SEISMIC ISOLATION AND REHABILITATION TECHNOLOGIES FOR IMPROVING SEISMIC PERFORMANCE OF RC BUILDINGS IN ARMENIA

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ABSTRACT

Buildings are the backbone of the world's infrastructure. Without this backbone, civilization doesn't exist. The challenge to improve the seismic performance of existing reinforce concrete buildings in Armenia is aimed in this study.
The seismic response analysis has been done in this study for the target PRC residential building, located in Armenia. This is a typical construction solution in Armenia which has very low seismic capacity. When the Spitak earthquake occurred in 1988, all of this type of buildings collapsed or severely damaged. Moreover still now their number is continuing to be larger in the capital city Yerevan without any rehabilitation technic.
Rehabilitation of the building has been offered to realize the criteria by taking seismic isolation technology into consideration. The numerical simulation for the above building includes non-linear analyses, based on the non- linear model for structural members, which have been made using Stera 3D software. Time history response analysis has been done with and without seismic isolation. From the result of those analyses, it has been proved that the response of seismically isolated building is as follows: the good seismic effect was obtained through the response analysis in the most calculation cases. However in case of Armenia, as the upper structure's capacity for the target PRC residential building is low, in order to get the good seismic effect it was obtained that the optimum design for seismic isolation layer should be done from the non-linear analysis.
As a conclusion, in this paper a proposal design for the base isolated layer has been made based on the numerical results, Armenian building characteristics and Japanese seismic isolation technology.

Keywords: Seismic isolation, PRC building, seismic rehabilitation, nonlinear response analysis

1. INTRODUCTION

Earthquakes, floods, hail, landslides, mudflows, drought, erosion and desertification have caused vast social upheaval and economic damage to Armenia. In the 2005 report "Natural Disasters Hotspot – A Global Risk Analysis", the World Bank lists Armenia in the top 60 countries exposed to multiple hazards. In fact, more than 80 percent of Armenians are at risk of exposure to catastrophic events.

Armenia lies in the seismically active crescent that stretches from the Alps through the Caucasus and Central Asia to the Russian Federation along with Turkey and other earthquake endangered countries.

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The substantial earthquake hazard is due to interactions of major tectonic plates: the Indian and Arabian plates are moving north (20-30 mm/year), colliding with the Eurasian plate and resulting in the thrust faulting the ongoing process that created major mountain ranges from the Caucasus to the Himalayas. The collision zone stretches from eastern Turkey and the Caucasus to the west of the Caspian Sea, causing associated lateral faulting on its western and eastern sides, as the earth's crust is extracted along the regional fault zones. To the south, strike-slip faults between the Caspian and Black Seas make this an area prone to high and very high earthquake hazard.

2. OBJECTIVES

In 1988, the destructive earthquake occurred in Armenia with magnitude 7.0. At that time, the Armenian society faced the dramatic fruits of those years of construction. Particularly there were many precast RC buildings series 111, common construction solution in Armenia, and 95% of that type of buildings collapsed or severely damaged in epicenter and nearby cities after the earthquake. Moreover, nowadays the number of that series of building is 15% among all residential buildings in Armenia and to improve their seismic response against earthquakes is the urgent need considering that natural hazard, as an earthquake, is an unexpected phenomenon.
To rely on the above noted background, the following issues have been discussed in this study:

- To study Japanese experience for the seismic isolated buildings after the 1995 Hyogo-Ken Nanbu (Kobe) and 2011 Great East Japan earthquakes.
- To learn how to apply seismic isolation technology for improving seismic performance of a structure.
- To do seismic response analysis by numerical simulation for the building including non-linear analyses, based on the bi-linear model with and without seismic isolation, using Stera 3D software.
- To propose design for the base isolated layer based on the numerical results considering Armenian building characteristics and Japanese technology.

3. REHABILITATION OF 9-STORY PRECAST RC BUILDING, FRAME PANEL SERIES 111, IN ARMENIA

3.1 Structural Design for Seismic Isolation

3.1.1 Analyzed Building

The target structure is a 9-story precast reinforced concrete residential building, Frame Panel, series 111, located in Armenia, which completely collapsed or was heavily damaged in the 1988 Spitak earthquake. Out of 136 buildings, 127 (95%) were heavily damaged only in Leninakan city. It is typical construction solution among residential buildings in Armenia.

