FINDINGS

Fragility functions development framework is introduced for bridges subjected to extreme wave-induced forces.

Fragility analysis of bridges subjected to extreme waves

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This study provides a framework for developing fragility functions for bridges subjected to extreme waves. The efficiency of strengthening bridge piers using FRP jackets is investigated. The fragility analyses showed that the fragility of strengthened bridge was reduced by up to 46% for the extensive damage state.

Introduction

Coastal bridges are susceptible to severe damage due to wave-induced forces during extreme events such as coastal flooding, hurricanes, storm surges and tsunamis. As a direct impact of climate change, the frequency and intensity of these events are expected to increase in the future, highlighting the necessity of in-depth understanding of the safety and reliability of coastal infrastructure during these events. The main aim of this study is to provide fragility functions for bridges subjected to extreme wave-induced forces.

Methods

Sed A framework is adopted in this study to develop fragility models for bridges subjected to extreme waves. The framework is based on static analysis, and it accounts for the uncertainties in both wave and structural properties. Figure 1 shows the steps of the methodology. The inundation depth and flow velocity increments are first specified and checked with the Froude number (Fr) limit to remove the unrealistic cases of velocity. In this study, the maximum inundation depth and velocity were selected as 11 m and 20 m/s, respectively. The capacity curves at each inundation depth are obtained using the mean values of concrete compressive strength (27 MPa) and steel tensile strength (500 MPa). The three main damage states are defined for each inundation depth, and their corresponding drift ratios are obtained. The first damage state (slight) defines the first crack load of the pier. The second (slight) and third (extensive) damage states define the yield and peak loads of the pier. The structural models using random samples of concrete compressive strength and steel tensile strength are generated. In this study, 10 random samples of each of the concrete compressive strength and steel tensile strength using coefficient of variation (COV) values of 0.18 (normal distribution) and 0.11 (lognormal distribution), respectively. This means that 100 structural models for each inundation depth are obtained. In addition, 10 random samples were generated for the force coefficients using uniform distribution of the range between 1.25 to 2. For each inundation depth, the calculated forces are checked with 100 structural models, which gives a total number of cases of 1000. For each case, the drift ratios are computed and checked against the estimated damage states of each inundation depth. For one inundation depth, the number of cases at each velocity increment that exceed a certain damage state are divided by the total cases, which provide the damage probability.

