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Instrumented full-scale test with geogrid above the crown of a corrugated steel box culvert

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ABSTRACT: Corrugated steel box culverts are new structures in Europe. Box culverts are convenient where construction height is limited. Corrugated metal box culverts were developed in USA to meet a need for structures with large cross-sectional areas for water conveyance at sites with limited vertical clearance. Placing geogrid in the soil cover above the crown will increase the bearing capacity of the structure, and will decrease moments and deformations. This will make it possible to design more economical structures, and also decrease the necessary minimum height of cover. Comprehensive load testing was performed at the Road and Bridge Research Institute in Poland on a 3,55 m span instrumented steel box culvert. The test stand has the form of an 80 m long and 12 m wide reinforced concrete foundation with a system of anchors, a testing bay, and a steel frame serving as a support structure for the hydraulic load generating equipment. To the authors knowledge this is the first time in the world that load testing on a box culvert with geogrid has been performed in this scale.

1 INTRODUCTION

Corrugated steel box culverts are new structures in Europe. Corrugated steel box culverts were developed to meet a need for structures with large cross-sectional area at sites with limited vertical clearance.

Because box culverts are relatively flat and because they usually have small depths of cover, bending moments from live loads are quite significant, Bednarek (2000).

Traditionally the concrete relieving slab method is used to distribute live loads from traffic, Duncan et.al (1985).

A cost effective alternative to the concrete relieving slab, is to use geosynthetics reinforcement above the culvert. Placing geogrid in the soil cover above the crown will increase the bearing capacity of the structure, and will decrease moments and deformations.

Model tests at University of Oxford with steel strip reinforcement above the crown, were shown to give a reduction in crown bending strains and deflections of at least 50 %, Pearson and Milligan (1990). Similar results were shown in model tests with flexible steel arches and steel strips reinforcement in Canada, Kennedy et.al. (1988).

Finite element analyses of a box culvert with and without geosynthetics above the crown were conducted, Jeyapalan and Lytton (1982). These analyses showed that the the crown deflections decreased by about 30 % with geosynthetics.

2. TEST STAND AND INSTRUMENTED BOX CULVERT

The test stand (The socalled dynamic and fatigue test stand) has the form of an 80 m long and 12 m wide reinforced concrete foundation with a system of anchors, a testing bay, and a steel frame serving as a support structure for the hydraulic load generating equipment. The stand is outfitted with a system of hydraulic servos with a modern control and feeding system ensuring full control over the excited loads in real time, also in the case of dynamic loads.

The test stand with the instrumented box culvert is shown in Fig. 1

The test bin is 12 m long and 6 m wide. The backfill material consists of sandy gravel with maximum grain size 16 mm. The backfill material was placed in layers of 200 mm, and compacted. The actual measured average degree of compaction of the soil was: 1,01 below the footings, 1,00 at the top of the footings and 1,00 around the box culvert.

The load from the hydraulic actuators with capacity up to 2000 kN were distributed with a system of steel beams to simulate the road traffic load. Load testing were done with and without geogrid to study the effect of load spreading from geogrid. The structure was instrumented with strain gages, earth pressure cells and deformation inductors. Static and dynamic testing was performed to simulate the Polish Class A load for road traffic (4x200 kN/axle, total 800 kN).

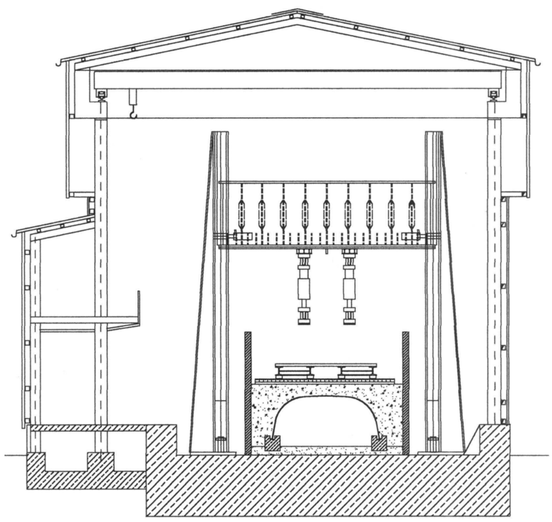

Figure 1 The test stand with the instrumented box culvert

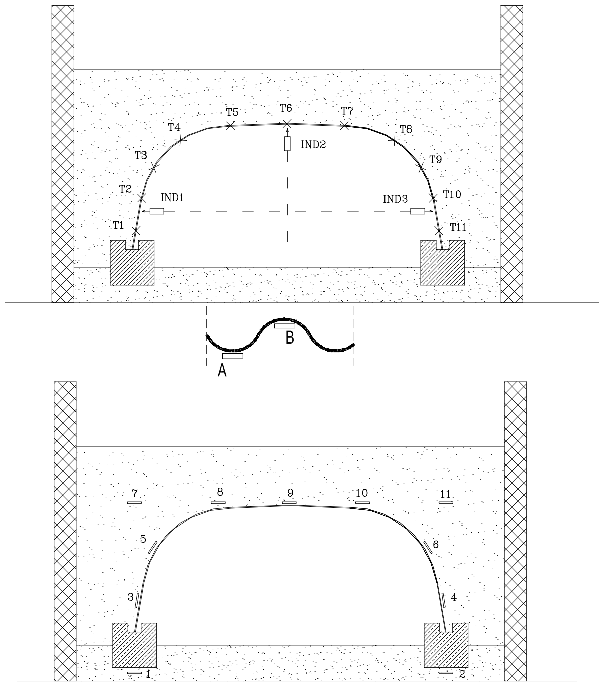

Figure 2. The test bin with the instrumented box culvert (T1–T11 – strain gages, IND1–IND3 – deformation inductors, 1–11 – earth pressure cells)

The instrumentation consists of 22 strain gages (11 locations with a strain gage in the top and bottom of the corrugation), 11 earth pressure cells and 3 deformation inductors (Fig. 2).

