International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 4 Issue 4, June 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Base Isolation Retrofitting Design for the Existing 9-Story Large-Panel Apartment Building

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ABSTRACT

In Armenia seismic isolation of existing buildings is becoming a more common method of providing protection from earthquake damage. Thanks to the works of the author of this paper in nowadays Armenia is well known as a country where seismic (base and roof) isolation systems are widely implemented in construction of new and retrofitting of existing buildings. The number of seismically isolated buildings per capita in Armenia is one of the highest in the world – second after Japan. The paper given below emphasizes that Armenia achieved significant results also in local manufacturing/testing of seismic isolation laminated rubber-steel bearings (SILRSBs). Several re-markable projects on retrofitting by base isolation of the existing buildings like apartment, school, hotel and hospital buildings are briefly mentioned in the paper to demonstrate the retrofitting experi-ence accumulated in Armenia. Based on the gained experience further developments take place and unique base isolation structural concepts and technologies created by the author are applied more and more to the existing buildings. In this paper base isolation retrofitting design and analysis by the Ar-menian Seismic Code for the 9-story large panel apartment building is described. This will be a first application of base isolation retrofitting technology to a building the bearing system of which con-sists of reinforced concrete large panels. It is stated that suggested seismic isolation strategy is reduc-ing the cost of retrofitting of the given existing building about 5 times in comparison with the cost of conventional strengthening. The other important factor is that applied structural concept allows retro-fitting without interruption of the use of considered building.

How to cite this paper: Mikayel G. Melkumyan "Base Isolation Retrofitting Design for the Existing 9-Story Large-Panel Apartment Building" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-4, June 2020, pp.199-209, URL: www.ijtsrd.com/papers/ijtsrd30937.pdf

IJTSRD30937

KEYWORDS: *Base isolation strategy, Existing buildings, Seismic protection, Seismic retrofitting, Structural concepts, Low-cost technology, No interruption of the use of the buildings, Seismic Code analysis*

1. INTRODUCTION

The retrofitting technique using base isolation has great potential for rehabilitation of ordinary civil structures such as apartment blocks and critical facilities such as schools, hospitals. Starting from 1995, 56 buildings and structures have been designed by the author of this paper with application of base or roof isolation systems. Of these designed buildings the total number of already constructed and retrofitted buildings has reached 48 (Fig. 1). Among them there are bathhouses, private residenc-es, school buildings, clinic and hospital buildings, business centers, hotels, and apartment buildings. The number of seismically isolated buildings per capita in Armenia is one of the highest in the world – second after Japan. In [1] it is stated that: "Armenia remains second, at the worldwide level, for the number of applications of such devices per number of residents, in spite of the fact that it is still a developing country". Together with that SILRSBs different by their shape and dimensions, as well as by damping (low, medium and high) were designed and more than 5000 SILRSBs were manufac-tured in the country, tested locally and applied in construction (Fig. 2).

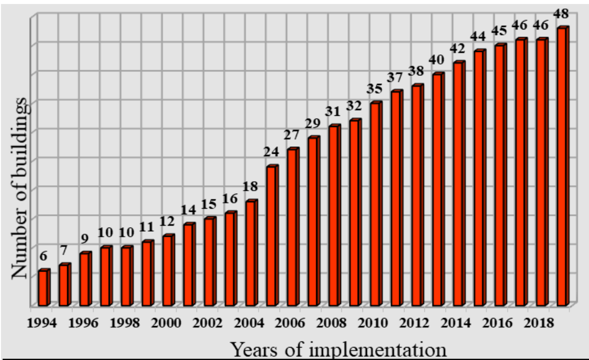


Figure1. Number of seismic (base and roof) isolated buildings newly constructed or retrofitted in Armenia by years

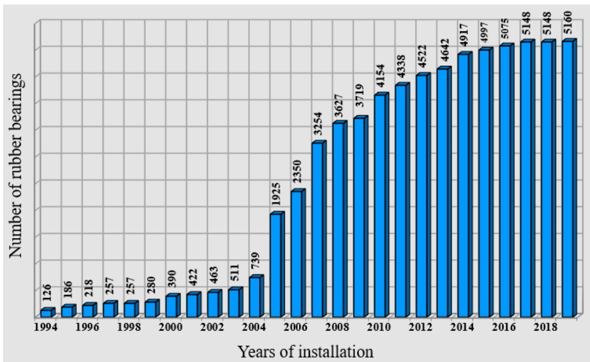


Figure2. Number of rubber bearings installed in the newly con-structed or retrofitted buildings in Armenia by years

Several remarkable projects on retrofitting by base and roof isolation were developed and imple-mented using technologies created by the author of this paper. One of them is retrofitting by base iso-lation of a 5-story stone apartment building (Fig. 3a) in the city of Vanadzor (Armenia). The operation was made without resettlements of the occupants. World practice provides no similar prec-edent in retrofitting of apartment buildings. The project was completed in 1996 [2].

Figure3. Projects on retrofitting by base and roof isolation utilizing different seismic isolation strategies developed by the author of this paper and implemented in Armenia and Russia

The next technology was utilizing the developed method of an additional isolated upper floor (AIUF) acting as a vibration damper. This technology of roof isolation was used in earthquake pro-tection design and implementation for two existing reinforced concrete (R/C) 9-story standard design frame buildings (Fig. 3b) also in the city of Vanadzor. The projects were implemented in 1996-1997 [3]. Then by the end of nineties, another project initiated by Prof. Eisenberg and Dr. Smirnov [4] on retrofitting of about 100 years old 3-story stone bank building was implemented in the city of Irkutsk (Russia) with increasing of the number of stories up to 4 (Fig. 3c). It was emphasized by them that for retrofitting the existing bank building using base isolation they have implemented the method de-veloped in [2] by the author of this paper who provided Russian and Chinese colleagues with all the needed drawings, photos, video film related to the retrofitting works carried out in Armenia. The other project is retrofitting of the 60-year-old 3-story stone school building which has historical meaning as well as a great architectural value (Fig. 3d). Unique operations were carried out to install the isolation system within the basement of this building and to preserve its architectural appearance. The project was implemented in the city of Vanadzor in 2002 [5, 6].

