I-10 MOBILE BAYWAY CONSIDERATIONS

01 Project Overview and Status
02 Storm Surge Modeling
03 Geotechnical Considerations
04 Structural Evaluation and Potential Alternatives
01 Project Overview and Status
Approximately 2,460 miles of Interstate 10 connect the West Coast to the East Coast. Extends from SR1 (Pacific Highway) in Santa Monica, California and runs to Jacksonville, Florida. The I-10 Wallace Tunnel and Mobile Bayway comprise a nationally recognized restriction to travel that emerges as routine gridlock on holiday and seasonal beach and tourist travel periods.

The I-10 Gulf Corridor
Wallace Tunnel Traffic Forecast

Source: Alabama Department of Transportation

Daily maxima occurs approximately 1-2 times a week during holidays and summer tourist season.
The I-10 Bayway Corridor

- Approximately 7.5 miles of 2-lane EB and WB bridges connect the eastern shore of the Mobile River to Spanish Fort across Mobile Bay
- The Bayway bridges include 4 river crossings
- The project considers addition of two lanes to each EB and WB bridge to address capacity needs
Bayway Project Goals

- Improve Level of Service
- Minimize impacts
- Facilitate:
  - Local demand
  - Commuters each way
  - Freight movements
  - Through traffic
  - Tourism and local business
  - States of Emergency
- Make the infrastructure survivable
02 Storm Surge Modeling
Storm Surge Bridge Impacts

Hwy 90 Pass Christian

Hwy 90 Biloxi

I-10 Twin Spans
Storm Surge Bridge Impacts
AASHTO 2008 and HEC-25 Vol 2 Guide Specifications for Bridges Vulnerable to Coastal Storms

- Design Parameters
  - Storms, Surge, Waves
  - Levels I, II and III

- Force/Moment Computations
  - Low frequency (wave frequency)
  - High frequency (slamming)

- Need to consider Sea Level Rise over structure lifetime
Storm Surge Risk

Catalog Storm Tracks 1851-2009

From National Hurricane Center
Storm Surge Risk

- Surge is governed by Site itself and 5 defining parameters
  1. Max wind speed (Central Pressure)
  2. Storm size (radius to maximum wind)
  3. Storm speed
  4. Storm landfall location
  5. Storm track angle at landfall
- (there are more than 20 others, but these are most significant)
- 5-way joint probability (JPM) can define all probable cases, but would require on the order of 1000 simulations per scenario
- Use ‘Optimal Sampling’ (JPM-OS procedure) to reduce requirements, results in ~150-200 simulations per scenario

Toro et al, 2010
Storm Surge Modeling: ADCIRC+SWAN
Storm Surge Risk – Level III Analysis

- Synthetic storm tracks to complete JPM-OS
- FEMA = 295 storms
- Estimate for Mobile Bay ~ 200 storms, could be reduced with some sensitivity analysis
- Results:
  - Max Surge Elevation at defined risk levels along the Bridge:
    - 10%, 4%, 1%, 0.2% annual chance
## Sea Level Rise Measurements

<table>
<thead>
<tr>
<th>Location</th>
<th>Record</th>
<th>SLR trend [in/yr]</th>
<th>100 year change [ft]</th>
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<tbody>
<tr>
<td>Global</td>
<td>1901-2010</td>
<td>0.067 ± 0.008</td>
<td>0.6</td>
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<tr>
<td>Mobile State Docks, AL</td>
<td>1980-2014</td>
<td>0.12 ± 0.06</td>
<td>1.0</td>
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<tr>
<td>Dauphin Island, AL</td>
<td>1966-2014</td>
<td>0.13 ± 0.02</td>
<td>1.1</td>
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<tr>
<td>Pensacola, FL</td>
<td>1923-2014</td>
<td>0.09 ± 0.01</td>
<td>0.8</td>
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Sea Level Rise Projections
Sea Level Rise Projections

