



International Journal of Recent Development in Engineering and Technology  
Website: [www.ijrdet.com](http://www.ijrdet.com) (ISSN 2347-6435 (Online) Volume 15, Issue 04, April 2026)

# Innovative Base and Roof Isolation Technologies Created in Armenia for Earthquake Retrofitting and Protection of Existing Buildings in This and Other Countries

Mikayel G. Melkumyan

*President, Armenian Association for Earthquake Engineering, CEO, "Melkumyan Seismic Technologies" LLC, Professor, Doctor of Sciences (Engineering), Academician*

**Abstract**— Earthquakes are catastrophic events that cause huge economic losses due to the vulnerability of the existing building stock. However, collapses of vulnerable buildings can be avoided if preventive measures, such as enhancement of their earthquake resistance, are implemented on time. This paper will allow the reader to become acquainted with a number of unique, modern and cost-effective seismic isolation strategies implemented with high efficiency in existing buildings, making them earthquake proof. These strategies can be easily realized, in very short periods of time, and without interruption of the use of the buildings. An important aspect here is that seismic isolation strategies are demonstrated on real examples of existing buildings with different structural systems, such as reinforced concrete frame buildings with shear walls and stone buildings with load-bearing walls. The cost-effectiveness of the suggested strategies is further proved by comparative analyses carried out for buildings both with and without seismic isolation systems. Protection of existing buildings from earthquake damage is getting more and more importance with every recent seismic event across the world. In this regard, seismic isolation of structures is becoming a more common method of providing such protection. Particularly, roof isolation techniques forming different types of dampers for earthquake protection and base isolation technologies for seismic retrofitting, both developed by the author of this paper, have received a wide application in Armenia. Also, the developed base isolation retrofitting technologies have already been implemented in Russia and Azerbaijan. A retrofitting design was accomplished for implementation in Romania and approved by the corresponding governmental body of this country. Paper also describes another retrofitting design developed by the author for Kazakhstan. It is worth noting that the mentioned seismic (roof and base) isolation strategies have great potential for rehabilitation of existing ordinary civil structures such as apartment blocks and critical facilities such as schools and hospitals.

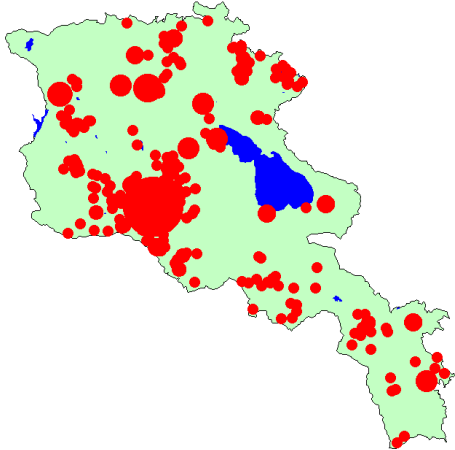
## I. INTRODUCTION

Armenia is located in the high seismic risk zone. In 1988 Spitak Earthquake of magnitude 6.9 the country lost 52,000 people and about 40% of its territory experienced severe damages and destructions [1, 2].

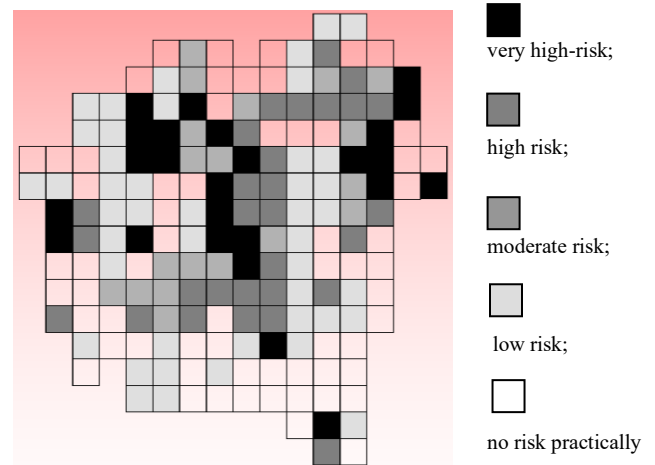
Figure 1 presents the map of distribution pattern for seismic risk in Armenia from which it is obvious that the highest risk is concentrated in the city of Yerevan – the capital of the country [3]. Before Soviet period there were mainly non-engineered one-three story structures constructed in Yerevan (Fig. 2). During the Soviet period a Seismic Code for the whole territory of USSR was developed. According to this Code the ground acceleration (seismic hazard) for Armenia was accepted equal to 0.1g acceleration. This level of hazard was as a rule taken into account during design and construction of various residential buildings, schools, hospitals, industrial facilities and other structures in Armenia. In rare cases buildings were designed and constructed for the level of ground acceleration equal to 0.2g. Currently new edition of the Seismic Code RABC-20.04 is in force in Armenia. According to that Code there are three levels of seismic hazard identified for different regions of the country with ground accelerations equal to 0.3g, 0.4g and 0.5g [4].