By given above brief information on several projects an objective is pursued to demonstrate expe-rience in the field of retrofitting by base isolation of existing buildings with stone bearing walls, as well as of earthquake protection by roof isolation of existing R/C frame buildings. Later, the author has developed and proposed principally new structural approaches for base isolation of the existing R/C frame buildings with and without shear walls. Thus, further developments have taken place for retrofitting by base isolation and unique operations on retrofitting of the 8-story HCHB (Fig. 3e) constructed in Yerevan about 45 years ago were accomplished. The seismic isolation of this existing building was created at the basement level. Detailed description of all phases for cutting the columns and shear walls and placing SILRSBs of the same sizes and physical/mechanical parameters are giv-en in [7]. Results of analysis of this retrofitted building by the Armenian Seismic Code and the time histories are presented in [8].

The next strategy is retrofitting by base isolation of about 55-year-old 4-story R/C industrial frame building with its simultaneous reconstruction into a 6-story hotel building (Fig. 3f). This build-ing is also located in Yerevan. New original technology on retrofitting by base isolation was devel-oped and applied to this building and the results of its analysis in accordance with the provisions of Armenian Seismic Code and also time history analysis are discussed in [9]. SILRSBs with high damping of about 15% were used. Created solution is proposed for the first time and envisages plac-ing the seismic isolators around the existing columns and then gradual cutting these structural ele-ments. Operations are designed to be performed for the existing columns in several stages.

The given paper focused on retrofitting design of the existing damaged 9-story apartment building constructed in Stepanakert in 1988. If the design is implemented, then it will be the first application of base isolation retrofitting technology to a building with large panel bearing system. Structural concept of retrofitting was developed for this building based on the acquired experience briefly de-scribed above. Special attention in the design is given to strengthening of the first floor's damaged large panel walls by R/C jackets. Base isolation interface for this building is designed at the level of basement floor. The building is analyzed based on the provisions of the Armenian Seismic Code.

2. SOME CHARACTERISTIC PECULIARITIES ON BASE ISOLATION RETROFITTING DESIGN FOR THE EXISTING BUILDINGS WITH LOAD-BEARING WALLS

Isolation of structures from horizontal ground motions is gradually becoming a more common meth-od of providing protection from earthquake damage. It is practicable to design the isolation system so that the structure responds elastically to the design level earthquake. Thus, repair cost should be greatly reduced, and continued serviceability of the structure assured. The rehabilitation of existing structures by the insertion of isolators at foundation level has been carried out on historic buildings such as the Oakland City Hall, San Francisco City Hall [10, 11], Salt Lake City and County Building [12, 13, 14], etc. For these, isolation may provide the only viable means that is not unduly intrusive and damaging for the appearance of the building.

The first retrofit of existing 5-story stone apartment building, as it was mentioned above in Intro-duction to this paper (see Fig. 3a), has been carried out in Armenia in 1995-1996 [2, 15]. The devel-oped structural concept aims at retrofitting an existing building using a simple and innovative working approach [10, 16] according to the technology created by the author of this paper (Patent of the Republic of Armenia #579). This is a unique and pioneering seismic isolation project the idea of which was to furnish this building with seismic isolation by gradually cutting the isolators into the load-bearing walls made of tuff stones at the level of foundation upper edge by means of a two-stage system of R/C beams. SILRSBs are located by upper and lower recesses provided by annular steel rings bolted to outer steel plates which are connected to the reinforcement in the upper continuous and lower foundation beams; the isolators themselves are not bolted to the structure. This method of connection helps to minimize the cost of the isolators themselves and simplifies their installation on site [17]. Because the bearing is simply located in a recess, no tapped holes for bolted connections are needed in the endplate. The side, top and bottom rubber cover layers ensure the steel plates are protected from corrosion. This project was accomplished without re-settlement of the dwellers. There has been no similar precedent in the world practice of retrofitting apartment buildings.

After this successful start other project was developed and implemented in Armenia in 2001-2002 for retrofitting of the 60-year-old existing 3-story stone school #4 building (see Fig. 3d). The base isolation system was created at the level of the school basement in the middle part along the height of its load-bearing walls made of tuff stones [5, 6]. This approach implied some differences in retrofit-ting of the school building in comparison with that of the apartment building. In the case of the school building the lower continuous beams were structurally connected to the bearing walls of the basement. This afforded a possibility to strengthen the bearing walls by lower continuous beams be-fore cutting the building and passing its weight through the seismic isolators to the bearing walls of the basement. Such structural solution permits the bearing walls of the basement to reliably carry the concentrated vertical loads and does not worsen their behavior and stress-strain state compared to other known solutions mentioned above [12, 13]. The unique operations were carried out to install SILRSBs and the technique of installation is especially important for the considered building, which has a historical and architectural value. First, the building's external appearance should not be disfig-ured under any circumstances. Second, not a single stone of the façade should fall when making openings in the bearing walls. One may have to deal with three different situations in making open-ings in the existing walls of the basement [6, 10]. The relatively simple case is when the opening has the part of existing wall above it. In this case there is no need to use any additional supports, as the strength of the wall above the opening is enough to avoid collapse. A more complicated situation for making openings arises when any of the existing beams or girders is crossing the space of the open-ing. In this case one of the ends of the existing beam loses its support and it is necessary to create temporary supports to carry the dead load of the existing building. The operation should be per-formed very carefully to avoid any damages in the superstructure after making openings in the exist-ing walls. The most complicated case is when the opening does not have any part of the existing wall above it. For the subject matter school building such situations occurred at the entrance, where open-ings had to be made just beneath the columns and the arches. The arches had to be temporarily sup-ported before starting to make the openings. Then the opening under the column should have been gradually made using temporary mechanical jacks. During every step of implementation in such complicated cases of retrofitting it is necessary to take care of the condition of the existing structures to prevent development of any damages, as these structures are part of the valuable architectural ap-pearance of the building.

