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# EXPERIMENTAL APPROACH EMBANKMENTS AT SALT FORK RIVER BRIDGES ON US 177 AND THEIR INITIAL PERFORMANCE

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## ABSTRACT

This paper presents preliminary findings based on the initial performance evaluation of five approach embankments used in a bridge replacement project over the Salt Fork of the Arkansas River on US Highway 177 in Noble and Kay Counties, Oklahoma. The research involved instrumentation and measurement of four experimental approach embankments and one control approach embankment, all with similar dimensions. Instrumentation included total pressure cells to measure lateral earth pressure against the abutment wall, inclinometer casings to measure lateral movement of the backfill material and abutment walls, telescoping couplings on the inclinometer casings to measure settlement of the backfill and foundation, amplified liquid settlement gages for measurement of foundation settlement, and piezometers to measure pore water pressure. The four experimental backfills used were geotextile reinforced granular backfill, controlled low strength material backfill, dynamically compacted granular backfill, and flooded and vibrated granular backfill. The control section was unclassified borrow material placed at the contractor's discretion as long as density requirements were met. This paper documents and presents summaries of the preliminary findings regarding initial performance and construction cost of each approach embankment.

## KEYWORDS

Approach Embankment, Differential Settlement, Geotextile Wall, Controlled Low Strength Backfill, Dynamic Compaction, Flood and Vibrate Compaction

## INTRODUCTION

Differential settlement between bridges and approach embankments is a common problem throughout the United States. The research leading to this paper was aimed at finding practical solutions to the "bump at the end of the bridge." The research consisted of monitoring the performance of four experimental abutment wall backfills and comparing their performance to one another and identically instrumented control section. Five abutments were constructed during a bridge replacement project on US Highway 177 in Noble and Kay counties in north-central Oklahoma. The following is a discussion of the approach embankments and their initial performance.

## APPROACH EMBANKMENTS DESCRIPTION

Five approach embankments were the focus of the research, one control embankment and four experimental embankments.

### Control Section

The control section was representative of normal construction practices using performance specifications. Unclassified borrow and densities were specified. Compaction was achieved using a tracked front end loader with a full scoop driving over the backfill twice, perpendicular and parallel to the abutment wall.

### Geotextile Wall

The first experimental embankment was a geotextile stabilized wall constructed using non-woven geotextile and granular material. Twelve inch (30.5 cm) lifts were compacted using a walk-behind pad vibrator. The wall was constructed in eight lifts, each with three folded faces: one along the abutment wall and one on each of the wingwalls.

### Controlled Low-Strength Backfill

The second experimental approach embankment was constructed using a mix of fly ash, cement, sand, and water. Concrete trucks backed up to the forms and unloaded the flowable fill directly into the space behind the abutment wall. The compressive strength test results were below 300 pounds per square inch (21.6 $kg/cm^2$).

### Dynamically Compacted Granular Material

Dynamically compacted sand was placed as the third experimental approach embankment. Granular material was flooded, then compacted by dropping a 4 ft (1.2 m) cube of concrete (estimated to weigh approximately 4 tons (1814.4 kg)) from a height of 8 ft (2.4 m). A walk behind pad vibrator densified the 2 ft (0.61 m) perimeter near the abutment wall and wingwalls. Wall movement was monitored during compaction. The largest movement was 0.02 ft (0.610 cm).

### Flooded and Vibrated Material

The fourth experimental backfill was granular material that was flooded and vibrated. Lifts were placed at depths of 4 ft (1.2 m). The lift was then flooded with water and vibrated using a conventional concrete vibrator extended to the depth of the lift. The vibrator was inserted in a 1 ft (0.3 m) grid pattern.

## INITIAL PERFORMANCE

For quantitative comparison among the embankments, instrumentation was necessary. Each abutment was instrumented with: total pressure cells, amplified liquid settlement gages, piezometer, and inclinometer casings with telescoping couplings. Instrumentation was chosen to monitor: lateral movement of the abutment wall and the backfill, lateral stresses exerted upon the abutment wall, settlement, and pore water pressure.

### Lateral Movement of Abutment Wall and Backfill

Lateral earth movement was detected by using inclinometer readings and analyzing the data with computer software. In general, magnitudes were low with typical values of 0.05 in. (1.27 mm) in the direction of the centerline. Movement from inclinometer readings from the abutment wall, offset, and centerline was uniform in 3 of the 4 experimental embankments.

### Lateral Stresses Exerted Upon the Abutment Wall

The pressure exerted against the abutment walls was measured by the total pressure cells in units of pound per square inch. Values were used to compute theoretical Rankine active and at rest lateral earth pressures. Total pressure cells located at the bottom and center were closest to theoretical values, typically within 0.1 psi (0.01 $kg/m^2$). The highest vertical stress was at the control section, while the lowest stresses were recorded at both the dynamically compacted and flooded and vibrated embankments.

### Settlement

Settlement was measured by the amplified liquid settlement gages and the telescoping couplings of the inclinometer casings. The settlement gages show values that are greater along the centerline (versus the offset gages), which is consistent with vertical stress theory.

The telescoping couplings provided a good indication of movement, but the hook method used to measure casing movement in the couplings was not as reliable and accurate as the settlement gages. Although this may be the case, trends could be detected. The largest deformation occurred along the centerline, again consistent with vertical stress distribution theory. The geotextile wall showed the least settlement and the control section showed the greatest.

### Pore Water Pressure

Pore water pressure has played little role in the performance of the embankments. The elevation of the water table corresponded to river depth fluctuations which were a function or rainfall amounts. During flood stage, the water table reached elevations near the original ground surface. But, with the sandy foundation and embankment soils at the site, deformation was primarily elastic, which was not effectively influenced by the pore water pressure.

## PRELIMINARY FINDINGS

More than 6 months performance data is necessary for a final conclusion to be reached. Additional settlement and other time dependant variables can affect the performance. The data set used as the basis of this paper included only performance before the bridges were opened to the public. Although a final conclusion cannot be made, an evaluation of the data was performed. Simple comparison of performance led to the preliminary finding that the controlled low strength material backfill was the best performing approach embankment to date. All four experimental backfills performed better than the control section. Concerning cost of construction, the controlled low strength backfill was the least expensive of the experimental backfills, but all far exceeded the cost of the control section. An economical analysis accounting for the cost of damage from differential settlement between the bridge and approach embankment would be necessary to quantitatively determine the cost effectiveness of the experimental backfills. The results of an economical analysis combined with performance results would lead to a comprehensive final conclusion. A summary of cost of construction can be seen in the table below.

| EMBANKMENT | ESTIMATED COST |
|---|---|
| Control Section | $ 1,500 |
| Geotextile Wall | $ 25,000 |
| Controlled Low Strength Backfill | $ 14,560 |
| Dynamically Compacted Granular Materia | $ 15,000 |
| Flooded and Vibrated Granular Material | $ 16,000 |

*Table 1. Estimated Construction Cost (materials and labor)*

## REFERENCES

Benson, John M., *Construction of Experimental Approach Embankments at Salt Fork River Bridges on U.S. 177 and Their Initial Performance*, Oklahoma State University, 1996