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Collapsing Peak Up of a Large Highway Steel Pipe-Arch

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SYNOPSIS: This case history reports the collapse of a large highway steel pipe-arch (8.12 m rise - 10.95 m span), occurring just when backfilling reached the top of the arch. No fill was placed on top as backfilling proceeded; the arch raised, thereby flattening side radius. It shows that stability in a soil-structure interaction system requires not only adequate design of the structure barrel, it also presumes a well engineered backfill. Performance of the flexible steel pipe-arch in retaining its shape and structural integrity depends greatly on placement and compaction of the envelope of earth surrounding the structure and distributing its pressures to the abutting soil masses.

INTRODUCTION

Underpasses or grade separations are an increasingly popular method of eliminating traffic hazards and thereby improving road safety. Soil-steel bridges using corrugated steel pipe are frequently the most economical of the short span bridge alternatives used to achieve grade separations.

Nevertheless installation and construction procedures are of fundamental importance especially during compaction of the backfill. During the course of examining various buried flexible pipe installation, monitoring their behaviour and, of course, analyzing failure case histories, several observations have been made that are of interest to the pipe designer or constructor.

This paper presents records on the deformation shape of the pipe-arch due to backfill loads causing a collapsing peak up of a large highway steel pipe-arch.

The measurements taken during the construction phase are seen to have been poorly chosen to predict such a problem at an early stage. Nevertheless an experienced engineer should have been able to detect this type of failure by analyzing in detail the evolution of appropriate parameters.

PIPE-ARCH LOCATION

The case history describes a vehicular underpass serving as grade separation for automotive traffic promoting the safe movement of vehicles.

This local road has been carried under a highway at less cost than by building a bridge.

Figures 1a, b, c show the pipe-arch size, shape and its alignment, grade with respect to the highway and the diverse characteristics of its installation.

Sectional properties of the arc-and-tangent of corrugation are derived mathematically:

- moment of inertia I = 33.04 cm^4/m
- inertia modulus I/v = 95.48 cm^3/m
- pitch 152.4 mm
- depth 51.5 mm
- thickness 7 mm

Galvanized bolts were used to assemble structural plate sections at the bottom of pitch.

INSTALLATION

The pipe-arch was a large-diameter bolted structure. The bedding fill was constituted with sandy silt of two metre thickness. It has been shaped to the approximated contour of the bottom portion of the structure in order to afford a uniform support for its relatively flat bottom. It was then compacted under the haunches of the structure in the first stages of backfill. The soil adjacent to the corners of pipe-arch was of excellent quality, highly compacted to accommodate the high reaction pressures that can develop at this location.

The backfill material around and near the pipe-arch was well graded gravel of size D less than 80 mm. Excellent control of soil placement and compaction were maintained to fully mobilize soil-structure interaction. The fill was placed alternately to keep it at the same elevation on both sides of the structure at all times. Compaction of the backfill was done with vibrating compactors.

SHAPE CONTROL

The pipe-arch was divided into five sections for which length measurements were taken throughout the backfill procedure. Figure 2 illustrates the sections chosen for controlling the geometry.

The figure 3 shows the length variations for each of the chords during the backfill construction phase. It can be seen that these vary little until just before the onset of failure.

The figure 4 shows that the variation of rise and span measured with respect to a fixed point during the same period gives for an experienced engineer a much earlier indication of the geometrical distortion.
Fig. 1a Geometry and Size of the Pipe-Arch

Fig. 1b Sectional Elevation of the Long Span Structure

Fig. 1c Pipe-Arch Alignment with respect to the Highway

Fig. 2 Geometry Control from Chord Length Measurements
Fig. 4 Span and Rise Variations during Backfilling showing with Evidence a Failure Potential when Backfilling reached Half of its Height

Fig. 5a Cloverleaf Collapse of the Pipe-Arch
Fig. 3 Length Variations of Symmetrical Chords during Backfilling. No alarming Sign was evident until just before the onset of failure.
A REGRETTABLE MISTAKE!

Unhappily there was a very regrettable mistake. Fill or load was not placed on top as backfilling proceeded. The top of the pipe-arch peaked up, thereby flattening progressively the side radius as shown in the figures 3 where the structure shape was checked regularly during backfilling to verify acceptability of the construction. It can be seen that the shape of the pipe-arch was not maintained in admissible condition.

No magnitude of allowable shape changes was specified by the fabricant of the long-span structure. The manufacturer had provided no qualified construction inspector during all structure backfilling to aid the engineer. Nobody advised him on the acceptability of the proper monitoring of the shape.

When the backfill reached the top of the pipe-arch, there was a long pause without having fill or load on the arch. Four hours later, the pipe-arch collapsed all along its length as shown in the figures 5.

CONCLUDING REMARK

This case history illustrates that failures during construction projects can arise simply through a poor implementation of conventional technical procedures [1,2]

REFERENCES
