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Geo-Infrastructure Post-Flood Damage Assessment, Repair and Mitigation Strategies

tech transfer summary

Assessment of flood-damage to geo-infrastructure using advanced technologies and selection of appropriate repair strategies can help mitigate future flood-related damages.

September 2013

RESEARCH PROJECT TITLE
Western Iowa Missouri River Flooding — Geo-Infrastructure Damage Assessment, Repair and Mitigation Strategies

SPONSORS
Iowa Highway Research Board
(IHRB Project TR-638)
Iowa Department of Transportation
Federal Highway Administration
(InTrans Project 11-419)

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The mission of the Center for Earthworks Engineering Research (CEER) is to be the nation's premier institution for developing fundamental knowledge of earth mechanics, and creating innovative technologies, sensors, and systems to enable rapid, high quality, environmentally friendly, and economical construction of roadways, aviation runways, railroad embankments, dams, structural foundations, fortifications constructed from earth materials, and related geotechnical applications.

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SPR RB19-012

Problem Statement

The 2011 Missouri river flooding caused damage to many geo-infrastructure systems including levees, bridge abutments/foundations, paved and unpaved roadways, culverts, and embankment slopes in western Iowa. The total reported direct cost to repair flood-damaged transportation infrastructure on primary and secondary roadways in western Iowa was about $63.5 million. The extent of damage was in some cases directly observable, i.e., where segments of the roadway were washed away, but in many cases was undetermined, i.e., where the damage was below the pavement surface or around bridges.

Project Goals

The main goals of this research project were to assist county and city engineers by deploying and using advanced technologies to rapidly assess the damage to geo-infrastructure and develop guidance for repair and mitigation strategies and solutions for use during future flood events in Iowa.

Summary of Flood Damages Observed

Based on field reconnaissance of the flood-damaged areas (Figure 1), review of the damage inspection reports, and interviews with county engineers, the damages observed are summarized in Table 1.

Table 1. Summary of flood damages

Paved Roadways
• Voids at shallow depths (< 150 mm (6 in.)) due to erosion of base material • Voids at deeper depths (> 150 mm (6 in.)) due to erosion of subsurface material • Complete erosion of pavements and underlying base/subgrade material • Erosion of granular shoulders
Bridges
• Erosion of bridge approach backfill material • Erosion of embankment foreslopes
Culverts
• Erosion of culvert backfill • Separation of culverts • Water outflow blockage
Unpaved Roadways
• Erosion of gravel surface • Rutting under traffic loading (on gravel roads and other detoured roadways due to excessive loading, although not flooded) • Full breach of roadway embankments

Pavement damage due to erosion

Full breach of roadway embankment

Erosion of granular shoulder

Erosion of abutment backfill

Stripping of chip seal surface

Cement grouting to fill eroded base

Figure 1. Post-flood damages

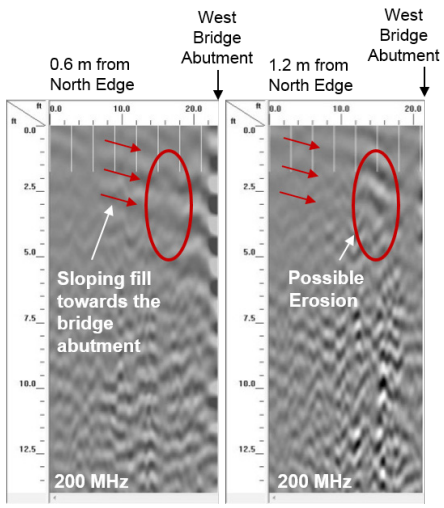

Figure 2. Ground penetrating radar scanning at a bridge site to identify subsurface voids/erosion in approach backfill