This means that seismic hazard in Armenia is very high and most of the existing buildings constructed in the country during about 100 years (70 years of Soviet period and about 30 years since Armenia gets its independence) will not be able to resist earthquakes of such a high intensity. Our investigations have shown that if the design level earthquake struck the city of Yerevan, then 80% of the existing building will be destroyed and 300,000 people will die [5].

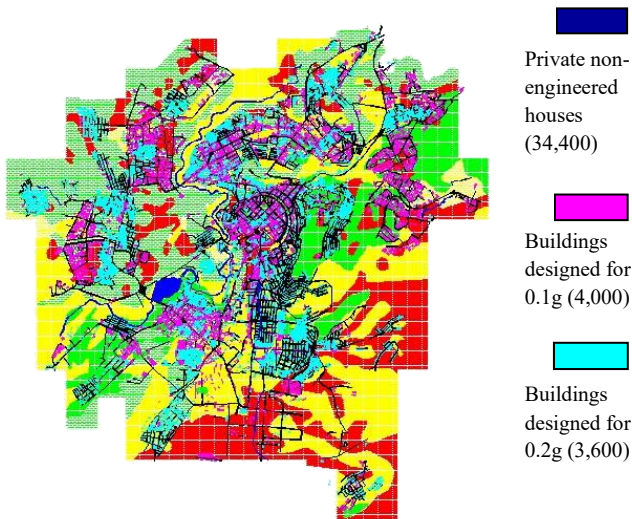
The analysis of data obtained for Yerevan has shown that about 26 km<sup>2</sup> of the zones of high seismic risk represent city area, that comprises 15% of the total area. About 5,389 buildings have been constructed here. Together with that 44 km<sup>2</sup> (24%) of the city area is occupied by 34,143 low-storied stone private non-engineered houses and also should be considered as a high seismic risk area. Remaining 2,185 buildings have a moderate risk of destruction (Fig. 3).



**Figure 1. Distribution pattern for seismic risk in Armenia**



**Figure 3. Map of distribution of seismic risk by sectors with one square kilometer area on the territory of Yerevan City**



**Figure 2. Existing buildings and structures in the Yerevan City and the design level of their earthquake resistance**

New technologies, using seismic isolation systems for the upgrading the earthquake resistance of the existing buildings and for construction of new buildings developed by the author of this paper have attracted attention of the international professional community. As it is mentioned in [6] "...the number of new applications of innovative anti-seismic techniques, especially seismic isolation, is particularly large in Japan, P.R. China and Armenia...". "Some other countries are beginning to follow the excellent example of Armenia (...where seismic isolators are locally manufactured also for foreign markets...)". "...an existing bank building at Irkutsk-City in Russia, retrofitted by applying the technology invented by Prof. Melkumyan in Armenia...". In [7] Armenia is mentioned among the few of developing countries where projects that apply low-cost base isolation systems for public housing have been completed. Also, in [8] it is stated that "In Armenia base isolation has been used to convert weak and vulnerable buildings to earthquake resistant structures". Reference is made to "... an existing five-story apartment building in Vanadzor, Armenia ... located in a highly active seismic zone.

It was retrofitted with seismic isolators without interruption to building occupancy”. Finally, in [9] it is stated that “In the developing countries, base isolation technique has rarely been used due to non-existence of domestic production of bearings and high cost of the bearings produced in the developed countries. In some of these countries, as is Indonesia, Iran and Algeria, there have been some attempts to popularize this technique through development of low-cost bearings and their installation in demonstration structures, but no attempt for production has been made and hence there hasn’t been any mass application of such bearings. A greater success in application of base isolation (with isolation of a large number of buildings) was achieved in Armenia where, in addition to placement of isolators in buildings, their production was also adopted”.

The above given maps of seismic risk of destructions of buildings and structures in Armenia and the developed method for quantitative assessment of seismic resistance of existing buildings [10] bring to conclusion that their seismic resistance is not provided and that seismic strengthening and upgrading of existing buildings is the crucial problem for the country. For countries where the seismic risk is not only very high but it also increased due to areas of urbanization, the task that mostly lacks solutions is the absence of state policy with respect to reduction of seismic risk. The strategy for the twenty-first century to reduce the seismic risk should be based upon prioritizing preparedness over the recovery.

The present transition period of the economic development in Armenia confirms that non-conventional approaches, allowing the retrofitting of existing buildings without interruption of their functioning, are more preferable. Within a very short period of time since 1995, new unique and cost-effective non-conventional seismic protection methods based on the application of seismic isolation technologies were developed and introduced by the author into construction practice in and outside of Armenia. The description of the structural concepts, which can provide the significant seismic safety for the existing vulnerable buildings, is given below.

## II. APPLICATION OF INNOVATIVE BASE AND ROOF ISOLATION TECHNOLOGIES FOR RETROFITTING AND PROTECTION OF EXISTING BUILDINGS IN ARMENIA

The retrofitting technique using base isolation has great potential for rehabilitation of ordinary civil structures such as apartment blocks.

