CLAY CONTENT OF LEVEE EMBANKMENTS AND ITS ROLE IN SURVIVABILITY OF LEVEES DURING OVERTOPPING EVENTS

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Summer 2008 Midwest Floods

- Largest runoff event since 1993
- Record flows on lower Iowa River in Iowa and Salt Creek near Hannibal, MO
- No significant impacts on flood infrastructure downstream of St Louis
- Corps of Engineers dams probably shaved 1.5 to 3.5 feet off the peak flows
Lock and Dam No. 22 at Saverton closed on June 14th
Sites selected for further study

- Kehs
- Brevator
- Winfield
- Cap au Gris
- Kings Lake
- Elsberry
- Kickapoo
- Bryants Creek
- Indian Graves
- Two Rivers
Winfield-Pillsbury breach on June 18th. Note overtopping.
Second story of house being rafted from Winfield-Pillsbury
Cap au Gris Levee District

- Three breaks, all along the right bank of the Mississippi River
• Cap au Gris breach which we surveyed and sampled. Very sandy silt.
Off-the-shelf technology

- Rod ‘n reel
- Sonar fish finder; allowed us to see downed trees
- GPS receiver
- Rubber raft
• Seepage paths often influenced by features such as tree root tracks, crayfish and/or ground squirrel burrows

• Permeability of silty earthen dikes close to the modern channel is about $1 \times 10^{-3}$ cm/sec, or about 3 ft/day
Ground based LiDAR
Comparing silt lines on trees with levee crests

• In the old days we were obliged to survey mud lines on structures to get maximum flood heights
Lock and Dam No 25 near Winfield closed down June 15th
• The Brevator District levees near Winfield survived 14 days of near-continuous overtopping, without failing
Erosion tests of samples recovered from the Brevator Levees revealed they have a much higher clay content than levees closer to the Mississippi River which did not survive overtopping.
Two kinds of overtopping-induced damage

Velocity-induced scour at toe of back slope, at flow transition. Accelerates when vegetation stripped off, depending on cohesion of embankment materials.

Scalloping and notching on the fetch side of the levee, due to wave pounding; and piping fomented by emergent seepage at the toe of the back slope.

Note: damage at back slope toe looks similar for both modes.
• Soil erodability test apparatus developed by Prof. Jean-Louis Briaud at Texas A&M University
• Erodability data for Midwestern Levees sampled after the 2008 floods
The key to levees surviving overtopping is the **clay content**. Much of the dredged material consisted of organic silt, which does not have substantive cohesion.
Natural levees and floodplains
LiDAR derived relief map of the lower Cuivre River, employing 1 m posting. Note cut-offs employed between meander bows on the Mississippi flood plain.
DOQQ imagery wrapped on the LiDAR and DEM surface, showing development of the Mississippi River flood plain at mouth of the Cuivre River.
Biggest Repair Problem

- Deep scour holes are perhaps the biggest engineering challenge in repairing dikes.
- These holes can be up to 40 ft deep and are backfilled with dredged sand.
- A 5 ft thick clay cap is compacted over the sand fill to provide a semi-impervious seepage ‘blanket’
The existing levee system is antiquated

- Levees were originally placed to reclaim floodplains for agricultural development and to protect urban commercial centers.
- Levees and floodwalls have allowed continuing development of urban commercial centers.
- The risk-consequence of a levee failure in densely populated areas can be several orders of magnitude greater than within most agricultural tracts.
- Since 1990 our national policy has shifted to promoting the removal of urban developments off the flood plains, whenever possible.
Making levees more resilient – and survivable

- The NSF-funded team is focusing on areas where levees have repeatedly failed.
- And, places where levees survived sustained overtopping, sometimes for several weeks.
In the 21st Century we will face economic pressures to make levees more resilient

- Levees need to be made more survivable.
- Some of the greatest damage occurs at forced breaches, to drain inundated tracts
- Levees could be retrofitted with engineered overflow weirs
- Rudimentary outlet works should be installed at the down-gradient ends of agricultural tracts, to obviate need for forced breaches
- Some environmentalists and civil engineers have advocated returning 25% of reclaimed floodplain, and promoting aquaculture crops in the lowest areas ("nutrient farms")
Aging Factors
that plague geotechnical engineers designing levees:

1) Erosion/aggradation impacts
2) Differential settlement
3) Changes in channel geometry, roughness, flow quantities, flood storage, recurrence frequencies, risk-consequence models, etc.
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This lecture will be posted at

www.mst.edu/~rogersda/levees

in .pdf format for easy downloading and use by others.