<table>
<thead>
<tr>
<th>Year</th>
<th>Sea Level Rise [ft]</th>
<th>Vertical Land Movement [ft]</th>
<th>Total [ft]</th>
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<tbody>
<tr>
<td>2067</td>
<td>1.2</td>
<td>0.5</td>
<td>1.7</td>
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<tr>
<td>2117</td>
<td>3.0</td>
<td>0.7</td>
<td>3.7</td>
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Storm Surge Loads

100-yr Storm in 2017
Storm Surge Loads

100-yr Storm in 2117

Vertical Load for 2017, 2067, 2117
Geotechnical Considerations
Historical Research

- Alabama Department of Transportation
- Archived Plans
- Driving Records
Preliminary Soil Parameters

- Mid-bay Interchange to Daphne/Spanish Fort
  - (Historical Stations 220+00 to 420+00)

- Based on Historical Information (Preliminary Work)
FBPier Modeling

- **FB-MultiPier** is a nonlinear finite element analysis program capable of analyzing multiple bridge pier structures interconnected by bridge spans (HDR).

- Geotechnical Team – reviewed soil parameters and load condition check.
Preliminary Pile Capacities for Retrofit Concepts

- 60 in Precast Concrete Pipe Pile
- LRFD Factored Resistance
Structural Evaluation and Potential Alternatives
Past Performance of Large Coastal Events

- Past performance of Large Coastal Events on Bridges can be Broadly Grouped into three Categories:
  - Shifting of Spans on the Bent Caps
  - Damage to Girder Ends and Bent Caps from Impact of Superstructure on Substructure
  - Damage to bents from Lateral Loads Transferred to Them
AASHTO Guide Specifications

- Contains Specifications for the Design of Bridges Vulnerable to Coastal Storms
- In 2004 and 2005, Hurricanes Ivan and Rita Caused Significant damage to Numerous Bridges in the Gulf Coast
- FHWA initiated a Pooled Fund Contract for the Development of the Guide Specifications
AASHTO Guide Specifications

Water Level = mean sea level if storm surge includes astronomical tide
           = mean higher high water level if astronomical tide not included in surge
\( \eta_{\text{max}} \) = wave crest height above storm water level
\( H_{\text{max}} \) = maximum wave height
\( \lambda \) = wave length
\( d_s \) = storm water depth at the bridge
\( d_g \) = girder height + deck thickness
\( d_b \) = girder height
\( Z_c \) = positive or negative distance from storm water level to bottom of girder
\( r \) = rail height
\( W \) = deck width
AASHTO Guide Specifications

Figure 6.1.2.1-1—Location of Forces and Moments

(a) Case I—$F_{V_{\text{MAX}}}$ with Associated Forces

(b) Case II—$F_{H_{\text{MAX}}}$ with Associated Forces

(c) Case III—Assumed Prorated Overhang Design Forces
Critical/essential-**Strength Limit State** should be used. Performance levels:

- **“Service Immediate”**
  - Sufficiently undamaged, stable and aligned for rescue and recovery after cursory inspection
  - Backfill behind abutments can be sacrificial

- **“Repairable Damage”**
  - Some repairs needed to go in service
  - Owner species outage duration
  - Load posting can be considered
  - Pre-positioned replacement spans may be used to meet outage limit
Many Choices to be Made:
  - Selection of Design Event – What event or Events are to be Considered
- Retrofit Strategies – Which ones will be Used
- Levels of Analysis – Which of the Three levels of Analysis is to be Used?
Storm Events Evaluated

- 25-year Return Period (2017 and 2067 SLR)
- 50-year Return Period (2017 and 2067 SLR)
- 100-year Return Period (2017 SLR and 2117 SLR) - Baseline
- Level III Analysis (Future Task)
- Existing Bayway is 40 years Old so SLR beyond 2067 (50 yr.) was not Considered for 25-year and 50-year Storms.
Retrofit Strategies

1. Strategy
   - Bridge designated as “critical/essential”
   - Bridge to be “service immediate”
   - Maintenance/Durability
   - Constructibility
   - No Weakening of Existing Piles - No drilling into Precast Cylinder Piles
   - Ignore uplift and horizontal restraint capacity provided by original bearings
Potential Retrofit Approaches