For the above-mentioned projects, the medium damping rubber bearings (MDRBs) with the damping of about 8-9% and the high damping rubber bearings (HDRBs) with the damping of about 13-15% from neoprene have been designed by the author of this paper. Medium or high damping rubber bearings are a simple, economical means of providing isolation. They have the low horizontal stiffness required to provide a long vibration period (typically 2 sec) to a structure mounted on such bearings. Their vertical stiffness is high, which minimizes rocking of the structure during an earth-quake. The damping needed to limit the displacement of the structure and reduce the response at the isolation frequency is incorporated into the rubber compound, and so generally no auxiliary dissipa-tion devices are needed. The service life of the bearings is expected to be several decades [18], and they should require no maintenance. Many projects throughout the world have installed seismic iso-lation systems based on such type of bearings [19, 20, 21].

3. STRUCTURAL APPROACH ON STRENGTHENING OF LOAD-BEARING LARGE-PANEL DAMAGED WALLS OF THE 9-STORY APARTMENT BUILDING USING R/C JACKETS

Retrofitting design of the 9-story large-panel building (Fig. 4) was developed by the order of the Ministry of Urban Development of Nagorno-Karabakh in 2018. The building has symmetric rectan-gular plan with main dimensions of 34.6×11.2 m. It has two exterior (300 mm thick) and one interior (200 mm thick) longitudinal load-bearing walls, as well as two exterior and six interior transverse load-bearing walls. All walls in transverse direction have thickness equal to 200 mm. The floors' slabs consist of precast reinforced concrete hollow-core panels.

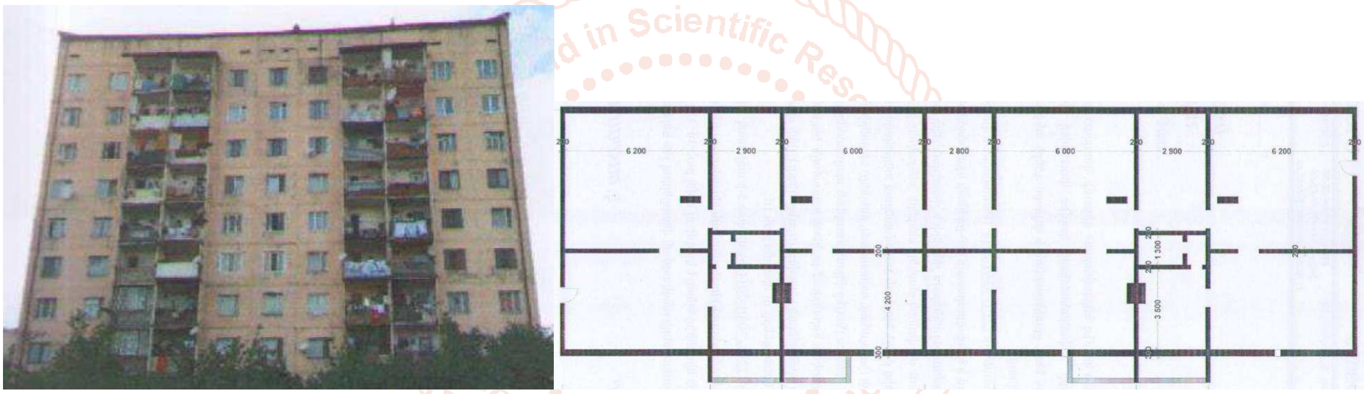
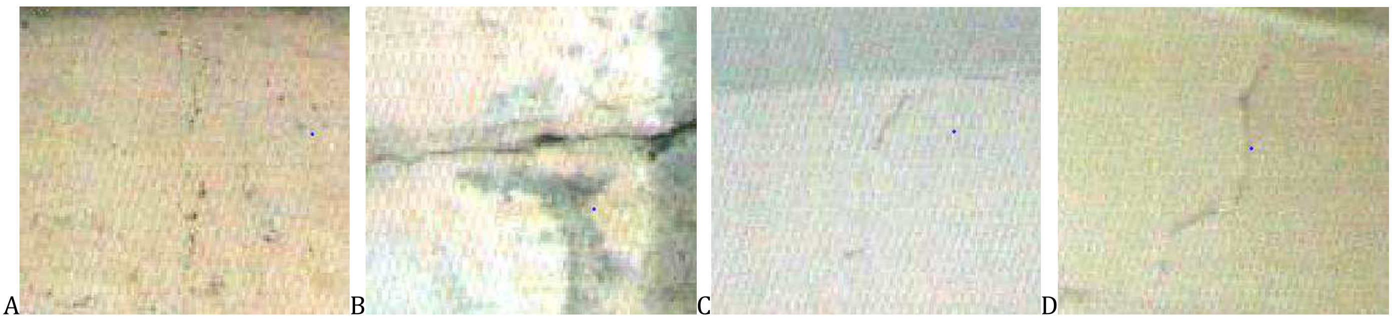


Figure4. View of the existing 9-story large-panel apartment building to be retrofitted by base isolation and plan of its basement

The building has damages concentrated mainly within the limits of the first floor (Fig. 5). Pictures in Figures 4 and 5 were taken from reports kindly provided by the customer. The structural concept of retrofitting using base isolation technology together with strengthening by R/C jackets of the dam-aged load-bearing large-panel walls and results of analysis of the considered building are described below. Thus, before starting implementation of base isolation system, the developed design envisag-es strengthening of the existing load-bearing walls by R/C jackets.



A B C D

Figure5. Views of the vertical (a), horizontal (b) and incline (c, d) cracks in the existing large-panel load-bearing walls of the first floor of 9-story apartment building

Figure6 shows all four façades (two longitudinal and two transverse) of the building with indica-tion of R/C jackets designed for local strengthening of the existing walls. Obviously, there was an intention to make the jackets as symmetric as it is possible. From the given drawings one can see that in longitudinal façades the jackets are not envisaged only within the limits of balconies and the en-trances to the building. However, in transverse façades the jackets are envisaged to cover the whole exterior surfaces of the walls.

In both directions the jackets have the thickness of 80 mm and will be constructed covering the exterior surfaces of the load-bearing walls. Reinforcement in these jackets consists of 200×200 mm steel meshes with horizontal reinforcing bars having a diameter of 14 mm and vertical reinforcing bars with diameter of 12 mm. The vertical bars are anchored in the upper beams to be constructed above the seismic isolation plane.