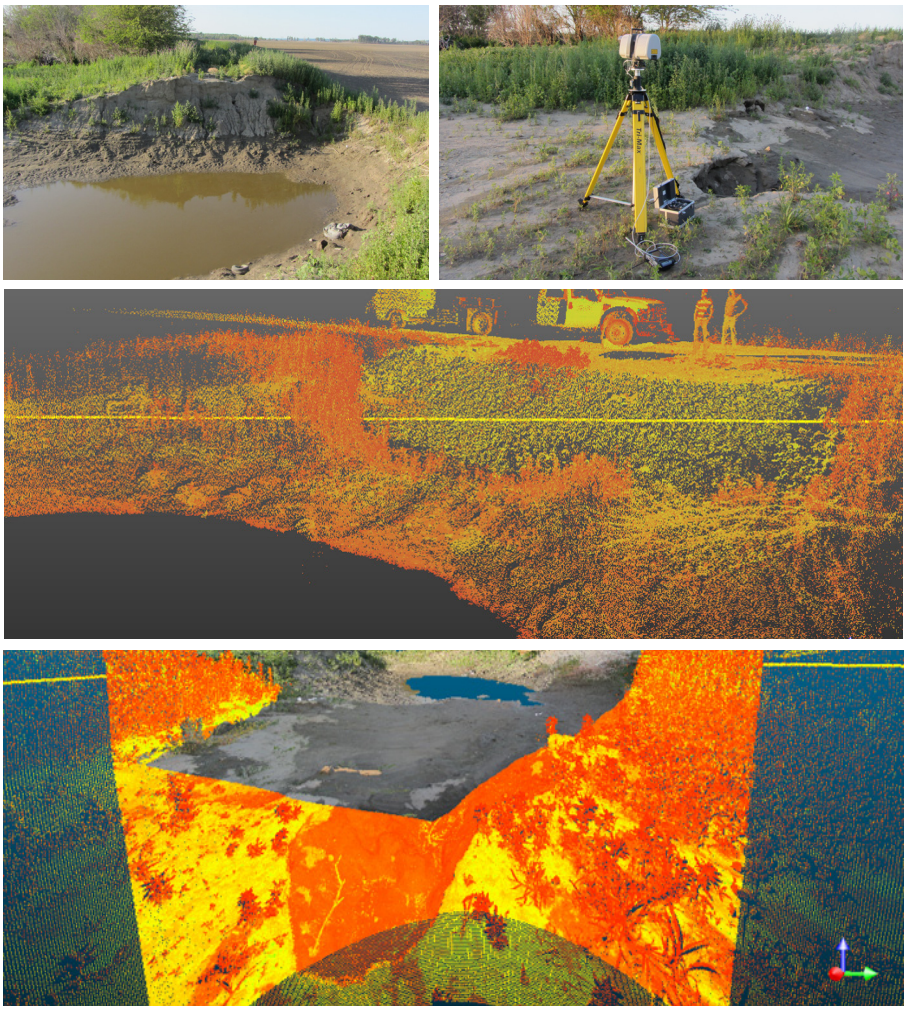

Figure 3. Laser scanning at a bridge site showing raw point cloud data and merged point cloud with photo

Figure 4. Falling weight deflectometer

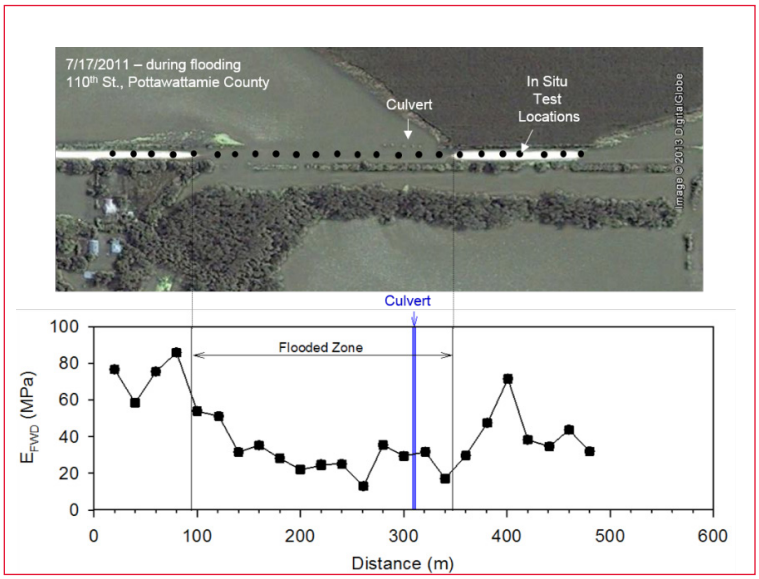

Figure 5. Aerial imagery (from Google Earth) and falling weight deflectometer (FWD) test results in flooded and non-flooded zones on 110th Street, Pottawatamie County

Research Approach

The research team visited selected sites in western Iowa to conduct field reconnaissance. Testing was conducted on bridge abutment backfills that were affected by floods, flooded and non-flooded secondary roadways, and culverts. In situ testing was conducted shortly after the flood waters receded, and several months after flooding to evaluate recovery and performance. Road test segments were selected with an objective to monitor performance of the flooded versus non-flooded areas by evaluating their subsurface foundation layer characteristics over time.

In situ testing involved conducting falling weight deflectometer (FWD)(Figure 4), dynamic cone penetrometer (DCP), ground penetrating radar (GPR) testing (Figure 2), and laser scanning (Figure 3) and performing hand auger soil borings. In situ testing was conducted on about 24 km (18.6 miles) of roadway. The test segments varied by flood condition (fully or partially flooded), and type of surfacing (gravel, chip seal surface over stabilized or unstabilized gravel base, portland cement concrete, and hot-mix asphalt).

