Multihazards Approach to Bridge Management

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Overview

- Bridge Management
- General Multihazards Approach
- Inspection / Bridge evaluations
- Structural Health in Civil Engineering
  - Structural Health Monitoring
- Retrofit and Repair
- Value of Multihazards Approach in Bridge Management
George Washington Bridge
Twin Arches, Troy, NY
Elevation
Bridge Management Philosophy

- **Past**
  - Safety
- **Present**
  - Safety
  - Security
  - Mobility
  - Reliability
  - Environment
  - Economy
Bridge Management Philosophy

- Elements
  - Information/Data
  - Resources
    - Personnel
    - Money
  - Technologies
    - Engineering
    - Financial
  - Implementation
Bridge Management Philosophy

- **Past**
  - Simplified design
  - Factor of safety approach
  - Component based

- **Present**
  - Global
  - Uniform reliability approach
  - Uniform probability of failure
  - Multihazard approach
  - Life-cycle costs
Elements of Bridge Management

- Asset (Bridge) management includes the following
  - Ensure safety
  - Cost effectiveness
  - Mobility
  For as long of a service life as possible
    - Longer service life can be considered as a cost effectiveness measure
Safety and Multihazards

- Safety includes
  - Ensuring Adequate capacity for service loads
  - Different hazard demands
    - Low occurrence or lower probability
  - During the service life of the bridge
    - Such as overloads: higher probability

- All of the above components of safety have multihazards implications
Cost and Multihazards

- Cost includes
  - Inspection
  - Repair / Retrofit
  - Operational
  - During the service life of the bridge

- All of the above components of cost have multihazards implications
General Multihazards Approach

- As hazards affect the bridge, they interact together through different aspects of the bridge.
- By identifying different ways/issues the hazards affect the bridge, optimizing those issues can result in achieving management goals:
  - Improved safety
  - Efficient cost expenditure
IMPACT HAZARD
OVERLOADS
General Multihazards Approach

Corrosion  Impact  Wind  Scour  Wear and Tear  Other

Safety  Hazards Interact through safety and cost issues  Cost
Inspection (Visual / Conventional)

- Scheduled
- Conventional
  - Wear and Tear
  - Corrosion (visual signs)
  - Fatigue (visual signs)
- Hazard specific
  - Seismic (rating, before event)
  - Scour (rating, before event)
- Special or unscheduled
  - Post-hazard
Inspection (Visual/Conventional)

- Can we change inspection procedures to accommodate multihazards considerations?
- One potential way is by recognizing multihazards behavior in bridge rating manuals and guides
Bridge Ratings

- There are currently numerous bridge rating manuals and guides for different hazards
  - Seismic Ratings
  - LRF – LRFR
  - Wear and Tear
  - Scour
  - Etc.
Bridge Ratings

- Since there are some interaction between the hazards in the manner they affect the bridge

- The rating guides / manuals will then include some measure of interaction between the hazard effects
Bridge Ratings

Interaction Between Hazards Through Inspection and Rating Guides
Bridge Ratings

- If such an interaction is accounted for in different guides / manuals, there would be a net increase in efficiency in the bridge cost of ownership, without any loss of safety measures.
Bridge Ratings

- Cost of modifying guides manuals $C_{GM}$
  - One time cost
  - Cost of implementation included in $C_{GM}$

- Benefit of increased ownership $B_{GM}$
  - Efficiency
  - Recurring benefit
Elements of SHCE

- SHCE includes four components
  - Sensing (sensors) / measurements
  - Structural Identification
  - Damage Identification
  - Decision-Making

- First three components are popularly known as “Structural Health Monitoring” (SHM)

- All of those components can be affected by Multihazards considerations
Elements of SHCE

**Damage Identification:**
- Global vs. Local
- Type
- Extent
- Effect on the system

**Structural Identification:**
- Modal Identification
- Parameter Identification
- Non-Physical (Neural Networks)
- Other?

**Decision-Making:**
- Do nothing
- Maintenance (type, timing)
- Repair (simple, extensive)
- Replace (Decommission)

**Measurements:**
- Sensors
- Instrumentation
- Technologies

BASEBALL PARADIGM of SHCE (Structural Health in Civil Engineering)
Sensors

- Optimum Sensor Locations for Multiple Hazards
- Optimum Sensor Numbers for Multiple Hazards
- Sensor fusion (sensor can be used to sense multiple hazards)
- When need more than one sensor type: optimize for more than one hazard
Structural Identification – Conventional Approach

Measurements (SHM Projects)

STRID Technique

Identify Structural Parameters

Conventional STRID Paradigm

Functional Relationships (e.g., Neural Networks)

Modal Parameters

Physical Parameters
Structural Identification – Multihazards

For a Given Defect / Damage from an SHM Project

Additional Multihazards

STRID Paradigm

STRID Technique

Identify the hazard, or hazards, that caused the defect
Damage Identification

- Damages can be hazard independent, or hazard dependent
- Methods for identifying Hazard-independent damages can result in an efficient SHM projects
- Examples of hazard-independent damage types
  - Cracks can be generated from excessive deformations: e.g. scour
Decision-Making

- There are immense decision-making tools that are available to bridge managers

- Those tools should be utilized to ensure adequate multihazards considerations
Decision-Making

Decision-Making Tool Box

Statistics
  - Different Statistical Methods

Probability
  - Different Probabilistic Methods
  - Markov Chains
  - Signal Processing

Stochastic
  - Cost-Benefit / Value
  - Life-Cycle Cost
  - Rate of Return, Present Value, etc.