The first retrofit of 1A-450 series stone apartment building of standard design has been carried out in Armenia in 1996 [11]. The developed structural concept aims at retrofitting an existing building with seismic isolators using a simple working technology [12]. This is a unique and pioneering seismic isolation project implemented for an existing 5-story stone building (Fig. 4) without interruption of its use.

The idea is to furnish this building with seismic isolation in the foundation by gradually cutting the isolators into the walls at the level of foundation upper edge by means of a two-stage system of R/C beams. Base isolation method for existing buildings with bearing walls that involves placing seismic isolators at the level of the foundation or basement solves the problem as shown in Figure 5 according to the innovative technology developed by the author of this paper (Patent of the Republic of Armenia #579).

a.



b.

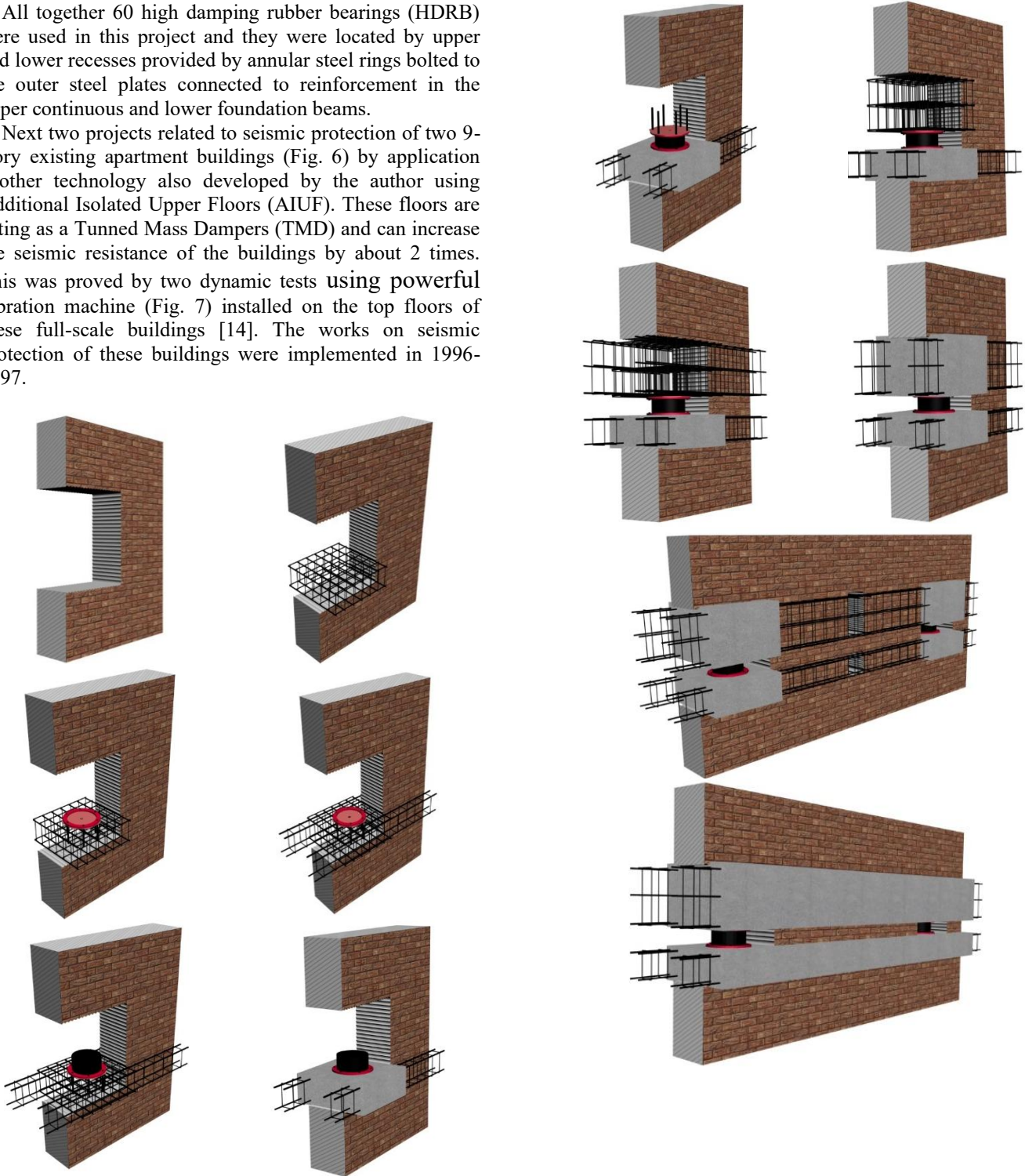


**Figure 4. General view of the existing 5-story stone apartment building retrofitted by base isolation (a) and fragments of its isolation system (b)**

The above-described operation was accomplished without re-settlement of the dwellers [13]. There has been no similar precedent in the world practice of retrofitting apartment buildings.

All together 60 high damping rubber bearings (HDRB) were used in this project and they were located by upper and lower recesses provided by annular steel rings bolted to the outer steel plates connected to reinforcement in the upper continuous and lower foundation beams.

