PennState College of Education | CSATS Center for Science and the Schools | Research Experience for Teachers | PennState College of Engineering ARCHITECTURAL ENGINEERING | NSF

Analysis of historical buildings under blast loading

Robert Mayne[1], Joe Kallas[2], Rebecca Napolitano[2]

[1]Chariho Regional High School, RI, [2]Pennsylvania State University, Department of Architectural Engineering.

Question

How do the **features and attributes** of historic buildings affect their **vulnerability under blast loads**?

Introduction

On August 4, 2020, **2700 tons** of ammonium nitrate stored in the Port of Beirut **exploded** resulting in:

- **220** dead,
- over **5,000** injuries,
- an estimated **300,000** homeless.[1]

Countless historical structures were damaged or destroyed.

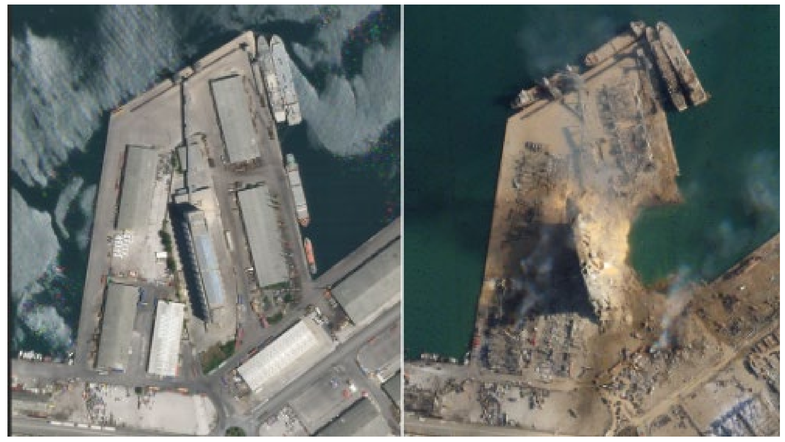

Fig. 1 Before and after satellite images of the Port of Beirut – CNN.com

Fig. 2 Three story historical structure of side facing the port.. Photo credit: Rami Rizk.

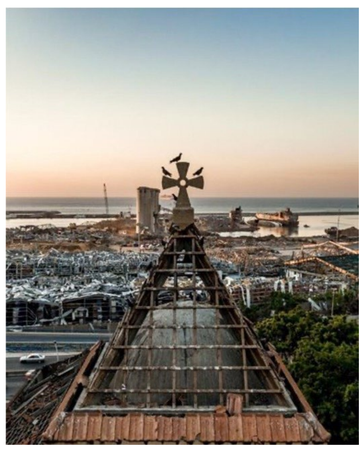

Fig 3 Drone image facing the port. Photo credit: Rami Rizk

Data Recording

Fig. 4 Generated 3D photogrammetric textured model of the building from Fig 2.[1]

Fig. 5 Textured orthophotos output of the four elevations and top view of building from Fig 2.[1]

A 3D digitization mission was formed after the explosion to **report the state** of historic buildings and to provide accurate models for **structural analysis.**

These models are being used to determine architectural, structural, geographic, and other features of these structures that may make them vulnerable.

Examples of variables of interest.

- Types of openings
- Historical period built
- Construction materials
- Modifications made
- Roof type
- Topography

Data Analysis

In order to determine if two categorical variables are associated, a **Chi-Square Test for Independence** is performed.

H_0: Two variables are independent.
H_A: Two variables are not independent.

$$\chi^2 = \sum \frac{(Observed\ value\ - Expected\ value)^2}{Expected\ value}$$

Expected value = (row sum * column sum)/table sum.

Using a Chi-square distribution, the probability, p, of these results or greater is calculated. If this number is less than the significance level, usually 0.05, we reject the null hypothesis that these variables are independent.

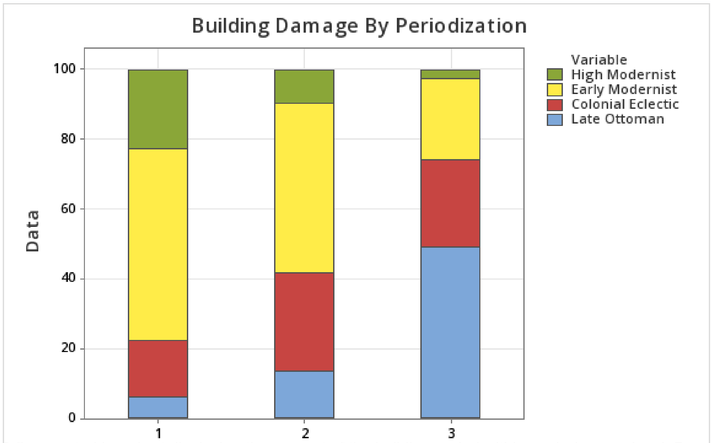

Fig. 6 Segmented bar chart displaying the percent of the building period within each damage level. Damage level is on a sliding scale from 0 to 4. Zero equates to no damage and four to destroyed. Due to very few buildings at zero or four, those damage levels were excluded.

Fig 6 appears to show a relationship between the period the building was originally constructed and the building damage level. A Chi-Square Test for Independence reinforces that the two variables are **not independent** of one another ($\chi^2 = 304.4$, $p < 0.001$).

Each of the recorded features were compared to the damage level of the building to determine independence. Very **few were not associated**.

Future Focus

Chi-square tests were performed to filter out categorical variables. Individual characteristics within categorical variables will be recorded as present or not in order to perform additional tests such as

- Logistic regression analysis
- Decision Trees
- Automated Neural Networks
- Linear Regression.

Goal of the research: Determine the **optimal combination** of features and attributes that would limit the damage level **not to exceed two** when subjected to similar blast loads.

References

[1]Kallas, Joe, and Rebecca Napolitano. "Image-Based 3D Modeling as a Damage Prioritization Tool for Historic Buildings in Post-Disaster Areas: The Case of the 2020 Beirut Blast." Journal of Cultural Heritage, vol. 62, 2023, pp. 314–321, https://doi.org/10.1016/j.culher.2023.06.007.

The RET for Teachers is funded by NSF Building Education Research Experience for Teachers Grant EEC 1855256.