Seismic Hazard Mitigation of Transportation Structures

Issam Harik

Department of Civil Engineering, and
Kentucky Transportation Center

University of Kentucky
Lexington, Kentucky USA
Outline

- Introduction
- Hazard Mitigation
- Conclusions
Outline

- Introduction
  - Hazard Mitigation
  - Conclusions
Disaster and Emergency Management

- Medical
- Power
- Water
- Law Enforcement
- Transportation
- Other
Hazards on Bridges and Highway Structures

- Man-Made Hazards
- Natural Hazards
Man-Made Hazard

A man-made hazard is an accidental or intentional event of unusual magnitude that threatens the activities of people or people themselves.
Man-Made Hazards

- Biological
  - Blast
- Chemical
  - Fire
- Nuclear
- War
- Other
Pike County, Kentucky, USA
Truck Impact

I-44, Lebanon, Missouri
Truck Impact

I-44, Lebanon, Missouri
I-44, Lebanon, Missouri
Truck Impact

I-44, Lebanon, Missouri
Activities in Kentucky
I-64 Parallel Bridges over US60

This outer girder on Eastbound I-64 over Eastbound US60 gets hit by trucks exceeding the height restriction due to low clearance at that station.
North

Eastbound US 60
(To Versailles)

Westbound US 60
(To Frankfort)

Westbound I-64
(To Louisville)

Eastbound I-64
(To Lexington)

The outer girder on Eastbound I-64 over Eastbound US60 gets hit by trucks exceeding the height restriction due to low clearance at that location.

This girder in Span 3 on Westbound I-64 underwent excessive deflection and vibration under truck loading. Cracks had formed on this girder and the adjacent girders.

This girder in Span 1 on Westbound I-64 underwent excessive deflection and vibration under truck loading. Cracks had formed on this girder and the adjacent girders.
North

Possible Instrumentation Plan

Eastbound US60 (To Versailles)

Crack Sensor
Strain gage
(Span 3)

Westbound US60 (To Frankfort)

Strain gage
Crack sensor
(Span 1)

Note: Depending on additional cost, instrumentation on Span 1 may not be placed

Eastbound I-64 (To Lexington)

Vehicle Height Sensor
Impact Detector

Camera #1

Westbound I-64 (To Louisville)

Camera #2
Truck Fire

I-65/I-59/I-20 Interchange in Birmingham, Alabama
Truck Fire

I-65/I-59/I-20 Interchange in Birmingham, Alabama
Tanker Truck Fire - MacArthur Maze Freeway
Oakland, California
29 April, 2007
Tanker Truck Fire - MacArthur Maze Freeway
Oakland, California
29 April, 2007
Tanker Truck Fire - MacArthur Maze Freeway
Oakland, California
29 April, 2007
BARGE IMPACT ON BRIDGES
Emergency crews surveyed the scene of the bridge collapse where Interstate 40 crosses the Arkansas River near Webbers Falls, Okla.

Barge collapses Oklahoma bridge

MOTORISTS TRAPPED AS VEHICLES FALL INTO RIVER

HERALD-LEADER WIRE SERVICES
WEBBERS FALLS, Okla. — A barge struck the Interstate 40 bridge over the Arkansas River early yesterday, causing a 600-foot section of the span to collapse into the river.

Officials said as few as seven people or as many as 20 might have died in the 7:45 a.m. collapse, but the fear that the remainder of the bridge would collapse slowed recovery efforts.

The barge’s crew said their pilot, Joe Dedmon, 61, of Florence, Miss., was at the helm at the time of the accident and appeared to suffer a seizure just before the collision, investigators said.

He had no previous medical conditions, according to Joel Henderson of Magnolia Marine Transportation Co., which owns the tugboat and barges.

See BRIDGE, A9
Barges smash bridge; cars plummet 85 feet

By Lynn Bronsky

PORT ISABEL, Texas — A group of barges smashed a 240-foot section out of the only bridge linking the mainland with South Padre Island early yesterday, and at least four people died after their vehicles plunged into the water 85 feet below.

An unknown number of people were missing. Thirteen were rescued from the Laguna Madre, part of the International Waterway shipping route along the Gulf Coast, and three were hospitalized.

Freezing winds were blowing at the 50-foot-deep water, and divers took pictures of their missing planes. No identification, said Cameron County Sheriff Cris Cortez. The sheriff said as many as 80 vehicles could be in the water.

Robert Fike, a sightseer near the four-lane bridge yesterday afternoon said the bridge had not been heard from her 18-year-old daughter, Tiffani, since she went to the island with friends late Friday.

"Nobody called, and they always call," Fike said, her voice trembling.

