

Seismic Performance of Story-Added Type Buildings Remodeled

Subjects: **Engineering**, **Civil**

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The infrastructure of old apartment buildings (>20 years old) makes it difficult to introduce convenient facilities and recent technologies such as those involving the Internet of Things and augmented realities. Applying housing technologies to existing older apartments can increase housing supply and potentially address the aforementioned issues.

remodeling

vertically story-added

isolation system

isolation period

maximum response acceleration

maximum response displacement

1. Background

Story-added type apartments have recently been introduced as an option to resolve housing supply shortage in areas that are undergoing rapid industrialization and urbanization. However, the infrastructure of old apartment buildings (>20 years old) makes it difficult to introduce convenient facilities and recent technologies such as those involving the Internet of Things and augmented realities. Several factors can inhibit the initiation of apartment reconstruction projects, including the following: (i) social issues associated with the rapid decline in residential quality; (ii) environmental disruption and waste of resources associated with apartment reconstruction; (iii) economic factors regarding a decrease in real estate value when buildings become taller.

Despite the demand for reconstructing residential apartments increasing, there is a panoply of adverse effects that can affect such reconstruction projects, including social issues arising from the overheated housing market, in which most buyers prefer new buildings, the lack of rental houses in the market, along with technical issues such as environmental destruction associated with the mass production of waste materials from demolished buildings, excessive carbon dioxide emissions owing to the increasing demand for large amounts of concrete, and the lack of natural aggregates for the reconstruction of apartments.

Furthermore, due to the continuing urbanization and industrialization of the society, there is a need to supply houses to meet the demand for housing. Thus, the government has begun to recommend the remodeling of existing apartment buildings in order to embrace the economic and environmental benefits of remodeling and increase the supply of houses by approximately 15%. The government recommends the vertical extension of older buildings in order to simultaneously solve issues associated with the lack of houses and the deterioration of old apartments.

However, recommendations for vertical extensions are accompanied by concerns about increased lateral loads caused by building vertical extensions, as well as increases in the number of stories and total floor area. That is, an increase in the total weight of a building can result in increases of wind load and seismic load. This eventually necessitates reinforcement of such buildings to account for the increased load on the foundation and the augmentation of members against the lateral resistance caused by increases in wind load and seismic load (ASCE/SEI41-17 [1]). An increase in the vertical load can be compensated for by a design capable of bearing approximately 15% of the axial load applied to the cross-section of a building, whereas the lateral load may exceed the level of the designed load with building extensions due to the lower safety factor of a horizontal load. This necessitates a separate lateral reinforcement of the building. The cost of developing a separate lateral reinforcement option may be equal to or greater than the cost of a new construction, resulting in economic losses connected with a remodeling project (refer to **Figure 1** and **Table 1**).