3.1.2 Rehabilitation Method

Rehabilitation of the building is offered to realize the criteria by taking seismic isolation (SI) technology into consideration as follows:

- SI is often the best way to significantly improve the seismic performance of a structure without affecting the outward appearance, the design or the interior space of the building.
- SI is suitable especially for rehabilitation of the residential buildings because it usually needs long time and at the same time there is no need for residents to evacuate.
- Very often SI may be the only way for the rehabilitation of buildings with very low seismic capacity, in comparison with conventional rehabilitation methods when it needs to install additional structural elements which will increase the total weight of the building.
- Rehabilitation by SI system is always cost effective in the long term of building's life.

3.1.3 Structural Design Method

Structural design method has started with push over analysis, then the assumption of yielding shear coefficient have been done, after what the selection of seismic devices. The modeling of building with and without seismic isolation have been made based on noted steps and then time history analysis have been done for both models. The evaluation has concluded the procedure (Fig. 1).

- Structural design has been made based on the non-linear time history response analyses, and based on the non-linear model for structural members, which has been made by using Dr. T.Saito's Stera 3D software.
- The maximum input acceleration ground motion is considered $400 cm/s^2$ in accordance with defined maximum design value in Armenia.
- The seismic devices: isolators and dampers are chosen from Japanese products as shown in Table1.
- Performing the parametric study
    - Ground motions: Spitak, Elecentro, Hachinohe and Taft .
    - Seismic isolation story
        - ✓ Yielding shear force coefficient: $\alpha_y = \begin{cases} 0.02 \\ 0.04 \end{cases}$
        - ✓ Isolation period: $T_v = \begin{cases} 2\ seconds \\ 3\ seconds \\ 4\ seconds \end{cases}$

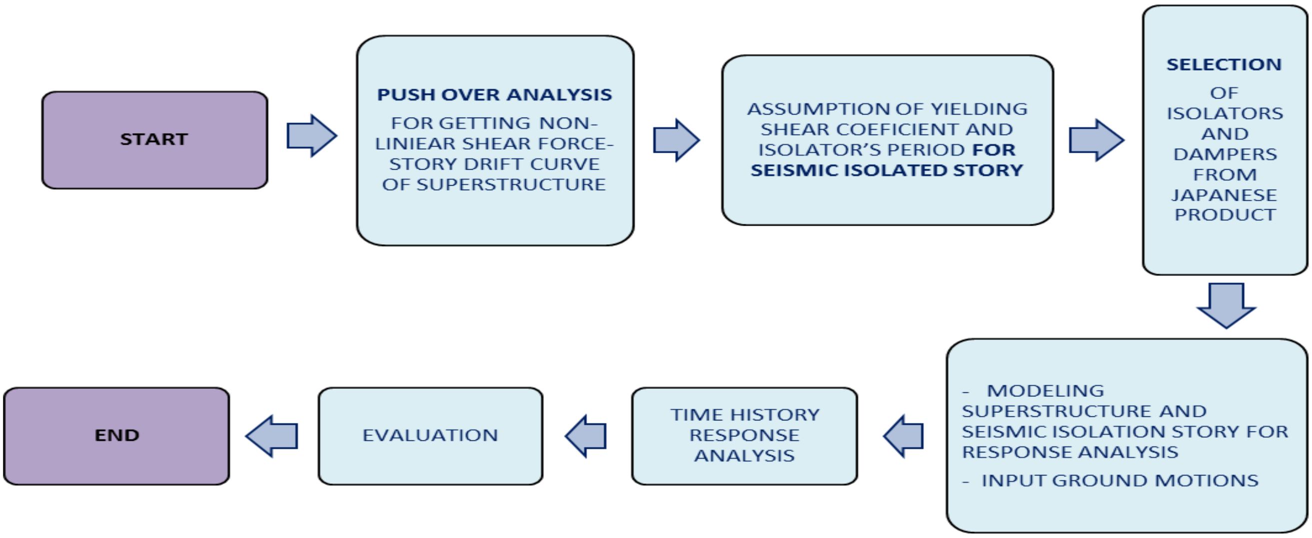

Figure 1. Structural design.