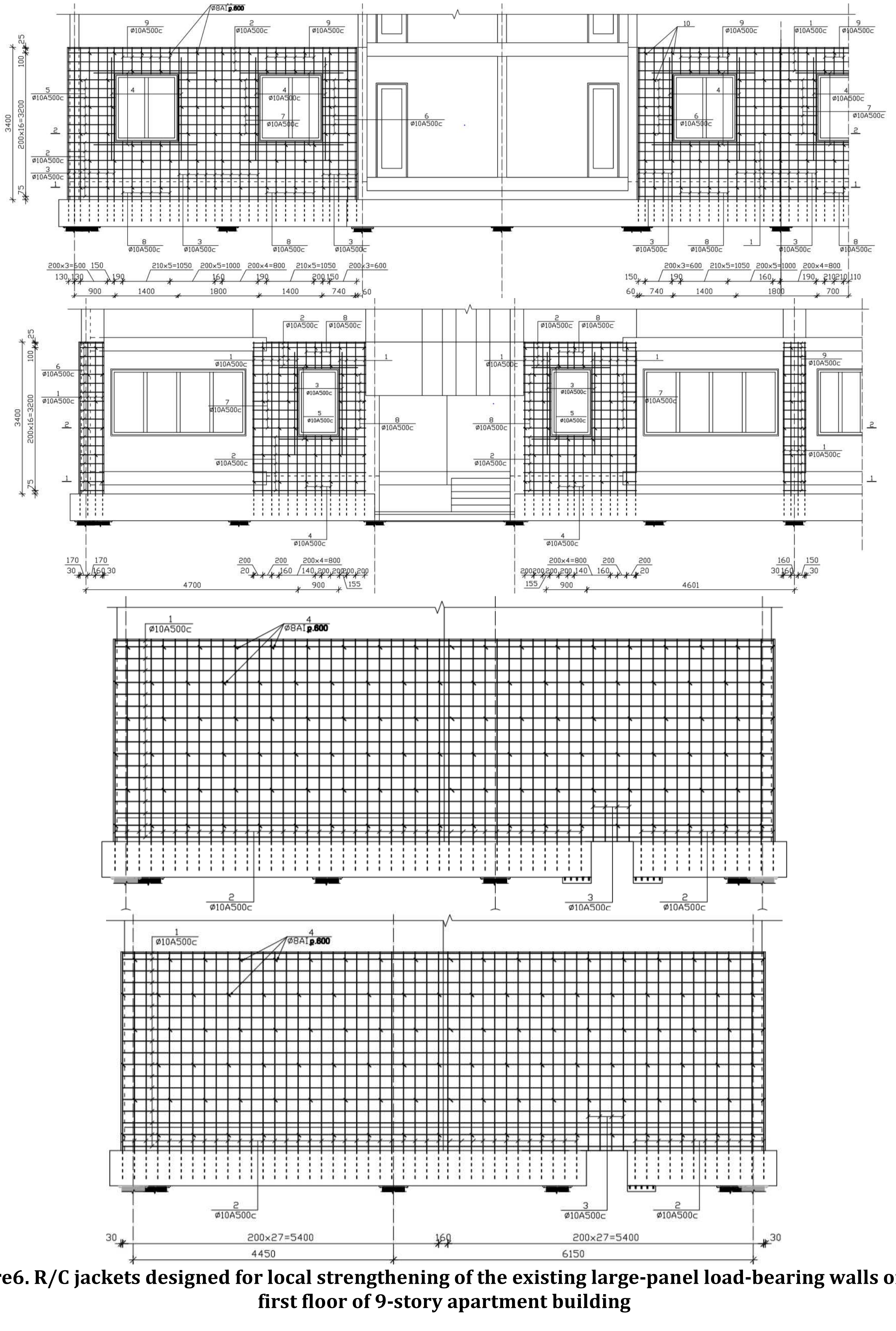


Figure6. R/C jackets designed for local strengthening of the existing large-panel load-bearing walls of the first floor of 9-story apartment building

The jackets are connected to the load-bearing walls by the reinforcing bars of diameter 8 mm which are placed in the holes of diameter 10 mm drilled with the spacing of 600 mm in the load-bearing walls. To provide reliable connection of the mentioned reinforcing bars with the body of large panels design requires the use of the epoxy glue. These bars must be reliably connected to the steel meshes of the R/C jackets. Before constructing the mentioned jackets, the cement injection in the walls' cracks must be performed.

4. PARAMETERS OF THE USED SEISMIC ISOLATION LAMINATED RUBBER-STEEL BEARINGS AND ANALYSIS OF THE BASE IAOLATED 9-STORY LARGE-PANEL BUILDING

Seismic isolation system of the considered building is designed at the level of its basement (see plan of the basement floor in Figure 4). SILRSBs of the same type and sizes were used to make the seismic isolation system. Total 62SILRSBswere used with aggregate horizontal stiffness equal to 0.81×62=50.22kN/mm. These are manufactured in Armenia according to the Republic of Armenia Standard HST 261-2007 with the sizes and physical/mechanical parameters given in Figure 7

External diameter of the bearing (D): (380 ±2.0) mm;
Internal diameter of the bearing's central hole (d_1): (19±1.0) mm;
Height of the bearing (H): (202.5 ±2.5) mm;
Thickness of the rubber layers (S): (9 ±0.1) mm;
Diameter of the steel shim plates (d_2): (360 ±0.5) mm;
Thickness of the steel shim plates ($_{S1}$):(2.5 ±0.1) mm;
External diameter of the upper and lower flanges (d3): (376 ±0.5) mm;
Thickness of the upper and lower flanges (S2): (20 ±0.2) mm;
Thickness of the upper and lower flanges' protective layer (S_3):(2 ±0.1) mm;
Mass of the bearing: (77.5 ±2.5) kg;
The bearing must withstand a maximum (design) permissible vertical loading of 1500 kN;
Shear modulus of the bearing's rubber must be (0.97 ±0.15) MPa;
Vertical stiffness of the bearing: no less than 300 kN/mm;
Horizontal stiffness of the bearing: (0.81±0.1) mm;
The bearing must withstand a maximum (design) permissible horizontal displacement of 280mm, without causing cracks greater than 3 mm deep and 6 cm long;
Shore A hardness of the bearing: 70±5 points;
Damping coefficient of the bearing: 13-15%

