ASSESSING THE POST-EARTHQUAKE REDUCTION AND RECOVERY OF THE
SHELTER-IN-PLACE HOUSING CAPACITY OF A RESIDENTIAL
COMMUNITY IN NOIDA, INDIA

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ABSTRACT

This study seeks to quantify the post-earthquake reduction and recovery of the
shelter-in-place housing capacity of a residential community in NOIDA, India. An
inventory of over 1800 buildings was acquired using a combination of field
observations and remote sensing data. The inventory consists almost exclusively
of infill frames buildings used as single and multi-family residences with over
70,000 occupants. The portfolio includes buildings ranging from 2 to 10 stories
with a number of salient features including built-in soft-stories, basement parking
and irregular plan configuration and infill layout. A magnitude 7 scenario event
was simulated on the Delhi Hardwar Ridge approximately 60 km northwest of
NOIDA. A performance-based methodology was implemented to assess the
distribution of damage in terms of functionality-based limit states and the
immediate and long-term implications of that damage to the housing capacity of
the target community. The effect of the wholesale replacement of the existing
building inventory with an enhanced seismic building system is also evaluated.

Introduction

The San Francisco Planning and Urban Research Association (SPUR) defines “shelter-in-place”
as the ability of residents to remain in their home while it is being repaired after an earthquake
[1]. This implies that the building will be safe enough to occupy during the months immediately
following the event. It has been shown that the ability of residential buildings to achieve this
performance limit state significantly enhances post-earthquake recovery particularly in urban
regions. Most of the previous approaches to modeling post-earthquake recovery have relied on
the generic damage states used in loss estimation (none, slight, moderate etc.). A rigorous
evaluation of seismic resilience requires probabilistic methods for assessing limit states that
influence post-earthquake functionality that can be incorporated in modeling the recovery of the
building stock. This study implements a performance-based framework that incorporates a set of
building performance limit states that specifically inform community recovery. The framework is
implemented to assess the immediate post-earthquake reduction and recovery trajectory of the
shelter-in-place housing capacity of a residential community in NOIDA, India.

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Overview of Methodology

An overview of the implemented resilience framework is illustrated in Fig. 1. It starts with a performance-based assessment of individual buildings in the target community, the outcome of which is a building level recovery function. These functions are then aggregated to model community level recovery. The effect of external influences and socio-economic factors are incorporated at the building scale.

Fig. 1 Performance-based recovery modeling framework

Building Inventory for Target Community

The testbed community is located in the city of NOIDA, (New Okhla Industrial Development Authority) which is part of the National Capital Region of India. NOIDA was formally instituted as a city in 1976 and is located in the state of Uttar Pradesh approximately 10 km southeast of Delhi. The city is divided into “sectors” that fall under five categories; (1) residential, (2) commercial, (3) industrial, (4) information technology, and (5) institutional. The building inventory used in this study was acquired using a combination of field surveys, remote sensing images and discussions with residents of the community. The inventory consists of 1823 buildings (1123 single family and 700 multi-family) representing a total occupancy of approximately 73,000 residents (about 10% of the city population). The survey was conducted in 5 residential sectors (34, 50, 51, 61and 62) chosen based on their differences in building heights, year of construction and socio-economic standing of their residents.

Building Level Performance Assessment

A set of 13 surrogate buildings are developed as archetypical representations of the inventory in the test-bed communities. The surrogates capture the variation in the key structural characteristics that influence seismic performance including (i) building height, (ii) base configuration (soft story, full height infill etc.), (iii) plan shape (rectangular vs irregular) and (iv) seismic design considerations (code conforming vs non-code conforming). These characteristics
are defined based on field observations and previous experience with the structural performance of infill frames. Structural models are constructed and used to generate fragilities for the post-earthquake inspection, occupiability, demolition and collapse limit states. A performance-based resilience assessment framework [2] is then implemented to model recovery at the building scale. Fig. 2 shows the limit state fragilities and recovery function for a single 4-story multi-family residential building corresponding to a magnitude 7 scenario earthquake. Fig. 2b shows that there is a 70% expected loss in the housing capacity of this building immediately following the event. The shape of the building level recovery curve is related to the probability distribution of the limit states. The initial slope is governed by the probability of occurrence of the inspection limit state, whereas the tail end of the recovery curve is influenced by the demolition and collapse limit states.

![Fig. 2](image)

**Community Scale Performance Assessment**

The seismic performance of the testbed community is assessed for a magnitude 7 scenario earthquake on the Delhi-Hardwar Ridge fault. Spatially correlated spectral acceleration intensities (corresponding to the building elastic 1st mode period) are generated at every building site for the scenario earthquake. These are coupled with the limit state fragility curves for the surrogate buildings to assess the distribution of damage. The performance-based framework [2] is then used to model the immediate loss and recovery trajectory of the housing capacity for the community. The recovery curve for the existing building inventory is shown in Fig. 3. It shows that about 50% of the pre-earthquake housing capacity is lost at the time of the event. Similar to the building-level recovery curve, the shape of the community level recovery curve is influenced by the distribution of buildings in the various limit states. The initial slope of the recovery curve is influenced by the fraction of occupants in buildings that are in the inspection limit state and safe enough to occupy following inspection. The larger the fraction of initially displaced residents in buildings in this limit state, the steeper the initial slope. The slope of the recovery curve following the re-occupancy of the inspected buildings is governed by the fraction of the
residents in repairable buildings. The slope of the tail end of the recovery is primarily influenced by the fraction of collapsed and demolished buildings. The overall pace of the recovery can be assessed by the time to recover some percentage of the pre-earthquake capacity. For the existing inventory, it takes 711 days to recover 95% of the pre-earthquake capacity. Fig. 3 also shows the effect of the wholesale replacement of the existing building stock with buildings incorporating an enhanced seismic performance system. This is reflected in the fragility curve parameters used for the surrogate buildings. This reduces the time to recovery 95% of the pre-earthquake housing capacity by about a factor of 2 to 374 days.

Figure 3 Comparing the trajectory of the recovery of housing capacity for the existing building stock and the “complete replacement” with enhanced seismic system buildings

Conclusions

This study implements a performance-based framework that can be used to model recovery at the community scale. The framework incorporates functionality-based building limit states that are explicitly linked to post-earthquake recovery. The immediate post-earthquake reduction and recovery of the housing capacity of a residential community is assessed. The results of this type of study can be used to inform post-disaster planning with the goal of reducing the long term impact of an earthquake on a residential community. Valuable information can also be obtained regarding the post-earthquake temporary shelter needs of a community and the potential for significant outmigration of the affected population. It also provides a framework for measuring the impact of enhanced seismic performance on community resilience.

References