Table 1. Seismic isolation devices for design.

Natural Period (second)	Natural Rubber Bearing	Steel Damper
2	R110-500-3.75x26 (4 pieces) R110-500-3.75x26 (8 pieces) R90-600-4.5x26 (4 pieces)	NSUD40x2
3	R50-500-3.75x26 (4 pieces) R50-500-3.75x26 (8 pieces) R45-600-4.5x26 (4 pieces)	NSUD40x4
4	R30-500-3.75x26 (4 pieces) R30-500-3.75x26 (8 pieces) R30-600-4.5x26 (4 pieces)	NSUD40x4

110 – hardness of rubber
500 – diameter
3.75x26 – thickness of the one layer of rubber

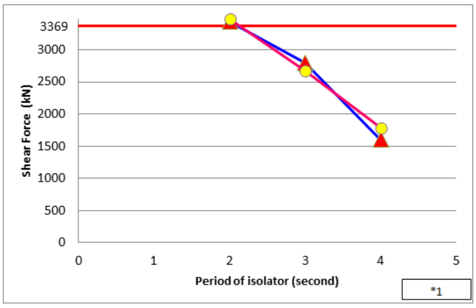

Figure 2. Max shear force on the 1st floor.

Without SI

With 0.02 shear coef. and Isolator with 2.0, 3.0 and 4.0 seconds

With 0.04 shear coef. and Isolator with 2.0, 3.0 and 4.0 seconds

3.2 Rehabilitation of Frame Panel Building by Seismic Isolation

The structure is RC frame for one direction and the other is RC panel. Natural periods of the building for the first three mods are 1.196 sec., 0.673 sec. and 0.394 sec. correspondingly.
Relationship between the story drift and share force based on push-over analysis is introduced in Fig. 4.

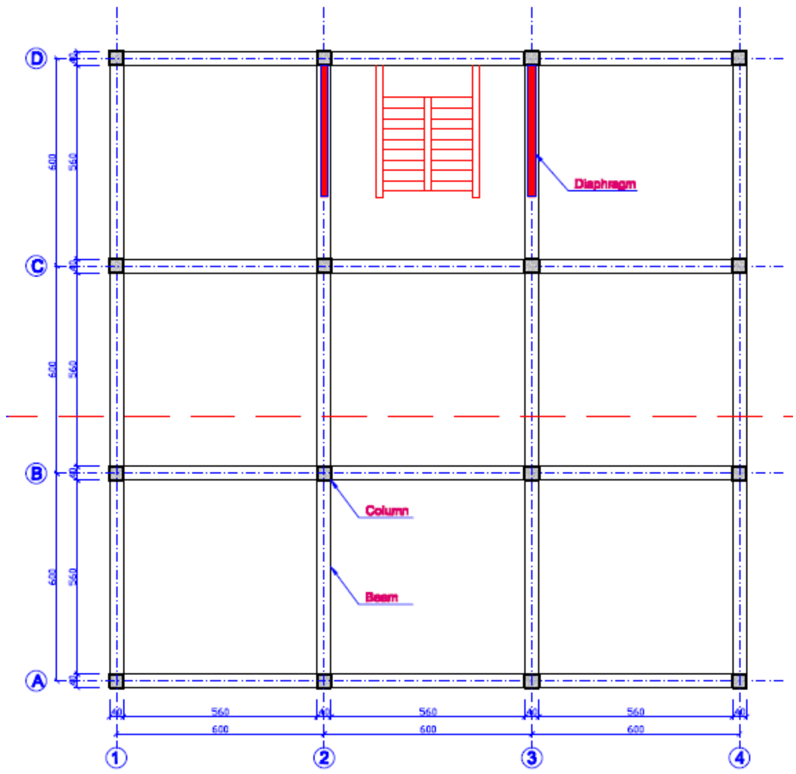

Figure 3. Plan of FB building.