Next two projects related to seismic protection of two 9-story existing apartment buildings (Fig. 6) by application another technology also developed by the author using Additional Isolated Upper Floors (AIUF). These floors are acting as a Tuned Mass Dampers (TMD) and can increase the seismic resistance of the buildings by about 2 times. This was proved by two dynamic tests using powerful vibration machine (Fig. 7) installed on the top floors of these full-scale buildings [14]. The works on seismic protection of these buildings were implemented in 1996-1997.



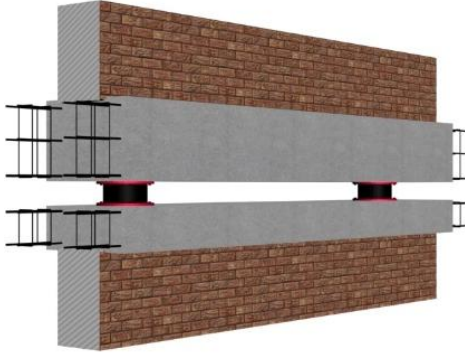


Figure 5. 3D views of the seismic isolation system installation stages in the existing building with stone bearing walls

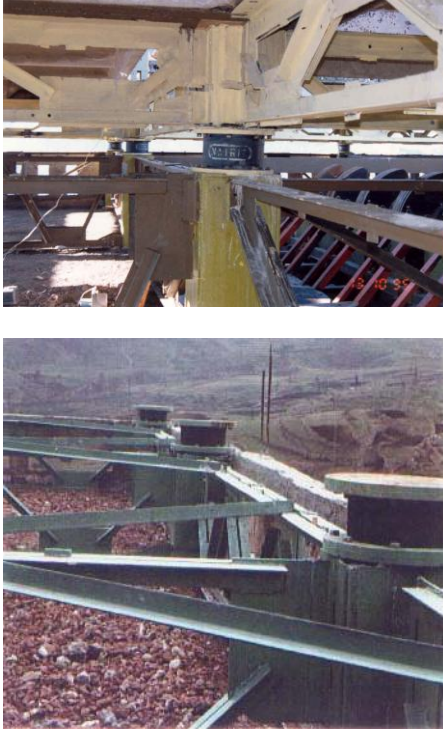


Figure 6. General views of the two existing R/C frame 9-story apartment buildings protected by AIUF in Vanadzor



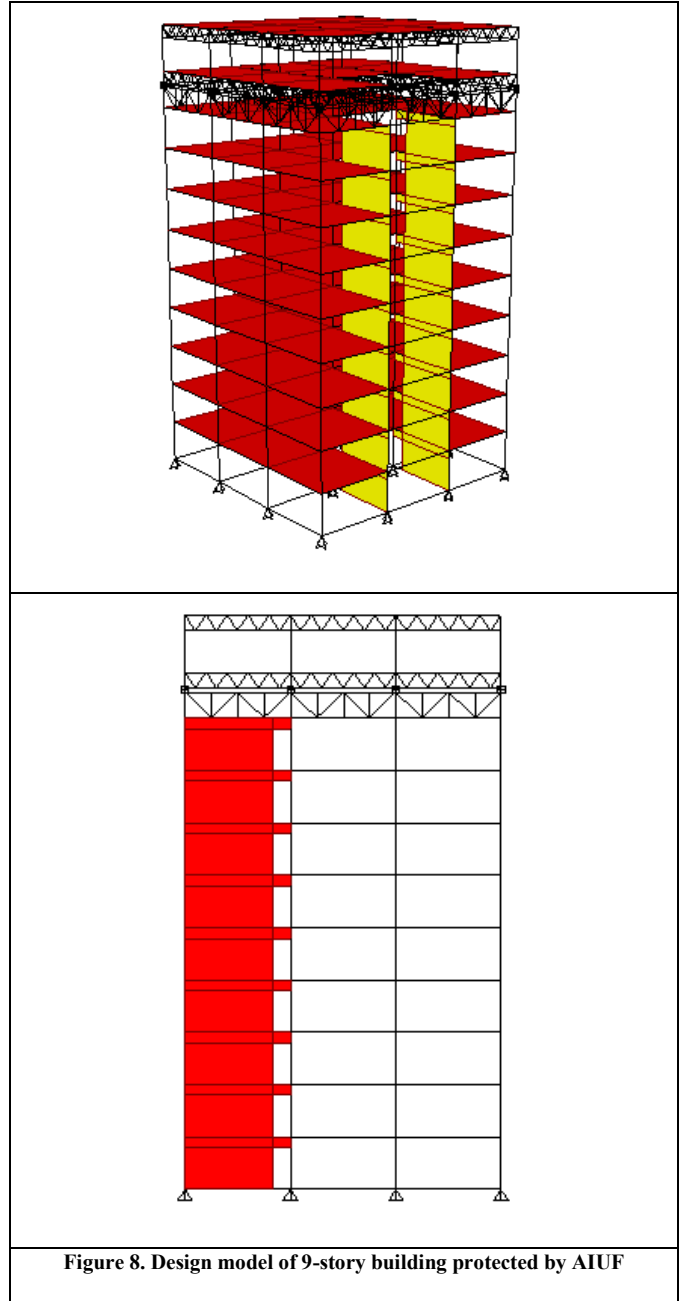
AIUF is actually a pendulum constructed as an additional floor on the top of the building. The mass of the pendulum is the mass of the whole additional floor, and the spring of the pendulum is represented by laminated rubber bearings (LRBs) as shown in Figure 7.