The geogrid used was a biaxially oriented polypropylene geogrid LBO 220 SAMP. Tensile properties of this geogrid were tested acc. to ISO 10319, GRI-GG1 and GRI-GG2 methods and as a result there was obtained the tensile strength of 7 kN/m at 2% strain and 14 kN/m at 5 % strain. The strength at peak was 20 kN/m in both directions and the strain at yield was 11,0% in machine direction and 10,0% in transverse direction.

Table 1. The loading program.

		Stage I	Stage II
Depth of cover [m]		0,60	0,60
Location of geogrids [m]		-	0,30
Static load	Level A – LL [kN]	870	870
	Level B – LLxDLA [kN]	1078	1078
	Level C – LLxDLAxSF [kN]	1582	1582
Fatigue load	Live load [kN]	870	870
	Number of cycles	500 000	500 000
	Frequency [Hz]	1,0	1
Maximum static load [kN]		1990	1990

Stage III			
		Load surface [m2]	Live load [kN]
Depth of cover [m]	0,6	5,0	1950
	0,3	5,0	1950
	0	5,0	1950
	0	1,5	585 – Failure load

Stage IV			
		Load surface [m2]	Live load [kN]
Height of backfill [m]	1,425		200
	0,92		200
	0,42	0,25	200
	0		200
	0		350 –Faileur test

LL – live load (800 kN), DLA – dynamic load coefficient (1,26), SF – partial safety factor (1,50)

During the test four loading stages (I, II, III, IV) were executed which differ by the loading value, depth of cover and presence of geogrid. The loading program is showed at the table 1.

Static testing with load up to 1990 kN and 0,6 m cover were done without and with geogrid. Dynamic testing with 500.000 cycles using a load of 870 kN at a frequency of 1 Hz were performed without and with geogrid. One layer of geogrid was placed 0,3 m above the crown.

3. OBSERVED RESULTS FROM TESTING

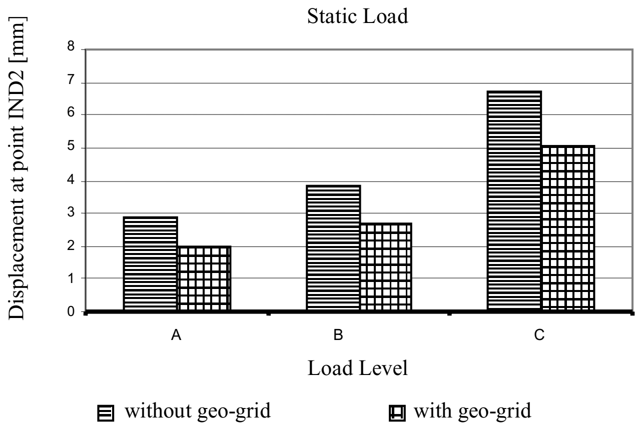

Figure 3. Deformation with static loads.

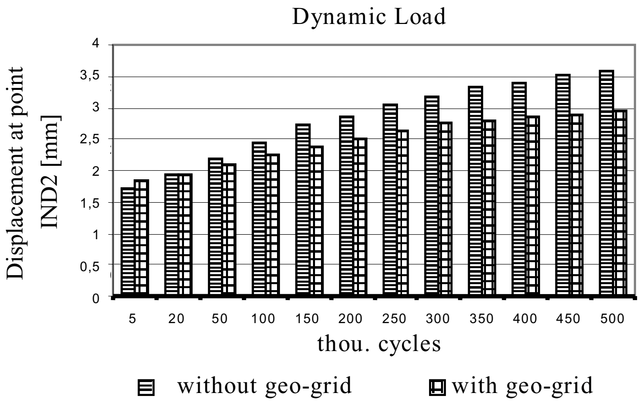

Figure 4. Deformation with dynamic loads.

The maximum deflection from static traffic load was reduced with 29,5 % for level A, 30,4 % for level B and 24,7 % for level C with the use of geogrid. The deflection of the crown of the box culvert was reduced with 17,8 % for the dynamic load with the use of geogrid.

4. CONCLUSIONS

This instrumented full scale test of a steel box culvert under live load shows clearly the potential of use of geosynthetics to increase the factors of safety and reduce the crown deflections with small cover.

The load testing shows that the box culvert has good safety even with small cover of soil. The use of geogrid will make it possible to reduce the minimum allowable height of cover.

Load testing with geogrid above the crown shows that this method can be considered as an alternative to the traditional relieving concrete slab used to spread the traffic loads.

5. REFERENCES

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