Economics

Decision and Utility Theories

Risk
  - Management
  - Assessment
Repair / Retrofit

- Can we employ a multihazards Strategy for Bridge Repair / Retrofit Efforts?

- For an accurate answer, need to observe how repair / retrofit efforts are conducted
Steps of RR Efforts

- Identify need / Cause
- Identify Level
- Secure Budget
- Perform RR

Each of these steps include potential of Multihazard considerations
One or More Hazards causes defects

Defect is observed by manual or automatic methods

How and which hazard caused the defect needs to be well understood for correct repair / retrofit decision
1 - One, or more, hazards cause a defect in a bridge

2 - Thus, the defect might be a result of MULIHAZARDS (can be wear and tear + corrosion)

3 - The defect is detected (either by visual inspection, or as a result of SHM)

4 - The ensuing analysis need to investigate all potential causes of defects, since misdiagnosis can lead to errorious repair / retrofit decisions

5 - The analysis should also include potential of hazards reinforcing and accelerating the creation of the defect

Need for Multihazards Considerations When Identifying need for repair and retrofit
Need and Cause

- Cost of Extra Analysis (Structural and Damage identification), $C_1$
- Benefit of accurate identification of source of defect, $B_1$
- Units of cost and benefit must same
Thus, another retrofit might be needed!
Level of Repair / Retrofit

1 - Analysis showed retrofit need for scour mitigation
2 - Retrofit was to place Riprap around footing
3 - The riprap would affect seismic performance, due to shortening of column height
4 - If performed as planned, it would cost more in the future to re-retrofit for seismic hazard

Level of repair and retrofit must include Multihazards effects, and the potential interaction between them
Level of Repair / Retrofit

- Cost of Extra Analysis, and extra retrofit measures, $C_2$
- Benefit of accommodating interaction between hazards during retrofit for one of them, $B_2$
Budget

- Three main components of the budget of any repair / retrofit are
  - Initial Cost
  - Discount Rate
  - Service life of both the bridge and the repair / retrofit itself
  - They all are dependent of multihazards considerations
Budget

Relative Frequency of Hazards (return period) → Different demands of hazards → Relative costs / benefits of single vs. multi hazard retrofits

Initial Costs → Discount Rate → Service Life (of bridge and retrofit)

Budget
Net Value of Multihazards Approach to Bridge Management

- The total additional cost for pursuing a multihazards approach is

\[ C_{\text{Multihazards}} = \sum C_i \]

- The total additional benefit for pursuing a multihazards approach is

\[ B_{\text{Multihazards}} = \sum B_i \]
Net Value of Multihazards Approach to Bridge Management

- The value for pursuing a multihazards approach is

\[ V_{\text{Multihazards}} = B_{\text{Multihazards}} - C_{\text{Multihazards}} \]

- Can also compute a benefit to cost ratio (BCR)

\[ BCR = \frac{B_{\text{Multihazards}}}{C_{\text{Multihazards}}} \]
Net Value of Multihazards Approach to Bridge Management

- If $BCR > 1$

- Then Multihazards approach to bridge management can be beneficial
  - Improve safety
  - With efficient cost expenditure
Knowledgebase

- Structures
  - Structural behavior
  - Failure mechanisms
  - Material behavior
  - Design methodology
  - Analysis methods
  - Commonsense
Knowledgebase

- Hazards (natural and manmade)
  - Loading
    - Spatial (structural dependant)
    - Frequency
    - Magnitude
  - Short- and long-term effects on structure
  - Interaction with other hazards
  - Influence on analysis
  - Influence on design
  - Mitigation methods
Knowledgebase

- Monitoring
  - Sensors
  - Instrumentation
  - Data collection methods
  - Data mining
  - Data analysis
  - Long-term durability aspects
Knowledgebase

- Decision making
  - Financial
  - Reliability
  - Financial Analysis
    - Estimating techniques
    - Benefit-cost analysis

- All above show the need for multi-disciplinary involvement
Closing Remarks

- Need automated design, analysis, and decision-making tools for progressing multi-hazard approach
- Multi-disciplinary aspect is automatically integrated into multi-hazard approach
- Can achieve increased safety at better value for money spent using multi-hazard multi-disciplinary approach
QUESTIONS?