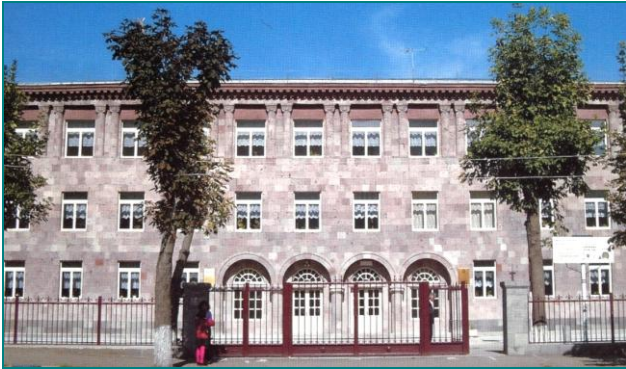
**Figure 7. General view of the vibration machine ready for testing of the building before the AIUF erection and steel rigid trusses constructed on the top of 9-story building and at the bottom of AIUF providing reliable connection of AIUF with the building through LRBs**

The design model of the building (Fig. 8) was created for non-linear seismic response analyses carried out by SAP200 program for the building with and without AIUF using degrading tri-linear model for columns and bilinear model for rubber bearings, as well as the “Melkumyan Hysteresis Model” for shear walls. The software used in the analyses of both buildings incorporated the developed rules of hysteresis model formation [15].



**Figure 8. Design model of 9-story building protected by AIUF**

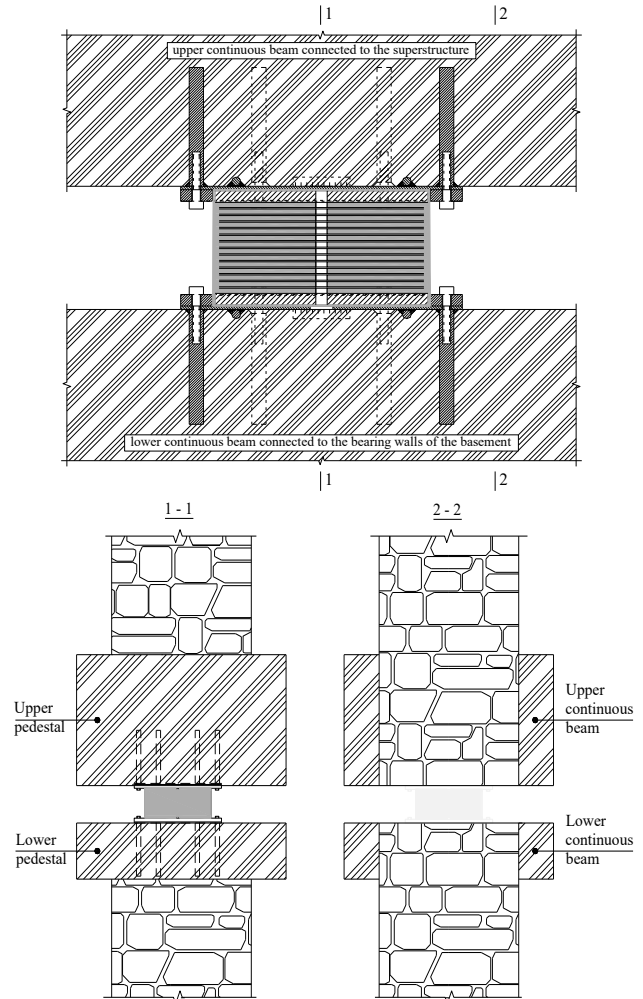
The other retrofitting project in Armenia was initiated for the existing 3-story over 60 years old school building with thick bearing walls made of tuff stones (Fig. 9). It was implemented in 2003. Actually, this building is a non-engineered structure with wooden floors.



**Figure 9. General view of the retrofitted by base isolation 3-story 60 years old school building that have historical and architectural value**

Seismic isolation interface for the school building was created in the middle part along the height of the school basement [16]. This approach implied some differences in retrofitting of the school building in comparison with that of the apartment building of series 1A-450 described above, where the isolation interface was created at the foundation's upper edge level. 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 before cutting the building and passing its weight through the seismic isolators to the bearing walls of the basement (Fig. 10). 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 [17].

Sometimes it is necessary to install temporary supports inside the opening in the plane of existing walls. In this case the supports should be made of steel, as after casting the concrete they will remain in the lower and upper pedestals. Later the parts of such supports between pedestals should be cut away.



**Figure 10. Location of medium damping rubber bearings (MDRBs) by upper and lower recesses provided by annular steel rings bolted to the anchors connected to the upper and lower continuous beams in the school building**

Sometimes it is necessary to install temporary supports inside the opening in the plane of existing walls. In this case the supports should be made of steel, as after casting the concrete they will remain in the lower and upper pedestals. Later the parts of such supports between pedestals should be cut away.