Results

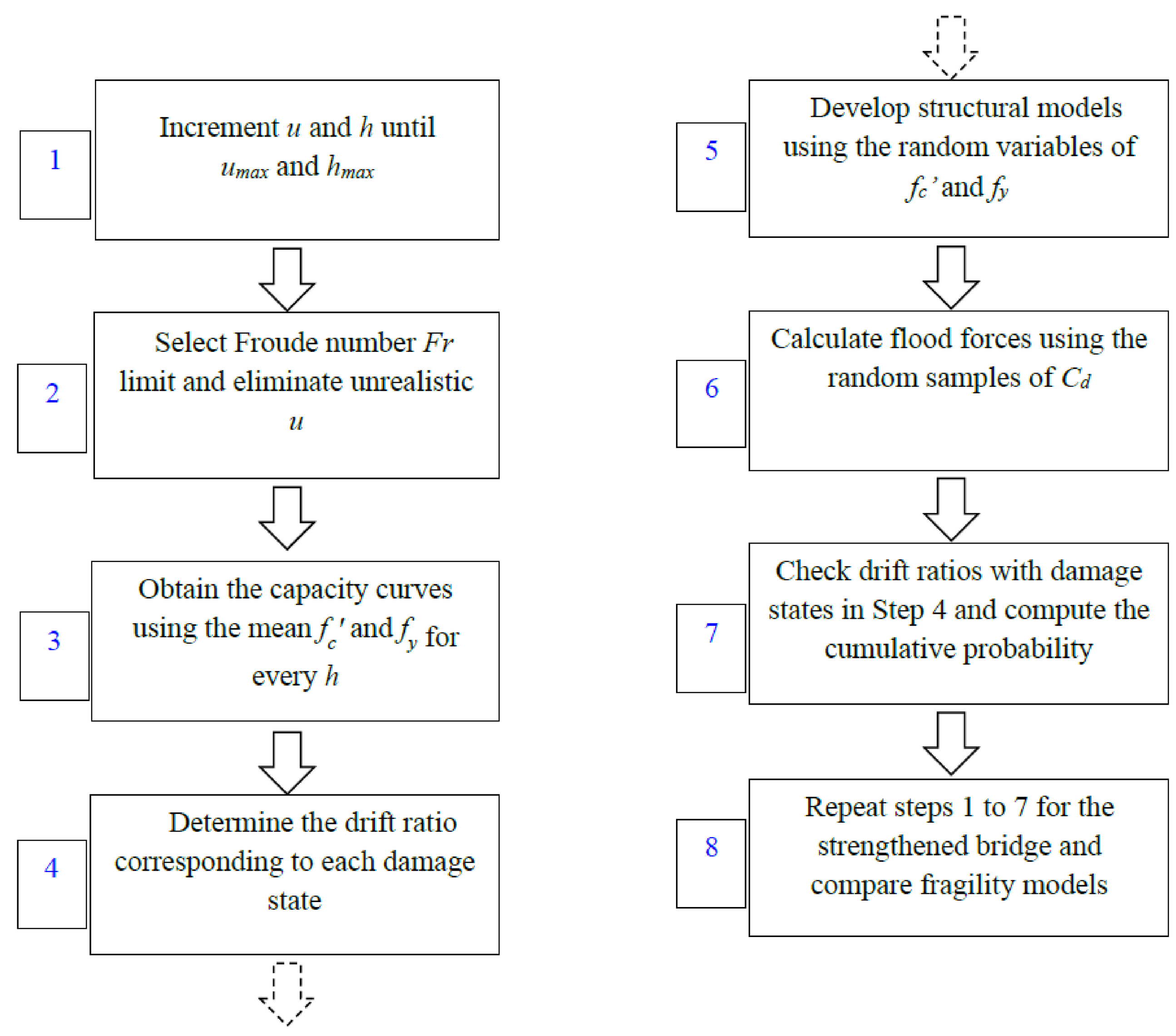
The most significant enhancement in the performance of the bridge was obtained at the extensive damage state, with up to 46% drop in damage probability at a velocity of 15 m/s. Figure 2 shows the fragility curve of both initial (as-built) and strengthened bridge. The maximum drop in damage probability for the slight damage state was about 21% at a velocity of 9.5 m/s, while it was about 40% for the moderate damage state at a velocity of 13 m/s. The fragility analysis results show the effectiveness of the use of fibre reinforced polymer jackets for reducing the vulnerability of bridges. This provides more resilient transport infrastructure that can assist in the post-disaster recovery, and hence reduce the consequent social and economic losses.

Discussion

This study provided a demonstration example of vulnerability evaluation of a bridge. The bridge piers were strengthened using fibre reinforced polymer jackets. The fragility analysis results showed the following main findings:

- A methodology was developed predict the fragility of bridges subjected to extreme waves. This methodology considers the inundation depth and velocity of flow as the main the intensity measures. It can be utilized to examine the effectiveness of different strengthening methods.
- The use of fibre reinforced polymer jackets is effective for reducing its vulnerability under extreme wave forces.
- Future research needs to focus on the investigation of the effectiveness of superstructure strengthening methods (e.g. shear keys and restrainer cables) for extreme waves forces. In addition, more research is needed to develop vulnerability models for bridges subjected to elevated temperatures, particularly from vegetative fires (i.e., bushfires).

Figures



Figures 1: Methodology for developing fragility functions of bridge.

