Case Study from T. Newson and M. Kanungo for TC38
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Overview

A 2.44-m by 2.44-m by 13.41-m buried reinforced concrete box culvert was constructed in 1982 at the Texas A & M University Research and Extension Center. The project was concerned with the design of culverts for shallow fills, as defined by AASHTO to be fills less than 2.44 m. The objective was to compare the measured data with the AASHTO design pressures and develop an improved method of predicting earth pressures on box culverts due to both dead and live loads. The culvert was instrumented with twenty earth pressure cells on the top and side slabs, and with six resistance strain gauges on the tensile reinforcing steel in the top slab. Measurements of top slab deflection were also made with a deflection dial gauge. Dead loads caused by the backfill and up to 2.44 m of cover were applied in 0.61-m increments. Live loads were applied at each level of cover by a test vehicle loaded to represent the alternate interstate design load, consisting of a 214-KN tandem rear axle. The vehicle was parked at various distances from the centerline of the culvert along a perpendicular roadway constructed on the embankment above the culvert.

Site conditions and culvert description

The test site was located in an open pasture (see Figure 1) near the eastern boundary of the TAMU Research and Extension Center. The general topography of the area included level or gently sloping terrain, with approximately 3 m of relief in the surrounding 2.5 acres (1.0 ha). It was decided to construct the culvert below the existing ground surface for the following reasons:

1. It would reduce the amount of required embankment material considerably.
2. The time required to place and compact the embankment material would be greatly reduced.
3. A smaller land area would be required for the site location.

Many storm run-off channels empty into a small pond northeast of the site. Since the embankment would block them, the channels were redirected to carry the runoff around the test site.

The culvert was a 13.41-m-long single cell box, with a cross-section of 2.44 m by 2.44 m (inside dimensions). It had 177.8-mm-thick slabs, 203.2-mm-thick walls and flared wings (see Figures 2 and 3). The culvert was constructed according to Texas SDHPT Standard Specifications for SC-NB Type 3 single culverts-normal. The 13.41-m barrel length was selected to allow for a 3.66-m roadway width across the culvert, at a cover height of 2.44 m and side slopes of 2:1.

The soils in the test site were sedimentary deposits from an ancient course of the Brazos River, consisting of thin layers of pea gravel, sugar sand, and silts interlain with thicker layers of a fine, red, clayey sand and a fine, light, tan sand. The geotechnical tests used to document the soil properties included sieve analyses, Atterberg limits, standard Proctor compaction, in-situ unit weight, moisture content determinations, direct shear and consolidation tests.

The culvert was constructed directly on the natural ground, which was a free-draining, fine, light tan sand [Soil A]. A 100-mm blanket of the light, tan sand was placed around and on top of the culvert to promote drainage. This blanket was assumed to prevent the pressure cells from measuring pore water pressure along with earth pressure. The backfill, embankment, and roadway were constructed of the readily available fine, red, clayey sand [Soil B], providing an adequately strong and stable roadway. From the grain size distribution (see Figure 4), it can be seen that the fines content (passing #200 sieve) of this material is 8.3%, i.e. between the range 5% to 12% of fines. The Uniformity Coefficient (C_u) and the Coefficient of Curvature (C_c) are 3.1 and 1.02 respectively. Based on these characteristics, the soil was assigned a dual symbol of SC-SP, according to the United Soil Classification System (USCS). Further geotechnical data about the natural ground [Soil A] and the backfill soil [soil B] are presented in Tables 1 to 4.

Instrumentation description

Twenty pressure cells were installed on the culvert; four on each side and twelve on top (see Figure 2). The side pressure cells were securely attached to the formwork prior to placement of concrete. This resulted in the active face of the cell being flush with the exterior wall of the culvert, providing greatest accuracy of reading at the soil-structure interface. However, the top pressure cells were installed immediately after placement of concrete, while it was still in a plastic state. A chisel was used to remove concrete from the exposed surface of the pressure cells after the concrete had hardened. Pressure cells no 1-4 and no. 20 were manufactured by Slope Indicator Company (Model No. 51482). Pressure cells 5-19 were manufactured by Terra Tec (Model No. T9010). The pressure cells had a full-scale range of 1724 kPa and a manufacturer’s specified accuracy of 0.1 percent full scale.

The strain gauges were attached to the reinforcing steel under laboratory conditions prior to the bars being tied in place on the culvert. The Micro-Measurements CEA-06-W250A-120 gauges were attached by spot-welding in the laboratory along with the necessary wiring and water-proofing. All lead wires from the pressure cells and strain gauges were routed though sections of 50.8-mm PVC pipes, to a terminal box inside the culvert.