Time history analysis has been done for 24 different cases, taking into consideration two different values of shear coefficient: 0.02 and 0.04, for each one 3 cases of isolator with different periods: 2sec., 3sec. and 4 sec. Discussed cases have been considered for 4 ground motions: Spitak, Elecentro, Hachinohe and Taft.

An example of reduction of the shear force and relative drift of the superstructure is introduced in Figure 2, for the isolators with different periods.

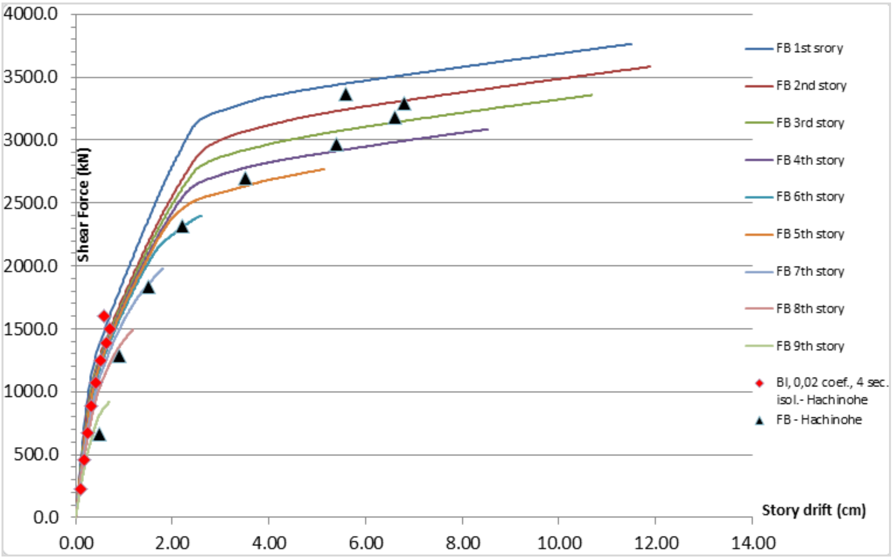

Figure 4. Relative drift of superstructure.

The isolated layer has been designed by the following devices: 16 natural rubber bearings (NRB) have been installed under each column of the building while there are 2 different types of NRB, due to the axial force of the columns: 12 pieces of R110-500-3.75x26 and R90-600-4.5x26. For absorbing earthquake energy, U shaped steel dampers have been chosen: NSUD40x2 and NSUD40x4.

The results due to time history analysis are shown as follows:

Increase of natural period:

Predominant natural period of the building, for the all considered ground motions, has been maximally raised in case of the 0.02 shear coefficient - from 1.196 sec. to 2.208 sec and in case of the 0.04 from 1.196 to1.747.

❖ **Reducing of shear force in the 1st floor**:

Compared with shear force of the 1st floor without seismic isolation, shear force with seismic isolation reduced by 80~50 % in most effective case.

❖ **Reducing of acceleration:**

Compared with maximum acceleration of input ground motion of 400 gal, 9th floor`s acceleration with seismic isolation reduced by 45~35 % and 1st floor’s reduced by 40~30 % in most effective case.

❖ **Reducing of story drift of superstructure:**

Compared with story drift of superstructure without seismic isolation, story drift with seismic isolation reduced by 30~15 % in the most effective case.

❖ **Maximum displacement of seismic isolator:**

Compared with limit shear strain 400% of isolator, the response drift of isolator became 100~180% and had enough safety margin against the limit state in biggest case.

4. CONCLUSIONS

In this Master paper, the proposal of rehabilitation design has been made using seismic isolation technology, as one of the most effective methods for the rehabilitation, for the seismically vulnerable precast RC buildings (series 111), which are widely spread as typical construction solution among residential buildings in Armenia. From the view point of seismic rehabilitation design with seismic isolation, Armenian low strength buildings could get the very high isolation effect except the isolation story's period of 2.0 sec. In case of 2 sec. period, as a result of design, a small amount damper must be used, therefore the big isolation effect could not be get.

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to my supervisor, emeritus Professor Dr. Shunsuke SUGANO and advisors, Dr. Toshihide KASHIMA and Dr. Matsutaro SEKI who guided me along my study path in Japan.

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