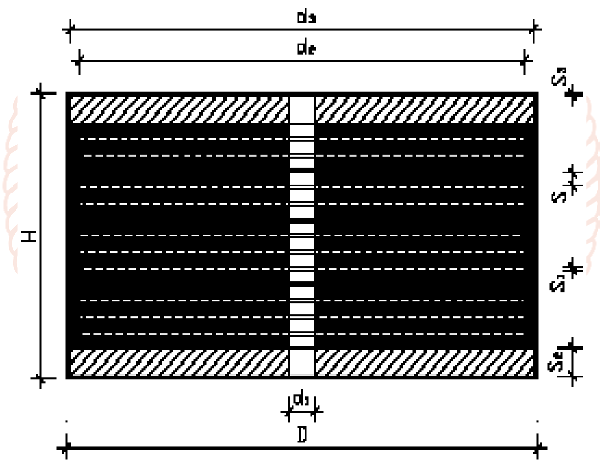


Figure7. Dimensions and physical/mechanical parameters of the seismic isolation laminated rubber-steel bearing

Together with the mentioned SILRSBs the seismic isolation system includes 11 bearings which can carry the vertical load and allow horizontal displacement, but they do not have horizontal stiff-ness (Fig. 8). We called them as bearings with no horizontal stiffness (BNHS)

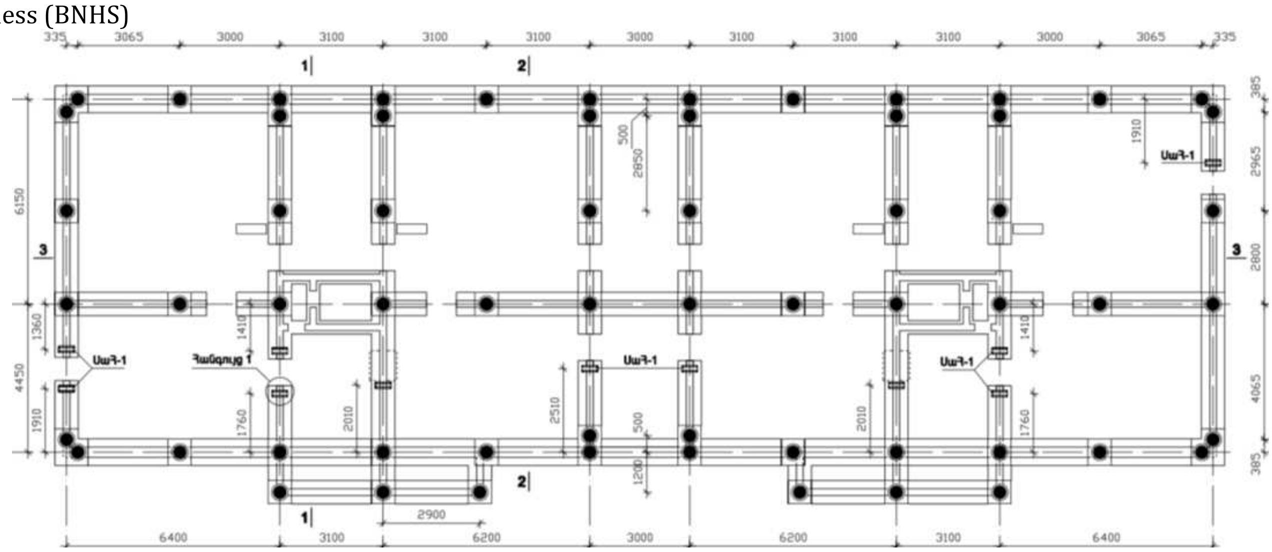


Figure8. Plan of location of SILRSBs and BNHS in the seismic isolation interface of 9-story large-panel apartment building

Analysis of the seismic isolation system and the whole structure was performed in accordance with the Armenian Seismic Code RABC II-6.02-2006 assuming the following parameters:

- Seismic zone 3 and soil category II;
- Soil conditions coefficient is K_0=1.0 and the site prevailing period of vibrations 0.3≤T0≤0.6 sec;
- Permissible damage coefficient for determining displacements – K_1=0.8;
- Permissible damage coefficient for analysis of seismic isolation system and reinforced concrete structures below it – K_{1z}=0.8;
- Permissible damage coefficient for analysis of the superstructure – K_1=0.4;
- Coefficient of seismicity – A=0.4.

Armenian Seismic Code requires that any base isolated building should be analyzed twice: first, by applying K_1=0.8 and the obtained results will serve as a basis to design the isolation system and structures below it, and then the second analysis should be carried out by applying K_1=0.4 and the derived results will serve as a basis to design the superstructure, to check the values of the inter-story drifts, as well as receiving the values of floors' accelerations, inertial forces, etc. It is also assumed that vibration period (T) of the base isolated building should be around 2 sec. According to the RABC II-6.02-2006 horizontal displacement of the base isolation system must be calculated by the formulas (6) and (32) of the Code:

$$D= K_1\times(T/2\pi)^2\times A\times K_0\times[\beta(T)/B(n)]\times K_{1z},$$

where dynamic coefficient β (T) depends on soil category and determined by the formulas given in the Code. In this case β (T) =0.95. B(n) depends on the damping of isolation system and for the value of 15% Code suggests this coefficient equal to 1.56. Thus:

$$D=0.8\times (2/6.28)^2\times400 \times (0.95/1.56)\times0.8=15.36 \text{ cm}.$$

Obtained value of horizontal displacement is smaller than the maximum permissible displacement suggested by the Standard HST 261-2007 (28 cm). This will provide high reliability of the designed seismic isolation system. According to the RABC II-6.02-2006 total seismic force on the top of iso-lation system (base of superstructure) must be calculated by the formula (35) of the Code:

$$S=K_{eff}\times D=50.22\times153.6=7714 \text{ kN}.$$

To calculate the vibration period of the base isolated 9-story large-panel building the masses of its floors were computed: the mass of the first floor is equal to 490 t, the masses of 2÷8 floors are equal to each other and equal to 570 t, and the mass of the 9th floor was calculated together with the mass of the attic floor and was equal to 710 t. Thus, the total mass M of the building is equal to 5760 t. According to the RABC II-6.02-2006 vibration period for the base isolated 9-story large-panel build-ing is determined by the formula (31) of the Code using the values of the total mass of this building (superstructure) and effective stiffness of isolation system:

$$T=2\pi\times\sqrt{Q}/(Keff\times g)=6.28\times\sqrt{5670}/50220=2.13 \text{ sec}.$$