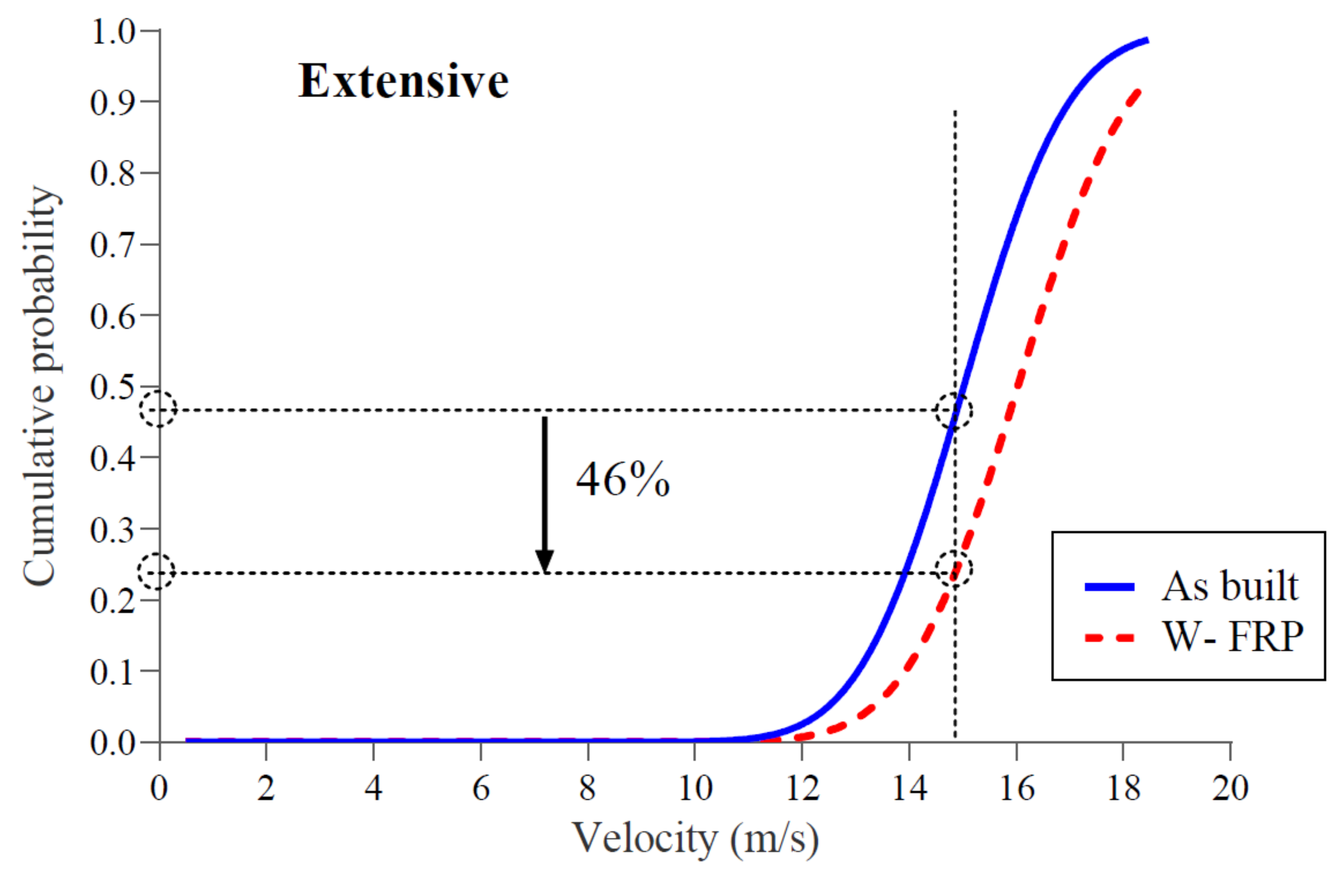


Figure 2: Comparison of fragility curve for as built and strengthened bridge at extensive damage state.

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