Key Findings and Outcomes

- FWD tests obtained shortly (< 30 days) after flooding indicated that the average modulus values in flooded zones were about 1.3 to 3.6 times lower than the values in non-flooded zones (see Figure 5 for example). In some areas, the foundation layers within the flooded zone gained strength over time, likely as the degree of saturation in the subgrade decreased. However, many sections did not show much improvement.
- FWD surface modulus measurements were influenced more so by the subgrade layer (which was relatively weaker) than the surface gravel layer.
- A simple chart was developed to predict modulus values from subgrade and gravel California bearing ratio (CBR) values along with typical values for different subgrade treatments, which can be helpful in determining target values.
- Erosion of backfill materials around culverts was observed at several locations, which in some cases resulted in potholes and complete breach of the roadways.
- Erosion of bridge approach backfill materials was observed at the two bridge sites assessed in this study, resulting in voids down to about 2 m (6.6 ft) below surface.
- Ground penetrating radar scanning identified changes in gravel layer thicknesses, culvert locations, weep holes under roadways, voids beneath pavements, and voids in bridge approach backfill materials.
- Three-dimensional (3D) laser scanning was performed at a breach site to demonstrate rapid and accurate volumetric calculations.
- A flow chart relating the damages, assessment techniques, and 20 different potential repair/ mitigation solutions was developed (Figure 6).

Implementation Benefits and Readiness

The state of Iowa experienced severe geo-infrastructure damage due to flooding in 2008, 2010, and 2011. The flood damage assessment methods and repair and mitigation solutions presented in the report will aid city, county, state, and federal agencies in a future flood event.

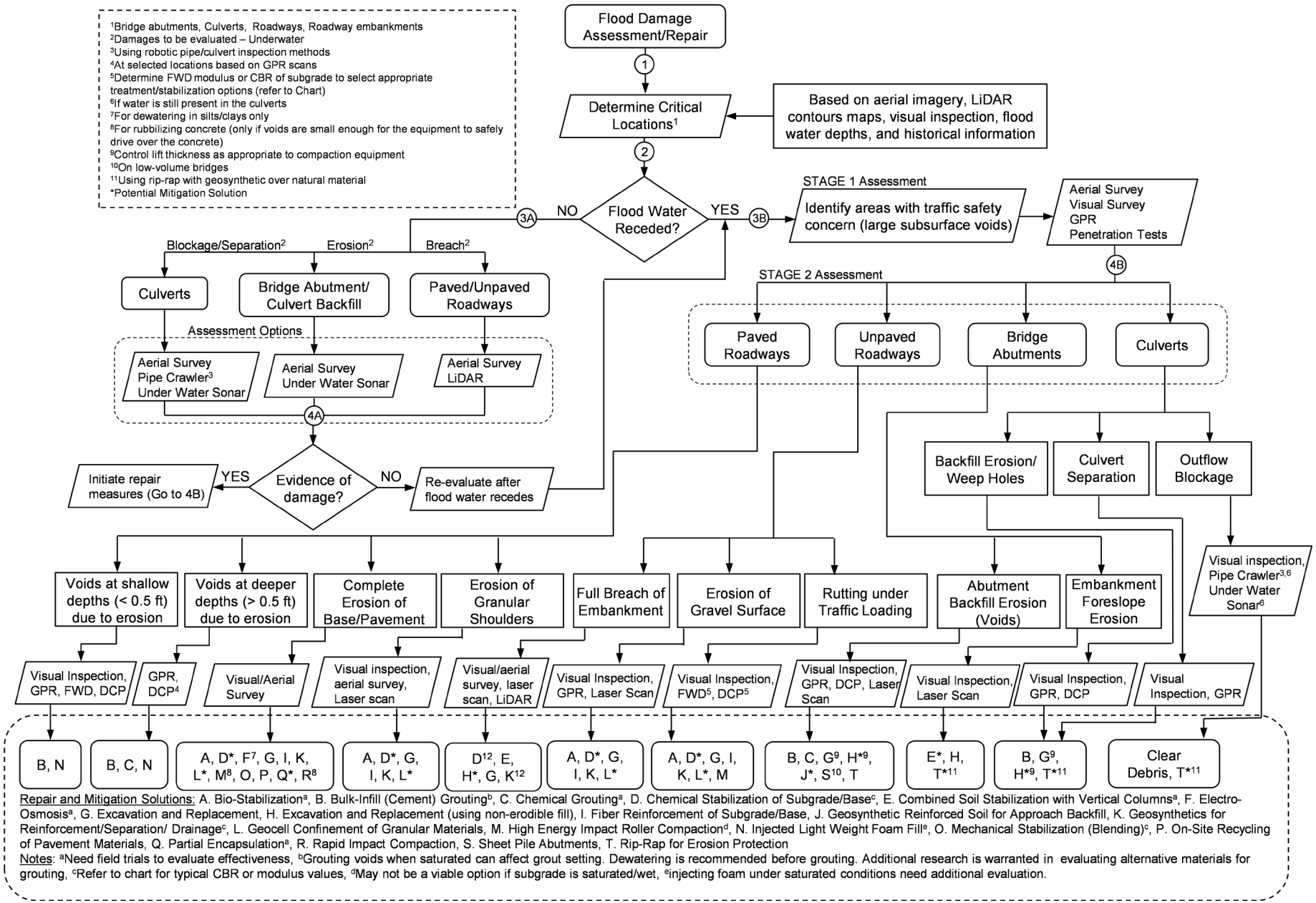

Figure 6. Flow chart to select assessment techniques and repair/mitigation solutions