This value differs from the initially assumed period of only 6.5%. Using the obtained values, it is possible to calculate the magnitude of acceleration just above the seismic isolation interface:

$$a=S/M=7714/5760=1.34 \text{ m/se}^{c2}.$$

From this it follows that due to application of base isolation acceleration at the level of the first floor of the superstructure decreases by about 3 times in comparison with the ground acceleration (4.0 m/sec2). This is very typical result showing the high effectiveness of base isolated structures.

5. STRUCTURAL CONCEPT OF RETROFITTING BY BASE ISOLATION OF THE 9-STORY LARGE-PANEL BUILDING

For design of isolation system along all exterior and interior load-bearing walls of the large-panel building the method of retrofitting by base isolation according to the above-mentioned Patent of the Republic of Armenia #579 was used. This base isolation method for existing buildings involves plac-ing of seismic isolators at the level of basement in the middle part along the height of its load-bearing walls solves the problem in the following manner (Fig. 9). According to the developed by the author innovative technology, openings with certain spacing are made in the basement load-bearing walls to accommodate lower reinforcement frames with seismic isolator sockets. It is very important that two adjacent openings in the walls are not made simultaneously. The order of making openings is given in design and shown in Figure 10. Binding reinforcement lower frames are passed along both sides of the bearing walls through already installed reinforcement frames of the lower pedestals. Then the latter are concreted after placing of seismic isolators in the lower sockets to form lower pedestals. In this particular case of the 9-story large-panel apartment building the dimensions of the openings are equal to 700×1100(h) mm, 1100×1100(h) mm or 1200×1100(h) mm and the spacing between the centers of the openings (or between the seismic isolators) varies and comprises 2800 mm, 2900 mm, 2965 mm, 3000 mm, 3065 mm, 3100 mm, and 4065 mm (see Fig. 8).

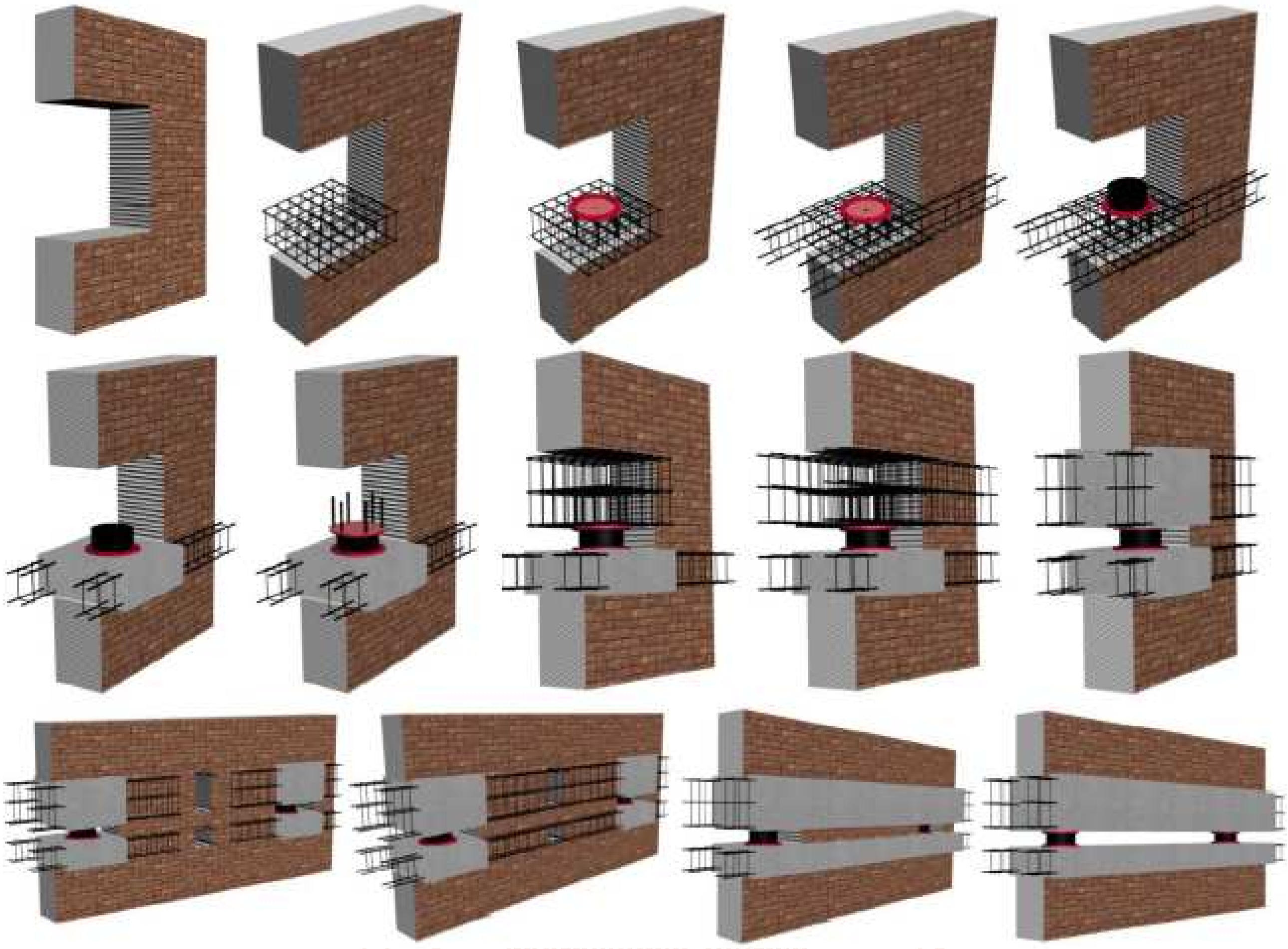


Figure9. 3D views of the seismic isolation system installation stages in the existing 9-story building with load-bearing walls

Upper sockets and upper reinforcement frames are placed on the isolators, passing along both sides of the bearing walls upper binding reinforcement frames through already installed upper rein-for cement frames of the upper pedestals. Then the latter are concreted to form the upper pedestals.

