The Geo Engineering Centre

Depth Beyond Knowledge™

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ANDREA LOUGHEED, MSC (2008)

RESEARCH SUMMARY

LARGE SCALE TEST FACILITY UPGRADE TO APPLY 2000KN AXLE LOADS

10M SPAN METAL BOX CULVERT ERECTED AND BACKFILLED

MEASUREMENTS OF DEFORMATION AND LOCAL STRAIN GIVE THRUST & MOMENT

LOADING WITH DUMP TRUCK AND 2000KN ACTUATOR

STRENGTH OF CULVERT 1.7 TIMES DESIGN EXPECTATION

FIRST CONTROLLED TEST OF METAL CULVERT TO ULTIMATE LIMIT STATE

HIGHLIGHTS

- **Project for Armtec of Guelph Ontario.**
- **Project has already changed methodologies of metal culvert design for surface live loads**
- **Data for 2D and 3D finite element analysis**
- **With Thurber Engineering, Vancouver, since January 2009.**

STRENGTH OF DEEPLY CORRUGATED METAL CULVERT

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 and her test culvert prior to backfilling in 2008.

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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UPGRADES TO THE LARGE-SCALE BURIED TEST PIT

Queen's has developed unique buried infrastructure test facilities including a test pit of 16m 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.

Culvert testing under a heavily loaded dump truck in 2008.