvert, measuring response without backfill, during backfilling, under a loaded tandem axle dump truck, and under simulated vehicle loading with force applied by an actuator. Surface strain measurements were used to calculate bending moments and thrusts, while deflections were monitored using an electronic theodolite.

Tests were performed at three cover depths, and up to forces much larger than design values to establish the ultimate limit state. Three dimensional live load spreading produced strength considerably higher than current design methods indicate. The ultimate limit state of the structure involved the formation of three plastic hinges at a total tandem axle load of 1100 kN. The plastic hinge initially formed at the crown, followed by hinges located at each shoulder. Post-test observations showed evidence of local buckling of the conduit wall, gaps between the plates at the seams, the tilting of bolts along the longitudinal seams, and surface cracks in the soil. Applying the material resistance factor of 0.9 to the ultimate load limit of 1100 kN measured for the structure yields a reserve capacity of 1.7 times the design strength required by the Canadian Highway Bridge Design Code.

Andrea’s data is currently being analyzed by PhD student Tamer Elshimi to establish three dimensional modeling techniques using ABAQUS and develop improved design methods for the CHBDC and the AASHTO load and resistance factor design standard.

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Queen’s has developed unique buried infrastructure test facilities including a test pit of 1.6m length, 8m width and 3m depth. This allowed Andrea to erect and backfill her 10m span metal box culvert, to test it under service loads, and to use an actuator system to test it up to its ultimate limit state. This is permitting unique measurements of the performance of buried infrastructure, up to strength limits. Andrea assisted with facility upgrades, including the installation of a set of eight high capacity rock anchors and a reaction frame to support the laboratory’s 2000kN actuator. At about 6 times typical maximum single or tandem axle loads, this permits system strength to be established under fully factored AASHTO and CHBDC highway vehicles.