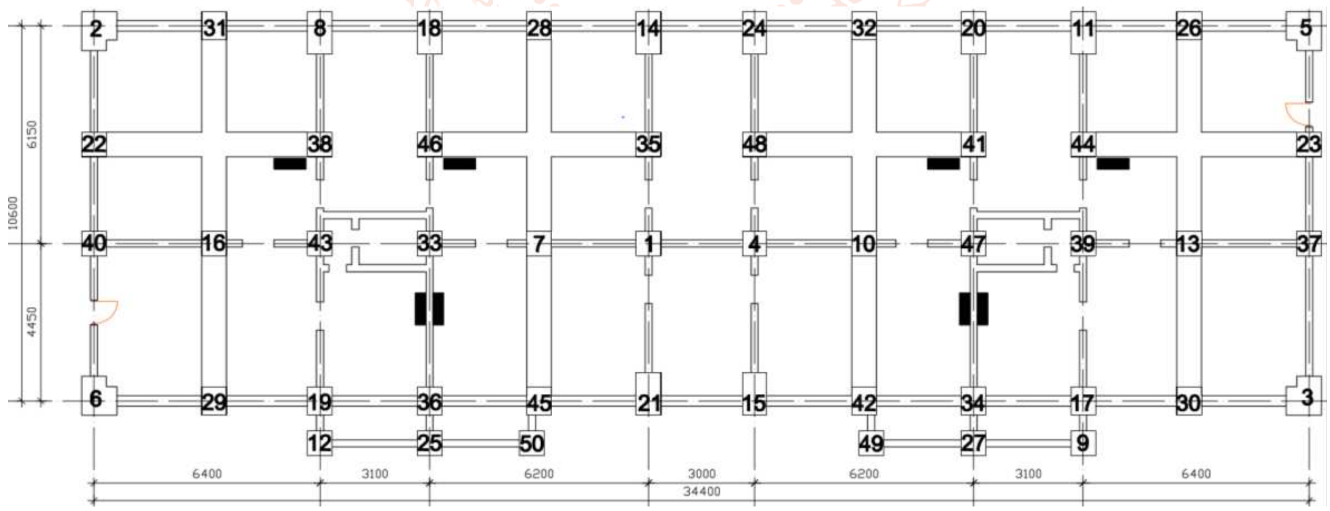


Figure10. The order of making openings in the load-bearing walls of the basement of 9-story large-panel existing apartment building for creation of seismic isolation system

When concreting the frames, ends of the binding reinforcement frames are left free beneath and above the seismic isolators. These free ends of reinforcing bars are tied to each other by the addition-al reinforcement frames of the adjacent lower and upper pedestals of seismic isolators. Then the parts between pedestals are concreted thus forming lower (see Fig. 8) and upper continuous beams along all load-bearing walls of the building's basement. The parts of the existing walls, which at this point remain between seismic isolators, must be then removed creating gaps and the building is hence sep-arated from its foundation, being linked to it only by the seismic isolators. Parts of walls existing be-tween seismic isolators should be cut off beginning from the middle of the building plan and continuing to its periphery. This will allow to avoid cracks at the top of the building considering the vertical deformations in SILRSBs during cutting of the walls. Figures 11 and 12 show vertical eleva-tions of the isolated building in transverse and in longitudinal directions, respectively.

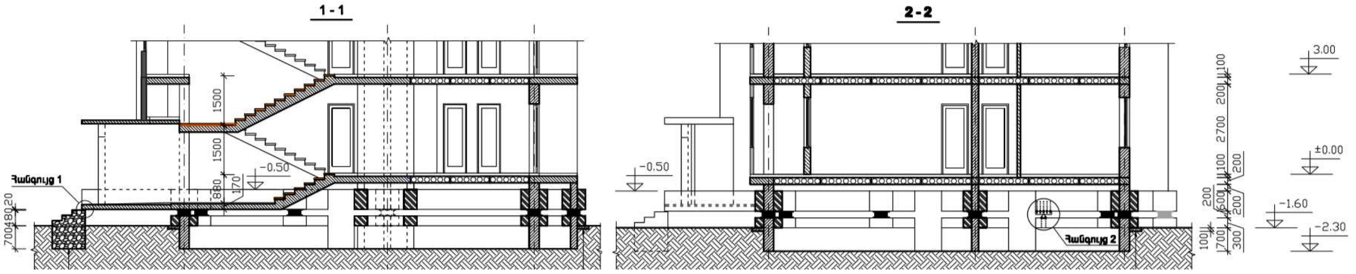


Figure11. Vertical elevations 1-1 and 2-2 of the base isolated 9-story large-panel building in transverse direction

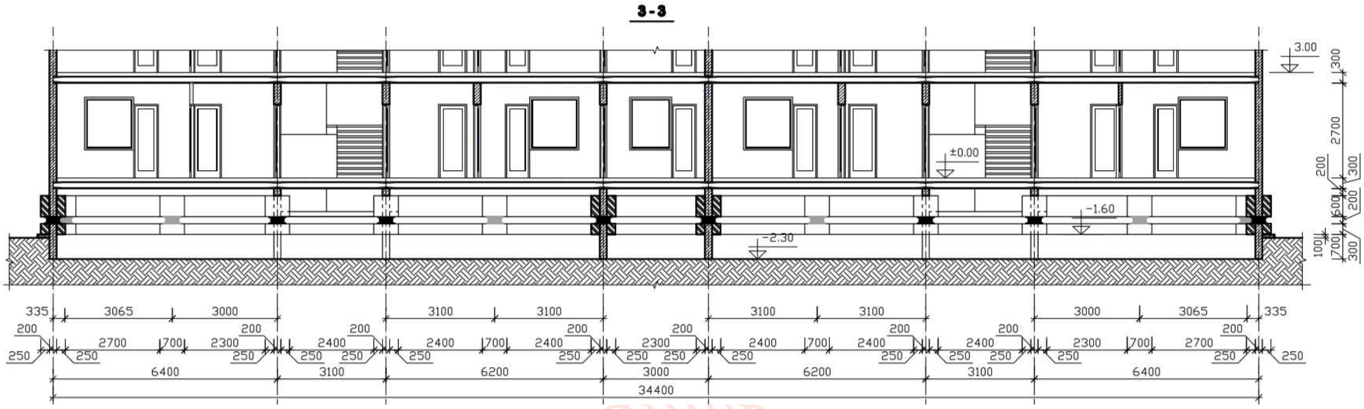


Figure12. Vertical elevation 3-3 of the base isolated 9-story large-panel building in longitudinal direction