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 openings had to be made just beneath the columns and the arches. The arches had to be temporarily supported before starting to make the openings (Fig. 11a). Then the opening under the column should have been gradually made. With this purpose, at the beginning the part of the foundation only under one quarter of the column section had to be taken out (Fig. 11b). This allowed installing a mechanical jack under the column. After that, the other part of foundation under another quarter of the column section could be demolished.

When this work has been finished, a temporary support under the one half of the column section should be installed and the mechanical jack could be taken out (Fig. 12a). Then again, the foundation under the other half of the column section should be gradually demolished and this part of the column section also should be temporarily supported. In cases like this the reinforcement frames of the lower and upper pedestals cannot be prepared in advance and should be made in situ (Fig. 12b).

The subsequent operations are similar to those described above. However, 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 appearance of the building.

a.



b.



**Figure 11. Temporary support under the existing arches (a) and the carved-out part of the foundation under the one quarter of the column section (b)**

a.



b.

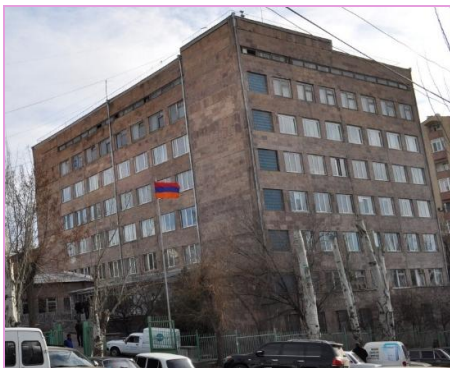


**Figure 12. Temporary support under the one half of the existing column section (a), and the temporarily supported existing column and the wall behind it with the reinforcement frame of the upper pedestal installed (b)**

It is also worth noting two other projects on retrofitting by base isolation of the 8-story Hematology Center building with R/C frames and shear walls, as well as 4-story industrial building with R/C bearing frames. The latter was simultaneously reconstructed into a 6-story hotel building. Existing Hematology Center building was constructed over 50 years ago (Fig. 13). The project on seismic isolation and reconstruction of this building was implemented in 2016. This project is based on the new seismic isolation method, the structural concept of which has also been developed by the author. During the development of the design principally new structural concept was proposed for seismic isolation of the building's R/C bearing frames and shear walls [18, 19].

The seismic isolation system is constructed at the level of the basement floor. The seismic isolators are placed under all columns of the superstructure, grouped in two or three pieces. They are placed also within the limits of the shear walls grouped in three pieces. The given structural solution, developed for cutting the columns and shear walls and placing the seismic isolators, is proposed for the first time ever and it is performed in 11 stages for columns and 12 stages for shear walls.

a.



b.



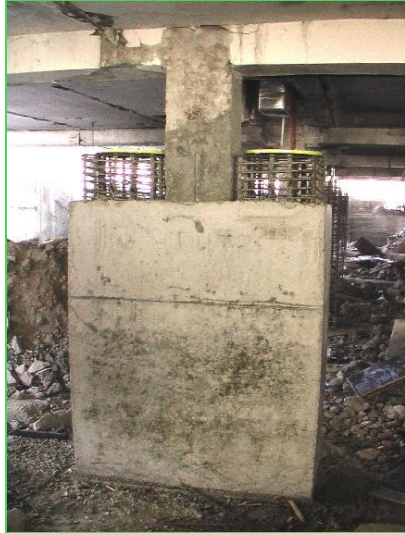
**Figure 13. View of the existing 8-story R/C Hematology Center Hospital Building (HCHB) before (a) and after retrofitting by base isolation (b) with simultaneous renovation of the whole building**

At the initial stage, the additional reinforcement around existing columns of the basement is installed and anchored both to the existing spread footings and newly designed beams that connect the spread footings to each other (Fig. 14). The mentioned additional parts increase cross-sections of the columns and ensure their required stiffness. Only after placing the reinforcement cages for these parts, concrete can be cast to make the designed mutually perpendicular strap beams that will connect the existing spread footings. Then the concrete must be casted on the parts containing additional reinforcement around the existing columns of the basement (Fig. 15). It is necessary to follow that the lower sockets of seismic isolators are in strictly horizontal position.

All operations related to cutting of the existing columns till the stage when cutting starts can be performed simultaneously for all columns. However, before starting the cutting operation the temporary steel supports should also be installed under the joint of the column and the beams in order to provide more reliability to the whole cutting process. The latter will start by removing of a part of the concrete of existing column (Fig. 16).



**Figure 14. Newly designed mutually perpendicular strap beams connect the existing spread footings of the basement columns and the reinforcement cages of newly designed columns are anchored in them**



**Figure 15.** Concrete is casted on the parts containing additional reinforcement around the existing column of the basement

When concrete is removed some buckling of the existing column's vertical reinforcing bars takes place (Fig. 17) as the seismic isolators will get vertical deformations under the influence of the dead and live loads of superstructure. It is necessary to measure on site the magnitude of the vertical deformations and to compare them with the experimental values received during the laboratory tests of isolators. Everything must be under strict control. Then process on cutting of the reinforcing bars of existing column starts (Fig. 18).