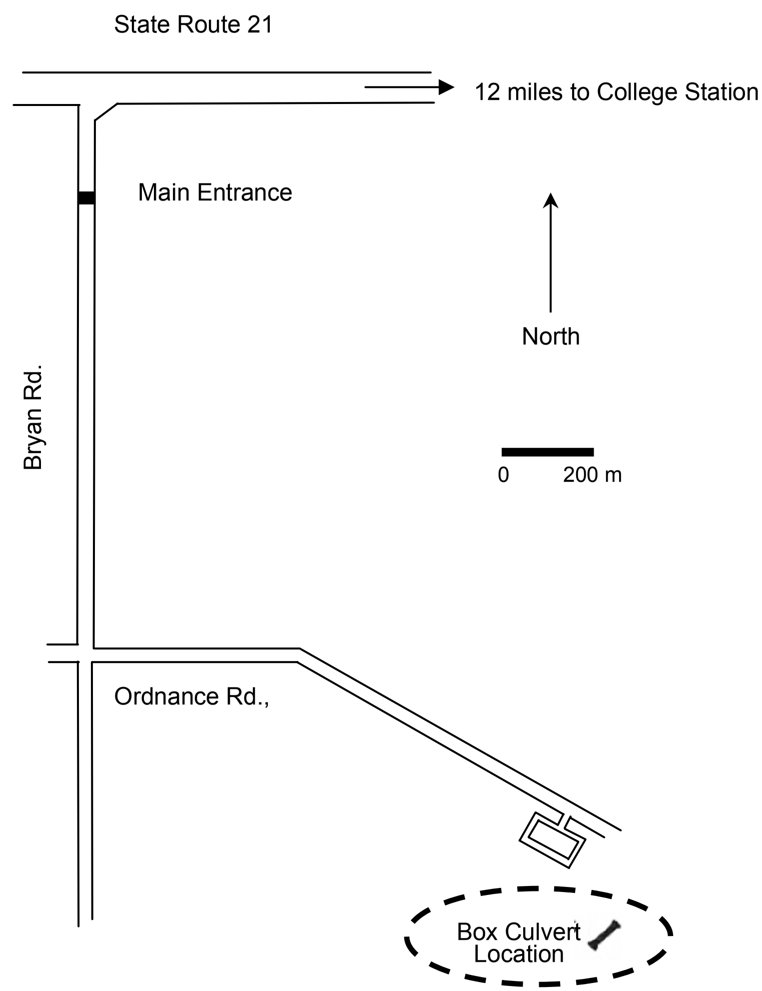

Figure 1. Location of the test site on the TAMU Research and Extension Center (after James et al.,1985)

