PROBABILISTIC SEISMIC RESILIENCE MODEL FOR SPATIALLY DISTRIBUTED SYSTEMS

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July 20, 2021

1 Problem Statement

To develop a probabilistic seismic resilience framework that will allow the decision on priority of retrofit for a spatially distributed system to be made based on:

i. Seismic Hazard at location
ii. Performance of Bridge
iii. Expected Loss
iv. Recovery after the occurrence of an event

2 Methodology

1. Probabilistic Seismic Hazard Assessment

PSHA quantifies the seismic hazard of a location by considering the uncertainties in time, location, and size of individual earthquakes and combining them using a probabilistic approach. This results in a hazard curve for the location.

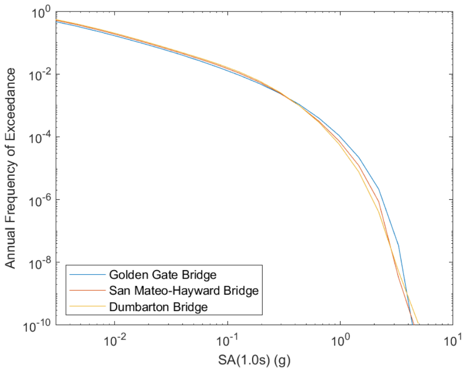

Fig. 2: Hazard Curves for the three bridges

2. Deaggregation of PSHA data

The hazard obtained from the PSHA data can be split into its contributing sources through deaggregation. This would allow us to identify the sources affecting all the locations of interest.

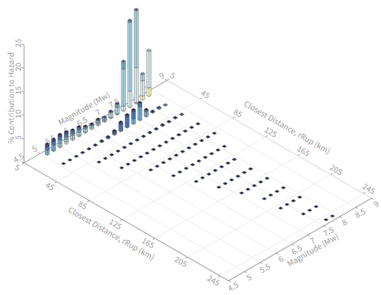

Fig. 3: Deaggregation Graph

3. Fragility functions

The fragility function would allow us to determine the probability of damage in a structure for a given ground motion. This allows us to determine the expected damage level and subsequently expected loss level due to various earthquakes from the sources of interest.

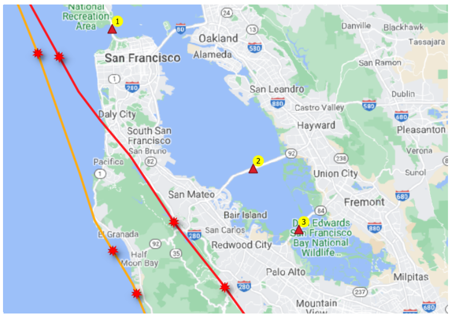

Fig. 1: Locations of Bridges and Faults

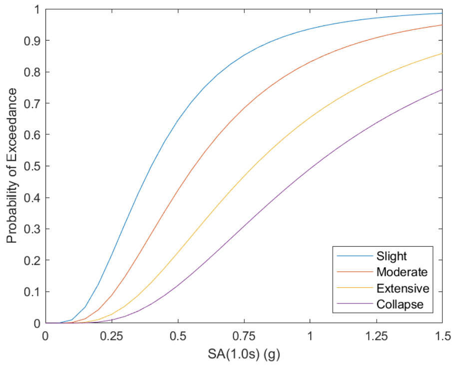

Fig. 4: Fragility Function for Golden Gate Bridge due to San Gregorio (North) Fault

4. Average Annual Loss

The expected losses from each earthquake event have to be combined into a single value to estimate the expected loss in any given year. The exceedance probability method can be used for this, wherein the losses are combined using various annual exceedance probabilities of each loss. The average annual loss can then be obtained by integrating the aggregate exceedance probability over the entirety of the loss.

5. Resilience

Resilience reflects the capability of a structure to continue being functional, albeit at a lower level, despite the damage incurred in an extreme event. The calculation of Resilience takes the recovery pattern, the time to recover full functionality, the losses, and the probability of event occurrence into consideration. The equation used is as below:

$$\bar{R}=\frac{1}{N_I}\sum_{I=1}^{N_I}\left\{\frac{1}{N_E}\cdot\sum_{E=1}^{NE}\frac{1}{T_{RE}}\cdot\int_{t_{0E}}^{t_{0E}+T_{RE}}\left\{\begin{array}{l}1-L(I,T_{RE})\cdot\begin{bmatrix}H(t-t_{0E})+\\-H(t-(t_{0E}+T_{RE}))\end{bmatrix}\cdot\\ \cdot\alpha_R\cdot f_{Rec}(t,t_{0E},T_{RE})\end{array}\right\}\cdot dt\cdot p_E(0,T_{LC})\right\}\cdot P(I)$$

Source: Cimellaro et al. 2006

3 Case Study

Bridge Name	Golden Gate Bridge	San Mateo - Hayward Bridge	Dumbarton Bridge
Location On Map	1	2	3
Length of Max. Span (m)	1280	230	104
Replacement Value (in 2019 $)	$ 523 Million	$ 418 Million	$ 182 Million

Source Name	San Andreas (Peninsula)	San Gregorio (North)
Colour in Map	Red	Orange
Source Set	UC33brAvg_FM31, UC33brAvg_FM32	UC33brAvg_FM31, UC33brAvg_FM32
Return Period	475, 975, 2475	475, 975

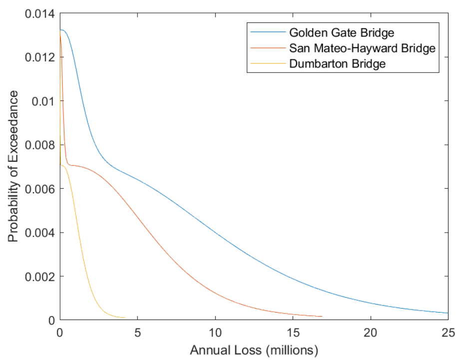

Fig. 5: Aggregate Exceedance Probability Curves for the three bridges

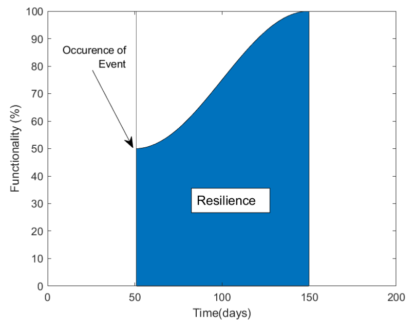

Fig. 6: A typical functionality curve showcasing recovery pattern

4 Result

Bridge Name	Golden Gate Bridge	San Mateo - Hayward Bridge	Dumbarton Bridge
Average Annual Loss	$93,524.57	$50,093.06	$10,439.35
Resilience	2.9403	2.9651	2.9927
Priority of retrofit	1	2	3

Acknowledgement

This project was done as a part of SPARK 2021 Summer Internship Program at IIT - Roorkee, and under the guidance of Prof. Saurabh Shiradhonkar.