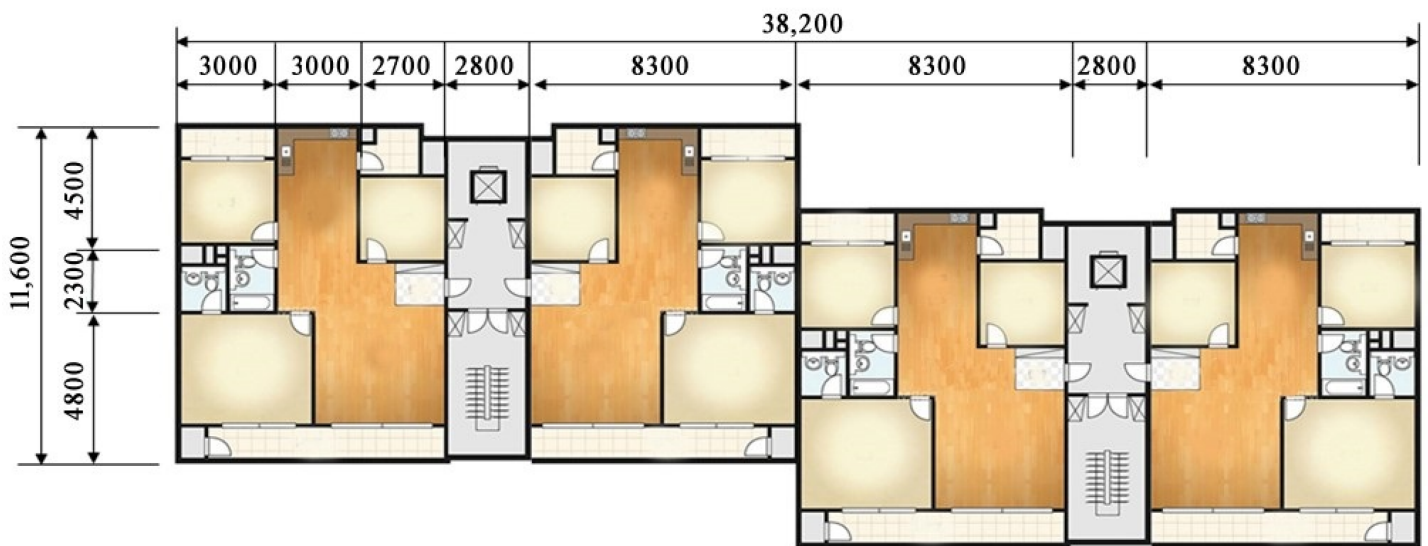


Figure 1. Floor plan of an apartment with an exclusive area of 85 m² (real apartment).

Table 1. Vertical stress before and after remodeling (apartment with an exclusive area of 85 m³).

Weight of Building		Wall	Slab	Live Load (Including Floor Finish)	Total Load
Weight of the first floor (kN)		2700	1780	1980	6460
Cross-sectional area of the wall (cm ²)		433,200			
Before remodeling of the building (15 Stories)	Total weight of building (kN)	40,500	26,700	29,700	96,900
	Average vertical stress of the first floor (kN/cm ²)	96,900/433,200 = 0.2237			
After remodeling of the building (18 Stories)	Total weight of building (ton)	46,080	32,760	37,440	115,380

Weight of Building	Wall	Slab	Live Load (Including Floor Finish)	Total Load
Average vertical stress of the first floor (kN/cm ²)			115,380/433,200 = 0.2663	
Increment in vertical load			115,380 – 96,900 = 18,480 kN	
Increment in vertical stress			0.2237 → 0.2663 (Approximately 12.0% of Allowable Stress of the Material)	system is ed to add

any separate structural members, which may damage existing buildings more than conventional approaches. Xiaoyu Gu (2020) has conducted about MR elastomer (MRE)-based isolators and demonstrated their performances through a shake table experiment to assess a three-story shear building [2]. Antonello De Luca (2020) has examined issues associated with the evolution of an Italian style of seismic isolation [3]. He highlighted the advancements made during the last 30 years, which involved the transformation of early pioneering concepts into cutting-edge solutions. Furthermore, Mohammad Masoud Pourmasoud (2020) has developed a “Multi-Directional Seismic Isolation (MDSI)” system and demonstrated its performance through experiments [4].

Recently it focused on seismic isolation systems have mostly reported the performance of seismic isolation by conducting pertinent experiments. Few papers have addressed the applicability of these systems.

The effect of the application of a seismic isolation system was analyzed to provide basic data required to examine the applicability and development of the system for vertical extension remodeling of an old apartment building. The seismic isolation system can vary according to the number of added stories in the vertical extension and the seismic isolation period of the building. A seismic isolation system was then applied to the actual building. The resulting effects were examined based on the computed optimal seismic isolation period. In addition, the applicability of the seismic isolation system to few-story buildings used as schools, where the application of aseismic reinforcement has recently been increased, was assessed. In this manner, basic data required for the development of plans for the vertical expansion of old buildings through the application of seismic isolation systems are presented.

2. Seismic Isolation Systems for Old Building Remodeling by Adding Stories

A seismic isolation system is a practical option for protecting important buildings (data centers, hospitals and so on) from powerful earthquakes and improving the aseismic performance of existing architecture. Recently, the number of designs that aim to exploit seismic isolation systems, especially designs for data centers according to client requirements, has been increasing. To reflect the reality of the situation, seismic isolation system requirements were added to ACI 318-19 [5].

Seismic isolation systems have been designed to be used for buildings such as residential welfare centers, apartments, composite buildings with both apartments and commercial facilities, data centers, computer centers, and so on. However, the number of newly installed seismic isolation systems is continuously declining due to rising frame structure building costs and extended construction duration [\[6\]](#)[\[7\]](#)[\[8\]](#)[\[9\]](#)[\[10\]](#)[\[11\]](#)[\[12\]](#)[\[13\]](#)[\[14\]](#)[\[15\]](#)[\[16\]](#)[\[17\]](#).

