

Missing the Big Picture in Mitigating Natural Hazards

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DOI: 10.2749/101686612X13363869853211

Abstract

Natural hazards pose risk to individuals as well as to the society. People are harmed by the damage to structures they own or occupy. People are also harmed by the damage to other structures around them—schools, hospitals, shops, utilities, bridges, etc. As the purpose of engineering design is to reduce the risk, the design standards should attempt to reduce both individual and societal risks from natural hazards. The current design standards attempt only to reduce the risk to individual structures. They are not very effective in reducing the societal (aggregate) risk as will be shown in this paper. Hurricanes in the coastal US are used to illustrate the main point. A new approach is proposed to reduce the societal risk from natural hazards.

Keywords: Natural hazards; hurricanes; catastrophe index; aggregate hazard; societal risk.

Introduction

A defining characteristic of natural hazards (e.g., earthquakes, floods, and hurricanes) is the effect on a large number of people at the same time. Natural hazards can take thousands of lives, displace millions of people, and cause billions of dollars in property damage. Natural hazards do not pose more risk to an individual's life than say automobile accidents, but natural hazards pose more risk to the society than any other hazard. The effect of a natural hazard can be felt by a large number of people for a long time.

Hazard can be defined as an adverse event (e.g., strong wind) and risk can be defined as the loss (of life, health, and property) due to the adverse event. Risk is a function of hazard as well as vulnerability (or weakness). For the same hazard, weaker systems are at greater risk. Engineering design standards attempt to reduce the risk to an acceptable level, although the acceptable risk is neither clearly defined¹ nor same everywhere.² The first step in reducing the risk is to assess the hazard.

There are two different viewpoints of the hazard posed by large-scale events such as hurricanes: (a) site-specific and (b) aggregate. The site-specific hazard

is from the perspective of individuals who own or occupy specific buildings. The aggregate hazard is from the perspective of the society or those responsible for the well-being of the society.³ The current design standards are based only on the individual perspective of natural hazards. This paper will (a) demonstrate the limitation of current design standards in reducing the societal risk; (b) identify areas along the coastal US where the societal risk from hurricanes is high; and (c) propose a new approach to reducing the societal risk.

Hazard Analysis for Design Standards

Owing to uncertainties in time, location, and size of hurricanes, the wind-speed hazard is computed using a probabilistic approach.¹⁻⁸ A large number of hurricane events is simulated by sampling key hurricane parameters (radius to maximum wind, central pressure difference, and translational speed) from their respective probability distributions derived from historical data.⁹ Each hurricane event produces a "footprint" of geographically varying wind speeds. Figure 1 shows the footprint of a hurricane event which makes landfall in South Carolina. This is one of the 71 515 hurricane footprints simulated for the multihazard loss assessment model HAZUS.⁹ In this simulation, all hurricane events are equally likely or they have the same chance of occurrence. In certain geographical areas the hurricane

footprints are bigger and/or they overlap each other more frequently. It is assumed that the hurricanes follow a time-independent (Poisson) process so that the occurrence of a hurricane has no effect on the future occurrences of hurricanes.

Currently, the probabilistic hurricane hazard analysis is performed on a site-by-site basis; this will be referred to as the site-specific probabilistic hurricane hazard analysis (SS-PHHA). At the selected site (shown by a red star in Fig. 1), there are 71 515 wind speeds produced by 71 515 hurricane events. Of course, not all hurricane events produce a significant wind speed at the site. The hurricane event shown in Fig. 1 produces a wind speed of 121 mph (54.1 m/s) at the selected site. The wind speeds from all hurricane events are arranged in an ascending order and a plot is generated between the wind speed and its rate of exceedance; this is known as the wind-speed hazard curve shown in Fig. 2.

On the hazard curve in Fig. 2 the rate of exceedance λ for any specific value of wind speed is read on the left-hand side. For a Poisson process, the reciprocal of the rate of exceedance is the return period of exceedance¹²:

$$T = 1/\lambda \quad (1)$$

By definition, return period T is the average time between successive occurrences of a Poisson process; it is usually measured in years. On the hazard curve in Fig. 2 the T is read on the right-hand side.

For a Poisson process, the probability of exceedance P during a time span τ is given by the following expression¹²:

$$P = 1 - \exp(-\lambda\tau) \quad (2)$$

By substituting $\lambda = 1/T$ in Eq. (2), we obtain:

$$P = 1 - \exp(-\tau/T) \quad (3)$$

The hazard curve shown in Fig. 2 essentially says that any value of wind speed is possible at the site; higher values of wind speed have longer return periods (or lower probabilities) of exceedance than lower values of wind speed. The wind speeds shown in Figs. 1 and 2



Peer-reviewed by international experts and accepted for publication by SEI Editorial Board

Paper received: August 15, 2011
Paper accepted: November 7, 2011

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1. Understanding the eBook Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage
 - The Rise of Digital Reading Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage
 - Advantages of eBooks Over Traditional Books
2. Identifying Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform

- Popular eBook Platforms
- Features to Look for in an Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage
- User-Friendly Interface
- 4. Exploring eBook Recommendations from Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage
 - Personalized Recommendations
 - Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage User Reviews and Ratings
 - Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage and Bestseller Lists
- 5. Accessing Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage Free and Paid eBooks
 - Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage Public Domain eBooks
 - Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage eBook Subscription Services
 - Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage Budget-Friendly Options
- 6. Navigating Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage eBook Formats
 - ePub, PDF, MOBI, and More
 - Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage Compatibility with Devices
 - Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage
 - Highlighting and Note-Taking Proceedings Of The Usasia Conference On Engineering For Mitigating Natural

Hazards Damage

- Interactive Elements Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage

8. Staying Engaged with Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage

- Joining Online Reading Communities
- Participating in Virtual Book Clubs
- Following Authors and Publishers Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage

9. Balancing eBooks and Physical Books Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage

- Benefits of a Digital Library
- Creating a Diverse Reading Collection Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage

10. Overcoming Reading Challenges

- Dealing with Digital Eye Strain
- Minimizing Distractions
- Managing Screen Time

11. Cultivating a Reading Routine Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage

- Setting Reading Goals Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage
- Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage

- Fact-Checking eBook Content of Proceedings Of The Usasia Conference On Engineering For Mitigating Natural Hazards Damage
- Distinguishing Credible Sources

13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development

- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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