Michael Burke, whose two cows had gone out with Tiffani, anxiously waited with Fike.

"I just want to know where my kids are. I hope they're all right and just can't call me," Burke said.

Recovery efforts were suspended late yesterday afternoon when the third 80-foot section of the bridge collapsed, said Adrian Almena, a spokesman for the Department of Public Safety. The search is resuming this morning.

The Coast Guard was notified around 2:30 a.m., that the tug Brown Water V and its four barges, loaded with coal and phosphates, had struck the}

South Padre Island has 2,000 permanent residents, and island levels were about 30 percent bound for the weekend.

Most tourists on the island camp to celebrate Mexico's Dia de Septiembre independence day.

In addition, thousands of volunteers had been expected yesterday to help with beach cleanup, part of Adopt-A-Beach day, said local police chief Randy Bastian.

The island is a spring break mecca, when crowds of up to 200,000 people stay on the island in March alone.

The barges were owned by American Commercial Lines Inc. of Jeffersonville, Ind., and were being pushed by a tugboat owned by Brown Water Marine Services Inc of Rockport, Texas, said American Commercial assistant vice president Jim Adams.
Amtrak Accident Scene, 1993
Activities in Kentucky
Instrumentation Plan - US 41N Bridge

Detect Impact on Pier B, or C, or D

Locations for Accelerometers at top of Piers B, C, and D
Natural Hazard

“A natural hazard is an unexpected or uncontrolled natural event of unusual magnitude that threatens the activities of people or people themselves.”

Source: www.naturalhazards.org
Eastern Section of I-10 Causeway

Hurricane Katrina, August 2005
Highway I-90, Gulf Coast of Mississippi

Hurricane Katrina, August 2005
Highway I-90, Gulf Coast of Mississippi

Hurricane Katrina, August 2005
Hurricane Katrina, August 2005

Flooded Roadway in New Orleans, Louisiana

Hurricane Katrina, August 2005
Typhoon #18, September 8, 2004

The Ohmori-Ohashi Bridge – Hokkaido, Japan
Construction of Temporary Bridge

(Completed on December 10, 2004)

The Ohmori-Ohashi Bridge – Hokkaido, Japan
Earthquake Hazard

- Airports
- Railways
- Bridges
  - Roadways
  - Navigable Waterways
  - Other
Earthquake Hazard on Bridges
The Loma Prieta Earthquake (1989)
Bay-Bridge

1989 Loma Prieta Earthquake
The Northridge Earthquake (1994)
Chi-Chi Earthquake, Taiwan (1999)
Tangshan Earthquake - China

July 28, 1976 at 03:42 AM
Outline

- Introduction

- Hazard Mitigation

- Conclusions
How Do We Cope With Earthquakes?

Earthquakes are very difficult to predict and are unpreventable. Therefore, mitigation of earthquakes requires designing structures (including buildings, roadways, bridges, etc.) that can withstand repeated shaking.

Source: www.naturalhazards.org
Earthquake Mitigation for Bridges and Highway Structures

- Pre-Event
- During-Event (Crossed out)
- Post-Event
Earthquake Mitigation of Bridges and Highway Structures

- **Pre-Event**
  - Seismic Evaluation & Retrofit
  - Post-Earthquake Planning
  - Other

- **During-Event**

- **Post-Event**
Earthquake Mitigation of Bridges and Highway Structures:

- Pre-Event
- During-Event
- Post-Event

Seismic Evaluation and Retrofit

- Post-Earthquake Planning
- Other

- Seismic Input
- Prioritization
- Seismic Evaluation
- Recommendation
- Seismic Retrofit
- Other
Earthquake Mitigation of Bridges and Highway Structures:

- Pre-Event
- During-Event
- Post-Event

Seismic Evaluation and Retrofit

- Post-Earthquake Planning
- Other

- Seismic Input
  - Prioritization
  - Seismic Evaluation
  - Recommendation
  - Seismic Retrofit
  - Other
Seismicity in the United States
New Madrid Zone
Activities in Kentucky
Acceleration time history for component-1 of the 500-Year event for counties identified by 0.3g-1

Acceleration time history for component-2 of the 500-Year event for counties identified by 0.3g-1

Acceleration time history for component-3 of the 500-Year event for counties identified by 0.3g-1
Maximum Credible Earthquake (MCE) Ground Motion: 0.2 Sec Spectral Response Acceleration (5% of Critical Damping), Site Class A (Hard Rock)
Maximum Credible Earthquake (MCE) Ground Motion: 1.0 Sec Spectral Response Acceleration (5% of Critical Damping), Site Class A (Hard Rock)