**Figure 16.** Concrete is casted on the parts above the upper sockets of isolators to support the superstructure and the process of cutting of the existing column starts after the concrete above the isolators gets its design strength

When all reinforcing bars of the existing column are cut then it is possible to install here hooks with the spacing of not more than 50 mm and also the lower socket of the middle seismic isolator (Fig. 19 and 20). The final views of the seismic isolators installed under the existing column and within the limits of the existing shear wall (Fig. 21 and 22).



**Figure 17.** Buckling of the existing column's vertical reinforcing bars after removing of a part of the column's concrete



**Figure 18. The moment of cutting of the vertical reinforcing bars of existing column**

The project on retrofitting by base isolation of the existing 4-story industrial building with R/C bearing frames and its simultaneous reconstruction into a 6-story hotel building was implemented in 2017 (Fig. 23). Project is based on the seismic isolation method, the structural concept of which has been developed by the author. During the development of the design principally new structural approaches have been proposed for seismic isolation of the existing building's R/C bearing frame [20]. This building has a bow-shaped plan, thirteen spans in longitudinal direction and three spans in transverse direction. The heights of floors in this existing building are different and given by the floor marks in Figure 24. It can be noticed from this drawing that the height from the upper edge of the existing foundation to the ceiling of the first floor is equal to 7.02 m. That is why it was suggested by the author to create within this space two floors and consider one of them as a basement and the other as a ground floor.



**Figure 19. Installation of the hooks and the lower socket under the middle seismic isolator after cutting of the vertical reinforcing bars of existing column**



**Figure 20. Concrete is casted under the lower socket of the middle seismic isolator and the upper socket and hooks are installed above it which are fixed with the spacing of 50 mm**

The existing columns, designed in accordance with the former Soviet Union building code, have the spread footings. However, according to the current Armenian Building Code the spread footings must be connected to each other. This was done by newly designed connecting foundation beams. Exactly in these beams the reinforcing bars of the newly designed columns are anchored (Fig. 25a and Fig. 25c).



**Figure 21.** Concrete is casted above the upper socket of the middle seismic isolator and all the temporary supports are removed



**Figure 22.** Fragment of the already cut shear wall and the adjacent column with the installed seismic isolators

The process on cutting the existing columns and placing the seismic isolators starts with removing the concrete cover layer of the existing columns as shown in Figure 25b. Then the reinforcement cages of the newly designed columns are installed around the existing columns and anchored in the connecting foundation beams. The next step is placing of the isolators' lower sockets (Fig. 25c) on top of the new columns' reinforcement cages. As concrete is casted on the parts of new columns around the existing basement columns (Fig. 25d), it is necessary to follow that the lower sockets of seismic isolators are in strictly horizontal position. Then the HDRBs can be placed in the lower sockets together with the upper sockets on them (Fig. 26a).

After that the reinforcement cages of the upper pedestals must be placed on isolators' upper sockets. Together with this, the process of reinforcing of the upper beams and slabs is going on (Fig. 26b). Then the concrete of all the structural elements above the isolation interface is casted as shown in Figure 26c. At the final stage, the parts of the existing columns between the newly constructed columns and the upper pedestals are cut (Fig. 26c) and the superstructure is isolated (Fig. 26d).

a.