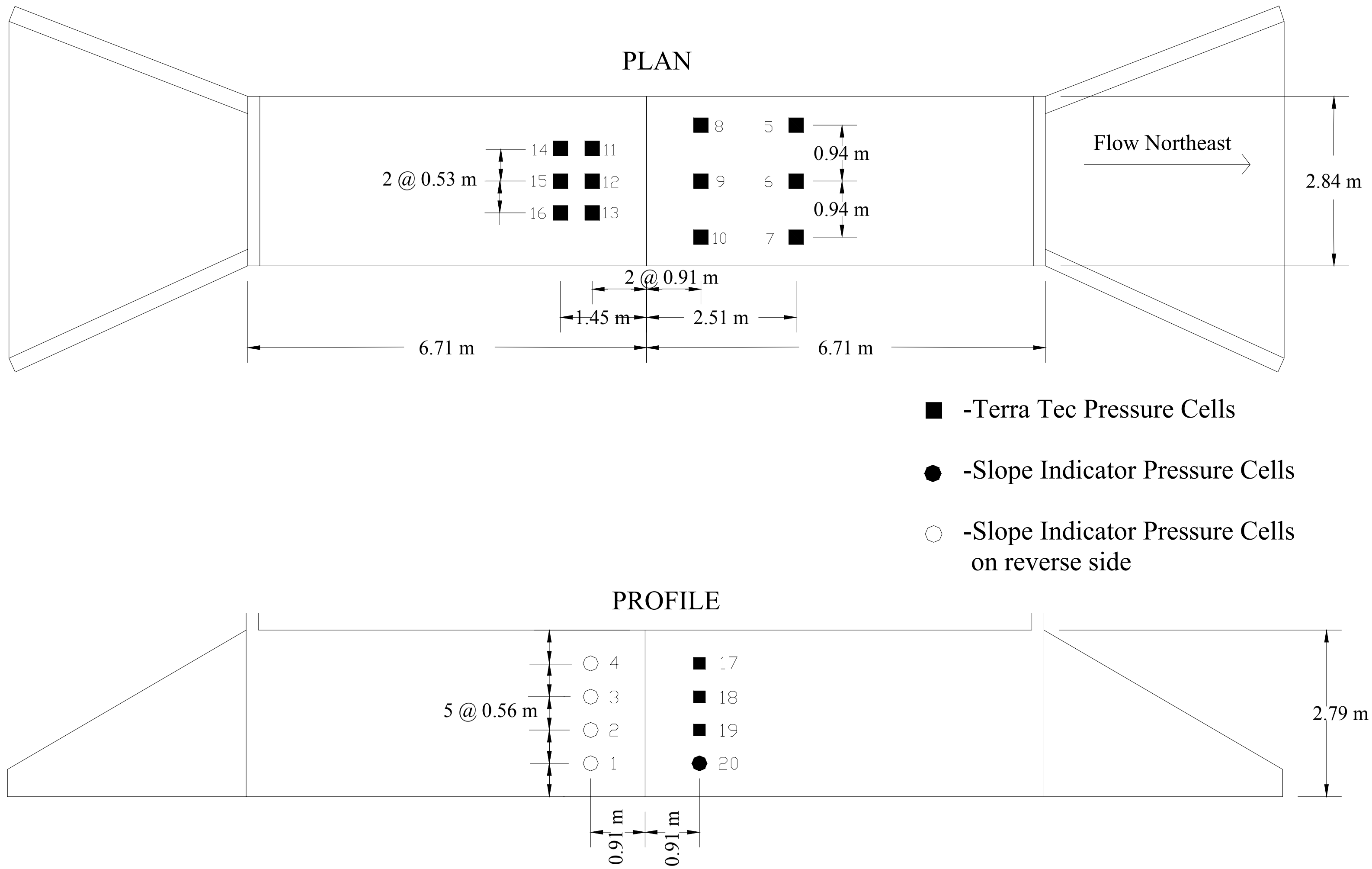

Figure 2. Culvert dimensions and position of pressure cells (after James et al.,1985)

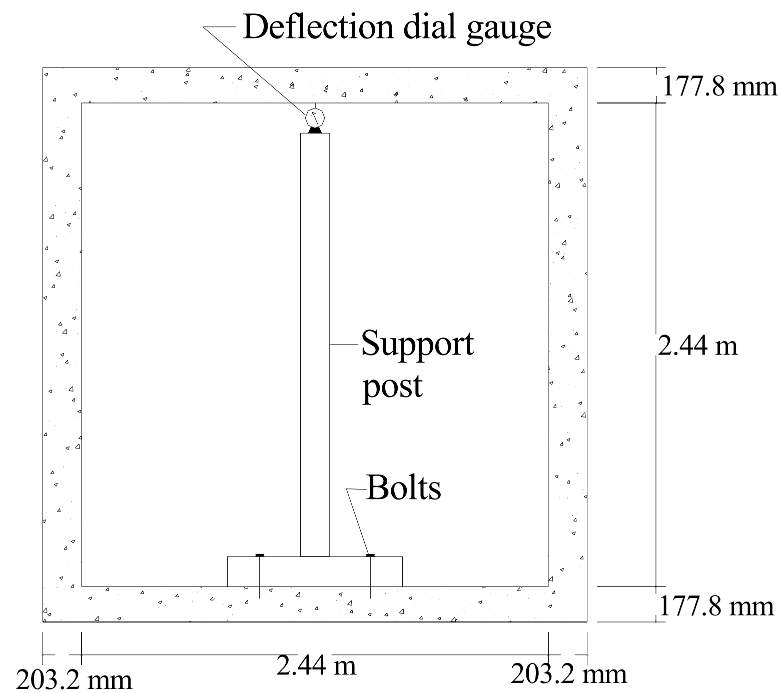

Figure 3. Culvert slabs and wall thicknesses and dial gauge mounting (after James et al.,1985)