Peak Ground Acceleration

- 0.01g
- 0.05g
- 0.10g
- 0.20g
- 0.40g

Legend:
- Green: Interstate
- Brown: Parkway
- Red: U.S. or State

SCALE

North

0 50 Miles

0 50 Kilometers
Earthquake Mitigation of Bridges and Highway Structures:

- Pre-Event
- During-Event
- Post-Event

Seismic Evaluation and Retrofit

- Post-Earthquake Planning
- Other

- Seismic Input
- **Prioritization**
  - Seismic Evaluation
  - Recommendation
  - Seismic Retrofit
  - Other
I-24 and Parkways
Seismic Retrofitting Manual for Highway Bridges
Preliminary Screening

Seismic Inventory of Bridges

This program is designed to aid the user in a preliminary seismic inventory of bridges in a particular region. The program will also allow the user to export an Excel spreadsheet or generate a report detailing the information.

Please make your selection below.

- Enter or Modify Data
- Preview Seismic Report
- Export Excel Spreadsheet
- Print Seismic Report

Close
Exit
### General Information

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge Name</td>
<td>Henderson_Audubon Parkway</td>
</tr>
<tr>
<td>Location</td>
<td>1.2 MI SE OF JCT US 41</td>
</tr>
<tr>
<td>Year Designed/ Built</td>
<td>1986</td>
</tr>
<tr>
<td>Alignment</td>
<td>Skewed</td>
</tr>
<tr>
<td>Skew</td>
<td>45 degrees</td>
</tr>
<tr>
<td>Overall Length</td>
<td>264.59 ft</td>
</tr>
<tr>
<td>Overall Width</td>
<td>37.5 ft</td>
</tr>
<tr>
<td>Detour Length</td>
<td>miles</td>
</tr>
<tr>
<td>Roadway carried by bridge</td>
<td>Parkway</td>
</tr>
<tr>
<td>Feature crossed by bridge</td>
<td>Roadway</td>
</tr>
<tr>
<td>Does the bridge cross a body of water?</td>
<td>No</td>
</tr>
<tr>
<td>Has the bridge been seismically retrofitted?</td>
<td>No</td>
</tr>
</tbody>
</table>

### Columns and Piers

- Additional Cl: [Fields for specific columns and piers information]

### Bearings

- Note: Feature crossed by bridge is the roadway, river, valley, or other landform that the bridge is used to cross.
- Description/Date of Retrofit: [Fields for retrofit information]
- Geometry: Regular
- Remarks: [Fields for additional remarks about the bridge]

---

**Note:**
- Feature crossed by bridge is the roadway, river, valley, or other landform that the bridge is used to cross.
- Description/Date of Retrofit: [Fields for retrofit information]
- Geometry: Regular
- Remarks: [Fields for additional remarks about the bridge]
PRIORITIZATION (Preliminary Screening):

Seismic Rank:

R ranges between 0 (Not Critical) to 100 (Highly Critical).
Earthquake Mitigation of Bridges and Highway Structures:

- **Pre-Event**
- **During-Event**
- **Post-Event**

**Seismic Evaluation and Retrofit**:
- Post-Earthquake Planning
- Other

**Seismic Evaluation**:
- Seismic Input
- Prioritization

**Seismic Evaluation**:
- Recommendation
- Seismic Retrofit
- Other
Steel Beam with RC Slab
Steel Beam with RC Slab
Pre-stressed Concrete I-Girder with RC Slab
Pre-stressed Concrete I-Girder with RC Slab
Single Span Bridges
Two-span Bridges
Multi-span Bridges
Evaluation Process
For Critical Bridges

- Field Testing
- FE Model Calibration
- Seismic Evaluation
Roebling Bridge over Ohio River
The Maysville Bridge
The Maysville Bridge
Task 3: FE Modeling ..... Maysville Bridge

Plan

3-D View

1st Vertical Mode

Elevation
Task 3: FE Modeling ..... Maysville Bridge

1st Transverse Mode (+Torsion)
The Owensboro Bridge
Owensboro Bridge
The Brent-Spence Bridge
I-64 over the Ohio River (Sherman-Minton Bridge) Between Louisville, KY and New Albany, IN
US 51 Bridge Over the Ohio River

Wickliffe, KY to Cairo, IL
Henderson, KY to Evansville, IN

Bridge on US-41

10-23-96
Bridge over Tennessee River
Earthquake Mitigation of Bridges and Highway Structures:

- **Pre-Event**
- **During-Event**
- **Post-Event**

**Seismic Evaluation and Retrofit**

- **Post-Earthquake Planning**
- **Other**

**Recommendation**

- Seismic Input
- Prioritization
- Seismic Evaluation

- Seismic Retrofit
- Other
Provide additional shear bolts or replace bearing
Earthquake Mitigation of Bridges and Highway Structures:

- **Pre-Event**
  - Seismic Evaluation and Retrofit
    - Post-Earthquake Planning
    - Other
  - Seismic Input
  - Prioritization
  - Seismic Evaluation
  - Recommendation
  - **Seismic Retrofit**
  - Other

- **During-Event**

- **Post-Event**
Lead-filled Elastomeric Isolation Bearing
Retrofit measure: Example

- Reinforced concrete column/pier
- Steel/FRP jacket
- Footing
Earthquake Mitigation of Bridges and Highway Structures:

- Pre-Event
- During-Event
- Post-Event

Post-Earthquake Planning:
- Seismic Evaluation & Retrofit
- Other

- Develop Contingency Plan
- Provide Training
- Instrumentation & Monitoring
- Other
Earthquake Mitigation of Bridges and Highway Structures:

- Pre-Event
  - Seismic Evaluation & Retrofit
  - Post-Earthquake Planning
    - Develop Contingency Plan
    - Provide Training
    - Instrumentation & Monitoring
    - Other
Activities in Kentucky
Bridge over Tennessee River
Henderson, KY to Evansville, IN

Bridge on US-41
Earthquake Mitigation of Bridges and Highway Structures

- An earthquake lasts for few seconds.
- Action during the event is not possible.
Earthquake Mitigation of Bridges and Highway Structures

Pre-Event

During-Event

Post-Event

Stage 1

Stage 2
Earthquake Mitigation of Bridges and Highway Structures:

- Preliminary Assessment
- Prioritization
- Recommendation
- Immediate Action
- Other

Stage 1

Stage 2

Pre-Event

During-Event

Post-Event
Activities in Kentucky
- Response Team: $\geq 2$ hours
- Driving: $\geq 4$ hours
- Delays: $= ??$ hours
- Other: $= ??$ hours

At Least 6 hours
Local Inspectors in Western Kentucky

Expert Support System (ESS)
Global Positioning System (GPS)
Geographical Information System (GIS)

Live Pictures
Electronic Data
Report

Stage 1

Stage 2

Stationary Team in Frankfort

Mobile Team en Route

Local Inspectors in Western Kentucky
Teams in Stage 1

- 0-Teams
- 2-Teams
- 3-Teams
Objective of Stage 1

Triage

In Cooperation with the

Kentucky National Guard
Kentucky Post-Earthquake Investigation Software (KyPEIS)

- Select Inspect or View
- Enter Name and Affiliation
- Press start if connected to GPS receiver and require data
- Next to continue
GPS receiver detection message

Check here to use GPS data to select bridge
Enter damage level

Next to continue
Next to continue
Next to continue
Local Inspectors in Western Kentucky

Expert Support System (ESS)
Global Positioning System (GPS)
Geographical Information System (GIS)

Stage 1

Stage 2

Live Pictures
Electronic Data
Report

Stationary Team in Frankfort

Mobile Team en Route

Teams in Stage 2
Outline

- Introduction
- Hazard Mitigation

- Conclusions
Conclusions

- We Can no Longer Accept the High Cost of Life or Ensuing Economic Losses When Natural or Man-Made Disasters Strike
Conclusions

- We Can no Longer Accept the High Cost of Life or Ensuing Economic Losses When Natural or Man-Made Disasters Strike

- We Cannot “Prevent” nor “Predict” Disasters
Conclusions

- We Can no Longer Accept the High Cost of Life or Ensuing Economic Losses When Natural or Man-Made Disasters Strike
- We Cannot Be “Prevent” nor “Predict” Disasters
- We Now Have the Means to Better “Prepare” for Disasters
Conclusions

- We Can no Longer Accept the High Cost of Life or Ensuing Economic Losses When Natural or Man-Made Disasters Strike
- We Cannot Be “Prevent” nor “Predict” Disasters
- We Now Have the Means to Better “Prepare” for Disasters

- We Now Have the Means to “Respond” Immediately Following a Disaster
Conclusions

- We Can no Longer Accept the High Cost of Life or Ensuing Economic Losses When Natural or Man-Made Disasters Strike
- We Cannot Be “Prevent” nor “Predict” Disasters
- We Now Have the Means to Better “Prepare” for Disasters
- We Now Have the Means to “Respond” Immediately Following a Disaster
- We Now Have the Means to Quickly and Effectively “Restore” Defective Structures Following a Disaster
Questions?
Thank You
and
Have a Nice Day