



# Creating Customized Fragility Curves for Resilient Building

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## PROBLEM

Fragility curves, which are a statistical tool that represent the probability of exceeding a certain level of structural damage due to various forces applied to a building, are used to assess anticipated building performance. For new construction and retrofitting alike, designers and builders need to understand the risks their buildings face from environmental loads such as hurricanes, floods, or earthquakes. The role of the fragility curve is important when building for resilience, but it is often overlooked due to the challenge of applying it early in the design and process. The anticipated damage estimation from fragility curves has far-reaching effects downstream in construction and maintenance over the building lifetime, but fragility curves are not readily generated for each building and each loading scenario. Instead, databases like those used by the Federal Emergency Management Agency's (FEMA) Hazus software rely on a set number of building types and loading classes. The ability to construct on-demand customizable fragility curves for a particular building with a particular load or maintenance level across the building's lifetime is still an open problem.

## APPROACH

Researchers use the Monte Carlo (MC) simulation approach to construct fragility curves. Named for the famed Monte Carlo casino, the MC suite of algorithms takes a probabilistic tack to a predefined problem. In the case of building resilience, the MC approach can assess damage of a structure for a given set of loads. As the damage inventory is generated based on a probability distribution through the MC simulation, the average values of damage can be recorded for each load value. Thus, the Monte Carlo approach to building resilience can readily generate customized fragility curves for a specific building and load as dictated by the building site. This simulation approach offers a unique ability to perform the damage analysis (deterministic) and the statistical analysis (probabilistic) simultaneously, as opposed to performing these separately. MC simulations can also provide more precise and quantitative definitions of damage levels, as opposed to qualitative and sometimes ambiguous labels such as 'simple', 'moderate', 'extreme', and 'complete.'

## FINDINGS

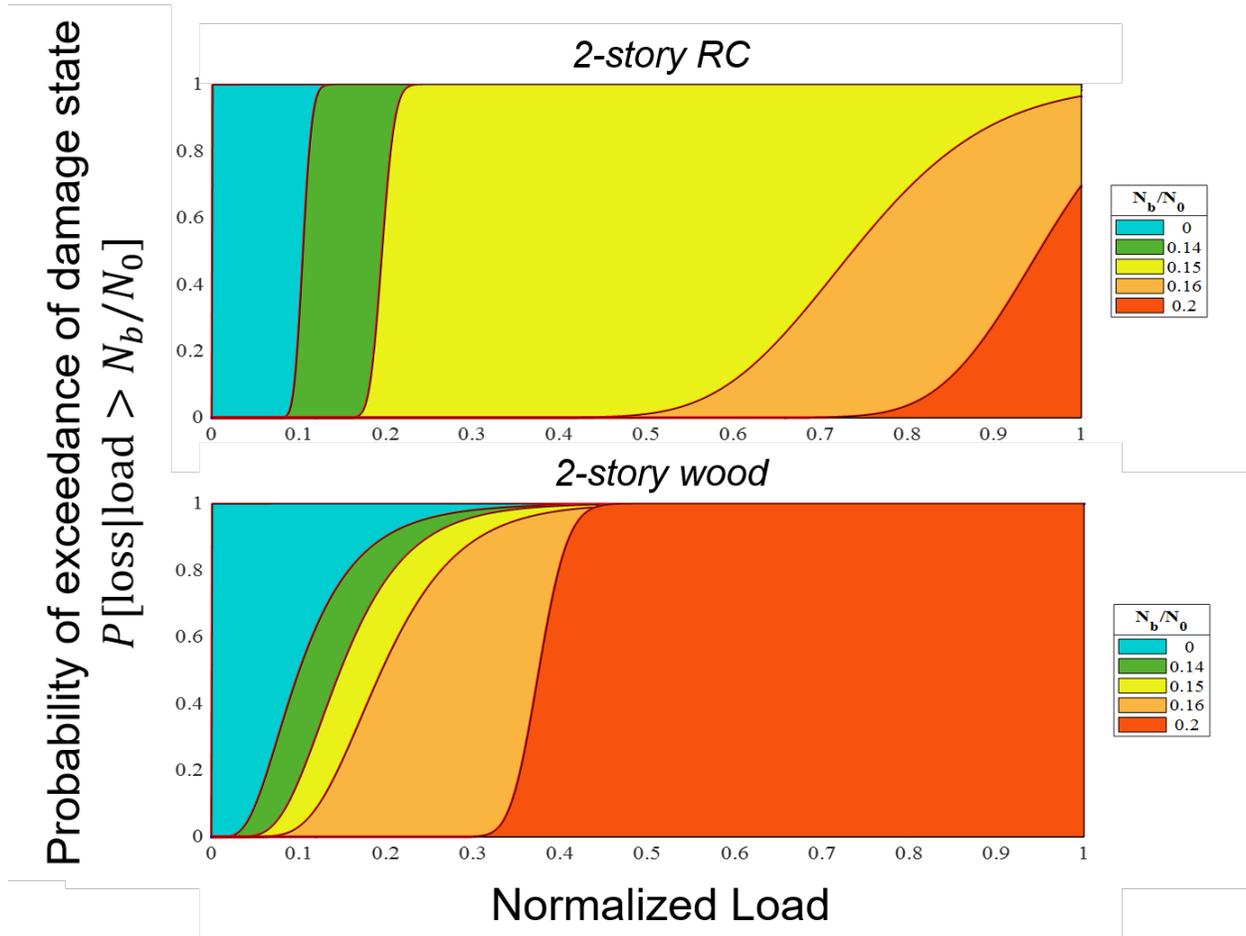
The Monte Carlo approach devised here readily outputs the necessary parameters for the construction of fragility curves (see figure on following page). We use this to create different sets of fragility curves for reinforced concrete and wood structures, which are identical except in building material used. The method also allows for specifying the anticipated loading type in addition to the definition of the building material. We can define the damage states quantitatively through the ratio of broken connections to total connections in the building. This method extends a greater level of control to the designers and engineers in constructing fragility curves and understanding the risks associated with their buildings. For example, fragility curves generated using this MC method show that the 2-story wood building is at greater risk of damage than the same building using reinforced concrete under lateral wind loading. Moreover, this same analysis could have been carried over for any building material, structure, and load. With this method, it will be possible to create custom fragility curves without needing to rely solely on comparisons with the nearest match from databases.

## WHY DOES THIS RESEARCH MATTER?

- The Monte Carlo approach performs damage and statistical analyses in tandem to generate necessary probability parameters for the fragility curves.
- Traditionally, fragility curves have been overly conservative. This approach allows them to also be building and site-specific.
- Reassessment of fragility curves on a case-by-case basis will be able to inform design, policy, and building code downstream for safer and more resilient buildings.

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Generated fragility curves for 2-story frame: reinforced concrete (top) loses 20% (red) of the structural integrity at a much higher load than the same structure constructed with wood (bottom).



Lateral wind loading on a 2-story frame