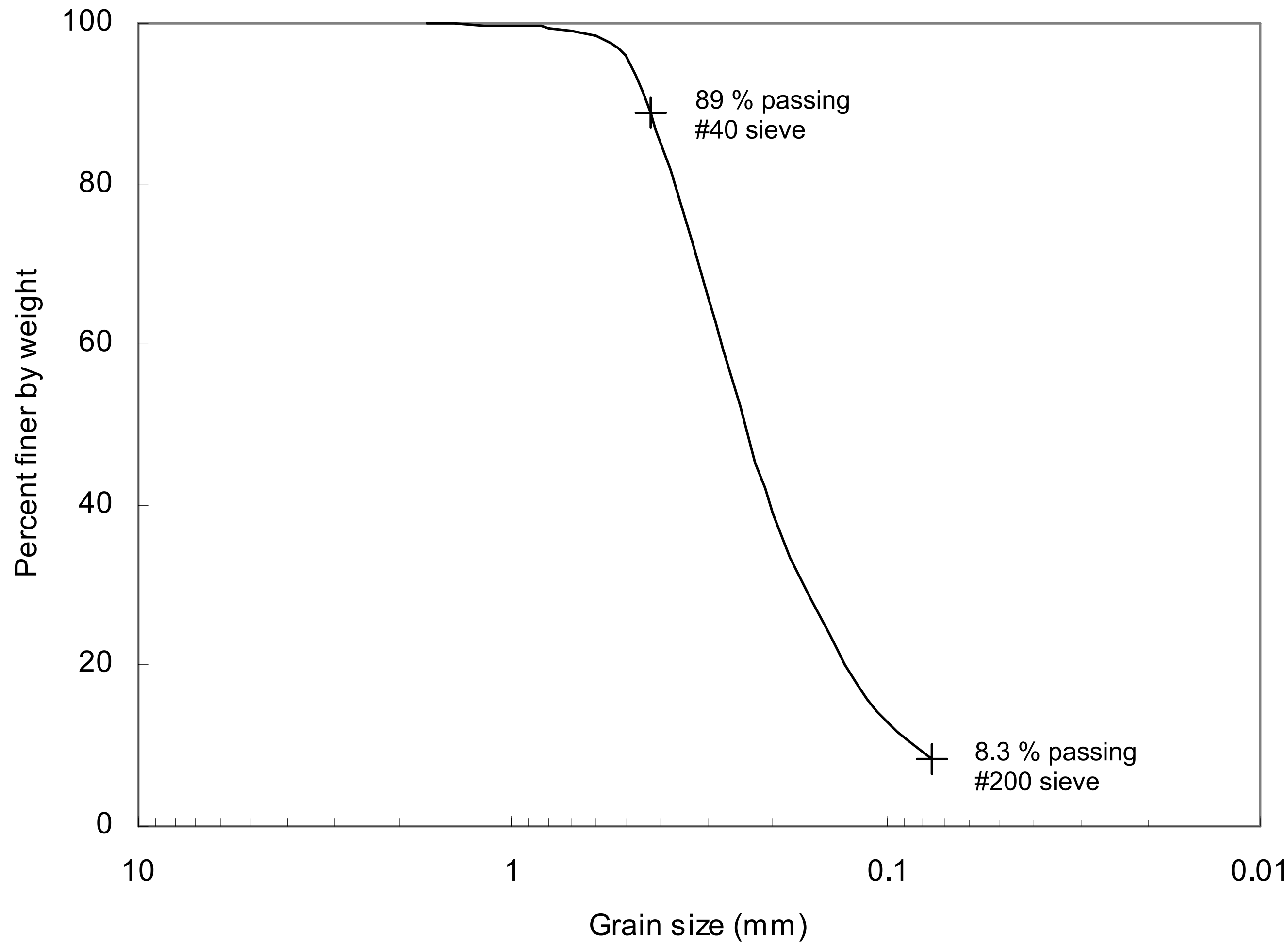

Figure 4: Grain size distribution of the fine, red, clayey sand – *Soil B* (after James et al.,1985)

Table 1. Soil Classification and Atterberg Limits (after James et al.,1985)

Soil Description	Classification		Atterberg Limits	
	Unified	AASHTO	Liquid Limit	Plasticity Index (%)
Fine, red, clayey sand *Soil B*	SC-SP	A-2-6 (0)	37.5	21.3
Fine, light, tan sand *Soil A*	SP	A-3 (0)	N/A	Non-Plastic

ASTM Spec. D4318-83

Table 2. Standard Proctor Compaction results (after James et al.,1985)

Soil Description	Maximum Dry Unit Weight (KN/m^3)	Optimum moisture content (%)
Fine, red, clayey sand *Soil B*	18.21	8.4

ASTM Spec. D698-78

Table 3. In-situ dry unit weights and moisture contents of the fine, red, clayey sand (*soil B*) at the test site (after James et al.,1985)

Location	Test Method	Dry Unit weight (kN/m^3)		Moisture Content (%)	
		Range	Average	Range	Average
Natural Ground	Balloon Volumeter	13.66-16.17	14.91	14.2-20.0	17.5
	Nuclear Density Meter	15.07-15.86	15.39	18.6-25.1	22.0
Backfill	Balloon Volumeter	---------	13.82*	---------	5.8*
	Nuclear Density Meter	13.50-15.39	14.76	20.8-23.1	21.9
	SDHPT Harris Cup	16.80-17.90	17.11	12.7-18.3	15.7
Compacted Roadway	Nuclear Probe	16.17-17.58	16.96	4.5-16.5	7.7

* Only one test of this type was performed
ASTM Specs. D2167-66, D2922-71, D3017-72

Table 4. Direct Shear and Consolidation Test results (after James et al.,1985)

Soil Description	Effective Stress Parameters		Range of Moisture Contents (%)	Range of Coefficient of Consolidation (cm^2/sec)
	φ′ (degrees)	c′ (KN/m^2)		
Fine, red, clayey sand soil B	31.8	0	22.6-23.4	$2x10^{-4}$ to $3x10^{-4}$

ASTM Spec. D3080-72