SEISMIC RETROFITTING OF SOFT-STOREY BUILDINGS USING NUMERICAL OPTIMIZATION

Lin Htin[1], Kishor Timsina[2], and Chaitanya Krishna[1,*],
[1] *AIT, Pathum Thani, Thailand,* [2] *Madan Bhandari University of Science and Technology, Nepal*
*Corresponding author: chaitugk@ait.ac.th

1. INTRODUCTION

In many developing countries, RC buildings with open ground floors for commercial or parking use and masonry-infilled upper floors for residences create a soft-storey mechanism, a major cause of collapse during earthquakes such as the 2015 Gorkha event as in Figure 1. These mostly non-engineered buildings have low ductility, poor detailing, and high vulnerability. Addressing this issue requires solutions that balance seismic performance with community needs [1], as existing methods—steel bracing, carbon fiber wrapping, or full infill—often face cost, disruption, and acceptance challenges [1–3].

Figure 1. Soft-storey collapses observed in the 2015 Gorkha Earthquake in Nepal

2. RETROFITTING METHOD

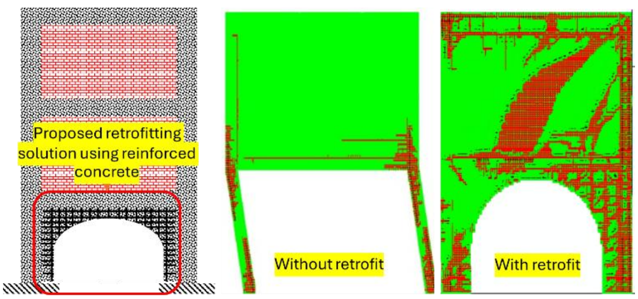

Figure 2. Optimized arch retrofit in the soft storey showing AEM deformations and failed springs for frames.

This study extends previous work on optimizing retrofits for soft-storey RC frames using RC shear walls with large openings[2]. A socio-technical optimization based on Sequential Quadratic Programming (SQP) minimizes total retrofit costs while meeting seismic performance targets. Key design variables include wall thickness, opening size, reinforcement details, and concrete strength. The method is implemented in the Applied Element Method (AEM).

3. NUMERICAL AND EXPERIMENTAL STUDY

A representative frame was modeled in AEM using surveyed dimensions and material properties. Static monotonic analysis quantified global stiffness and capacity, and the optimization loop iteratively refined shear wall configuration to match the performance of a fully infilled frame. The numerical study is shown in Figure 2 and following this understanding, an experimental work has been conducted using a scaled samples with and without the proposed retrofitting.

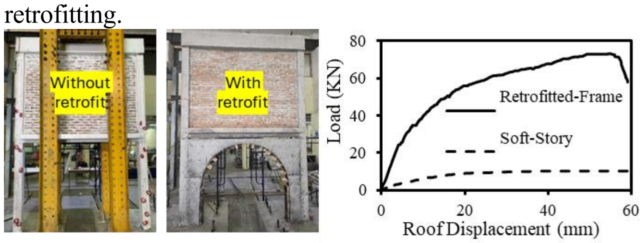

Figure 3. Experimental study of a ½-scale frame with and without retrofit under static load showing load-displacement

2. SUMMARY

The retrofitted frame achieved up to ten times higher load capacity and initial stiffness, and dissipated five times more energy than the unretrofitted frame while eliminating the soft-storey mechanisms. Crack propagation in the original frame was confined to ground-floor columns, whereas in the retrofitted frame it was distributed across columns and infill walls, indicating improved energy absorption and damage distribution. These enhancements were achieved while preserving functional ground-floor space, ensuring both seismic safety and social acceptance.

3. REFERENCE

[1] Timsina, K., Gadagamma, C.K., Numada, M., & Meguro, K. (2019). Sociotechnical evaluation of the soft story problem in reinforced concrete frame buildings in Nepal.
[2] Timsina, K., Gadagamma, C.K., Numada, M., & Meguro, K. (2019). Development of a numerical optimization framework for solving soft-storey problem in reinforced concrete frame buildings
[3] Timsina, K., Gadagamma, C.K., & Meguro, K. (2021). Enhancing seismic resilience of soft-storey buildings through optimized reinforced concrete infill solutions.