From the Figures 11 and 12 one can see that the base isolation system consists of the lower con-tinuous beams with the height of 300 mm to be constructed below the isolation interface, the gap (200 mm) where the SILRSBs are located and the upper continuous beams with the height of 600 mm to be constructed above the isolation interface. Thus, base isolation system will be constructed between the marks -1.60 and -0.50. The width of the lower and upper continuous beams from the both sides of the existing load-bearing walls is the same and equal to 250 mm. To tie these beams to the walls and to each other design envisages drilling holes of diameter 20 mm in the existing walls and placing reinforcing bars of diameter 16 mm in these holes (for lower beams in one level and for upper beams in two levels) using polymer-cement mortar.

The bearings with no horizontal stiffness, which we marked as BNHS, are envisaged in the design mainly at the doorways (see Fig. 8). To install them the openings should be made with dimensions of 500×800(h) mm where the BNHS must be temporarily fixed. Then, by the analogy with the above described method of installation of SILRSBs, the lower reinforcement frames are installed, and the binding reinforcement frames of the lower continuous beams are connected to them. After concrete under the lower part of BNHS the similar operations should be made above the upper part of BNHS (Fig. 12).

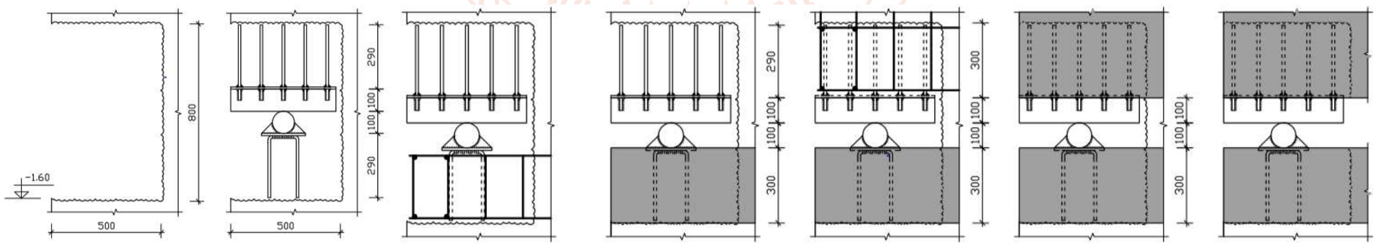


Figure12. Stages of installation of BNHS in seismic isolation system of the existing 9-story building with load-bearing walls

Special attention needs to be paid to the stairs at the entrances of the building. There are 20 mm gaps between the outside stairs and the entrance's slabs (see Fig 11, section 1-1). The main purpose of this gaps, as well as the 200 mm gap of isolation system is to ensure unhindered movement of the superstructure, as well as effective action of the seismic isolation system and accommodation of its horizontal displacement during any seismic impact.

Before the customer approached us with the request to develop the base isolation retrofitting de-sign for the existing 9-story large-panel apartment building using innovative technology, he had or-dered earlier to another company to develop a design for strengthening of the same building using one of the known conventional methods. Obviously, conventional strengthening requires eviction of tenants from the building. Construction cost calculated based on the design for conventional strengthening was about 1,000,000 USD and the time estimated for execution of conventional strengthening was about 2.5 years. After receiving and approving our base isolation retrofitting de-sign the cost and time estimation was accomplished by the customer and it appeared that the earlier received figures were significantly decreased to 185,000 USD and 6 months, respectively.

6. CONCLUSIONS

Several remarkable projects on retrofitting by base isolation of the existing buildings like apartment, school, hotel, and hospital buildings are briefly mentioned in the paper to demonstrate the retrofitting experience accumulated in Armenia.

Base isolation retrofitting design for the existing 9-story large-panel apartment building with some local damages in the load-bearing walls constructed in the city of Stepanakert in 1988 is presented.

As a tool for retrofitting the base isolation technology is used in combination with the 80 mm thick R/C jackets for strengthening of the damaged parts of existing load-bearing walls within the limits of the first floor of superstructure.

The innovative structural concept of retrofitting by base isolation is described in detail and some characteristic peculiarities of retrofitting are mentioned.

Total 62 SILRSBs were used in seismic isolation system. These are manufactured in Armenia ac-cording to the Republic of Armenia Standard HST 261-2007. Their dimensions and physi-cal/mechanical parameters are given. Together with SILRSBs 11 bearings with no horizontal stiffness named BNHS are used.

Some results of analysis of the base isolated 9-story large-panel apartment building by the Arme-nian Seismic Code are given showing that the structural elements below and above the seismic isola-tion plane will work only in the elastic phase. Total horizontal displacement comprises 15.36 cm, period of vibration – 2.13 sec and acceleration at the level above the seismic isolation interface – 1.34 m/sec2. An input acceleration of 0.4g at the foundation bed gets damped about 3.0 times in the superstructure.

Obtained results prove the high effectiveness of the created base isolation system and reliability of the building, which will suffer no damage under seismic impacts. Under the impact of the design level earthquake the inter-story drifts remain smaller than the permissible values.

Cost estimations and comparison of the construction cost of retrofitting by the suggested design with the cost of conventional strengthening have shown that significant cost savings (up to 5 times) could be achieved due to implementation of the created base isolation technology.

The time needed for performing of the construction works by the given design could be shortened for about 5 times in comparison with the time for conventional strengthening. Implementation of the elaborated design will not require interrupting the use of the 9-story apartment building.

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