Nonetheless, the application of seismic isolation systems to stories added to old apartment buildings as suggested is estimated to be feasible as it entails a shortened construction period and minimizes the amount of reinforcement needed to ensure the aseismic performance of existing buildings. The advantage of using a seismic isolation system in this manner is that it frees up space for floor plans or improves the design of floors of buildings that are above the seismic isolation system. In addition, aseismic reinforcement of an existing building can be minimized by reducing the load delivered to the existing lower structure of a building (refer to **Figure 2**).

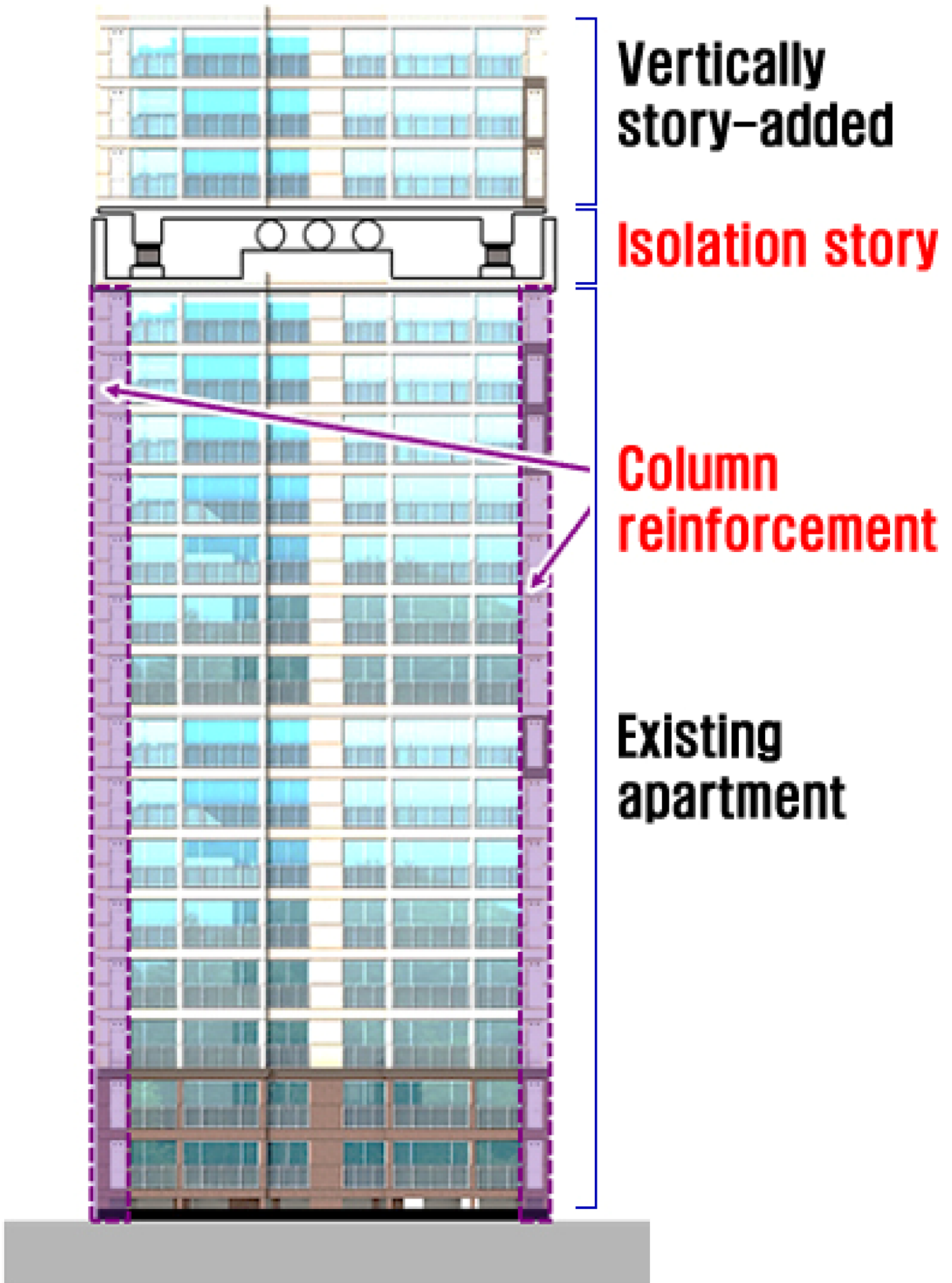


Figure 2. Concept of vertical story-added isolation.

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