2. Approach
   a. Reduction of Buoyancy Loads
   b. Reduction of Wave Loads
   c. Strengthening Connection of Superstructure to Substructure
   d. Strengthening the Structural Capacity of the Substructure
   e. Strengthening the Geotechnical Capacity of the Substructure
   f. Accepting loss of Superstructure to Protect Substructure
Retrofit Concepts

- Alternatives C and E require Retrofitting of the Existing Bayway against Storm Surge and Wave Impact Loads
- Retrofit Concepts were Developed to Account for the Variation in Magnitude of Loads and Bent Configurations
Foundation Strengthening

- The Lateral Loads and Vertical Uplift were Likely not Included in the Original design
- Aspects of the Substructure that Have not performed well in past Events include:
  - The Connection between the Pile and the Pile Cap
  - Bending Strength of Pile Immediately below the Pile Cap

Span Dislodged Before Bent Collapsed
Foundation Strengthening - Pile Types Studied

- Foundations with High Capacities to Resist Lateral Loads
  - Drilled Shafts
  - Precast Cylinder Piles
- Consider:
  - Environmental Impacts
  - Constructibility
  - Corrosion Resistance
- Existing Bridge Pile Options were all Precast piles
- Due to Highly Corrosive Environment Steel Piles were Not Considered
Foundation Strengthening
- Pile Types Studied

- Drilled Shafts were Eliminated due to:
  - Environmental Impact During Construction
  - Constructibility
  - Risk
  - Cost

- This Study Used 60” Diameter Precast Cylinder Piles
Bayway Analysis
Bent Retrofit Type A
Bayway Analysis
Bent Retrofit Type B
Bayway Analysis
Bent Retrofit Type C
Bayway Analysis
Bent Retrofit Type D
Bayway Analysis
Bent Retrofit Type E
Bayway Analysis
Bent Retrofit Type F
### Summary of Substructure Retrofits – 2 Pile Bents

<table>
<thead>
<tr>
<th>Storm / SLR</th>
<th>Retrofit Type</th>
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<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td></td>
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<tr>
<td>25yr, SLR 2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
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<tr>
<td>25yr, SLR 2067</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>50yr, SLR 2017</td>
<td>0</td>
<td>34</td>
<td>7</td>
<td></td>
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<tr>
<td>50yr, SLR 2067</td>
<td>62</td>
<td>57</td>
<td>28</td>
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<tr>
<td>100yr, SLR 2017</td>
<td>124</td>
<td>101</td>
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![Diagram of Retrofit Types]
# Summary of Substructure Retrofits – 3 Pile Bents

<table>
<thead>
<tr>
<th>Storm / SLR</th>
<th>Retrofit Type</th>
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<th>E</th>
<th>F</th>
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<tbody>
<tr>
<td>25yr, SLR 2017</td>
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<tr>
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<td>50yr, SLR 2067</td>
<td>G</td>
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<td>9</td>
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<tr>
<td>100yr, SLR 2017</td>
<td>H</td>
<td>18</td>
<td>24</td>
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</table>
Superstructure Retrofits Measures

1. Superstructure to Substructure Uplift – Cable Restrainers
2. Prestressed Beam Shear Capacity – FRP Wraps at Ends of Beams
3. Span Replacement

Depending on Load Intensity Along the Bridge, Various Retrofit Configurations were Developed
Negative Bending of Superstructure

- Failure of the Span Under Negative Bending is the Dominant Failure Mode of the Superstructure
- For Purposes of This Study it is Assumed that These Spans Need to be Replaced including their Connections to the Bent Caps

<table>
<thead>
<tr>
<th>Storm / SLR</th>
<th>Spans Lost in Negative Bending</th>
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<td>51</td>
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<td>50yr, SLR 2067</td>
<td>262</td>
</tr>
<tr>
<td>100yr, SLR 2017</td>
<td>421</td>
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</tbody>
</table>

Final cost analysis for the preferred alternative currently being finalized
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