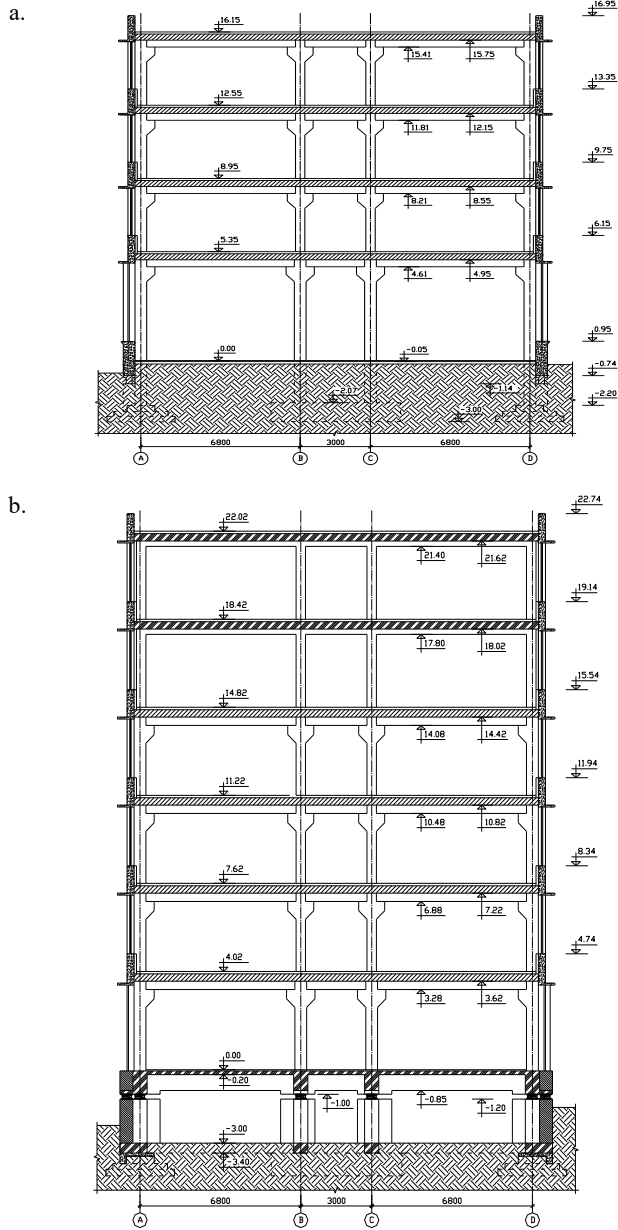


b.

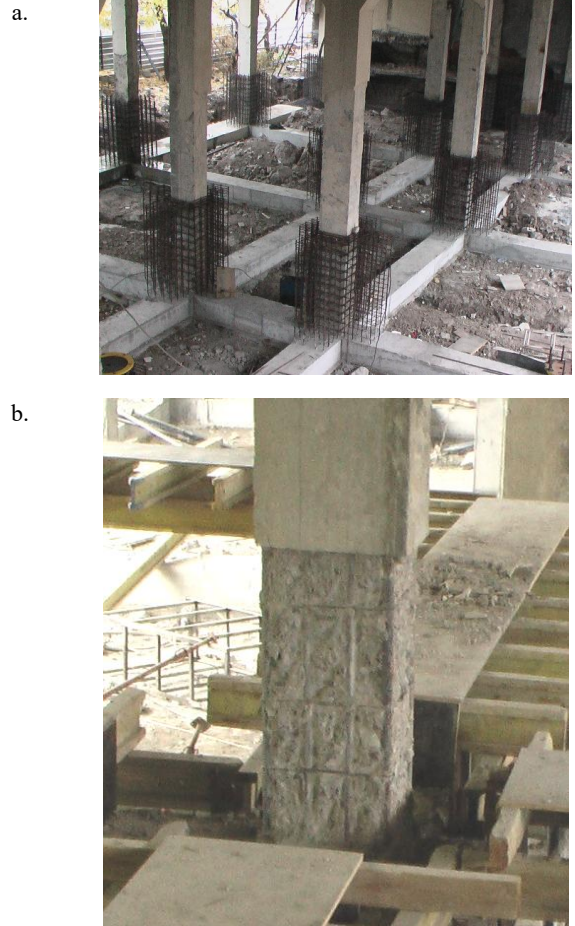


**Figure 23.** View of the existing 4-story industrial R/C frame building before (a) and after retrofitting by base isolation (b) with simultaneous renovation of the whole building

All the operations related to cutting the existing columns till the stage shown in Figure 26c can be performed simultaneously. However, the cutting of columns must start from the middle part of the building plan and gradually continue to the right and left edges of the building. Placing all isolators of the seismic isolation system and cutting all columns brings in separating of the building's superstructure from its base. Consequently, the mass of the building and horizontal seismic loads are passed to vertical structures and footings of the building only through the seismic isolators. Thus, the new columns of different shape are designed to be constructed around the existing columns and the HDRBs are placed on top of them grouped in two, three or four seismic isolators to carry the weight of superstructure.



**Figure 24. Vertical section of the existing 4-story industrial R/C frame building (a) and new vertical section of this building converted into 6-story (plus a basement) hotel building after retrofitting by base isolation (b)**



**Figure 25. Views of the connecting foundation beams with the anchored in them reinforcement cages of newly designed columns (a); existing column with the removed cover layer (b)**

The different cross-sections of the new columns were designed based on the results of calculations to ensure their required horizontal stiffness. Also dimensions of the cross-sections must be large enough in order to accommodate the isolators' lower sockets and to provide a possibility for easy concreting of the new columns around the existing columns. The cross-sections of the upper pedestals envisaged above the isolation interface are exactly the same as for below located columns.



**Figure 25. (Continued) eismic isolators' lower sockets installed before casting the columns' concrete (c); final view of the new columns constructed around the existing columns (d)**



**Figure 26. Views of the reinforcement cages of the newly designed upper pedestals and upper beams (a, b); after concrete of upper pedestals and beams above the isolation interface is casted the process of cutting of the reinforcement bars of existing columns is going on (c); final view of the joint where the existing column is cut, and the superstructure is isolated (d)**

III. APPLICATION OF DEVELOPED BY THE AUTHOR  
 INNOVATIVE BASE ISOLATION TECHNOLOGIES FOR  
 RETROFITTING OF EXISTING BUILDINGS OUTSIDE ARMENIA

*A. Implementation of base isolation for retrofitting of an existing 4-story stone bank building in Russia*

The first project on retrofitting of the existing building outside Armenia using the author's base isolation technology was implemented in Russia in the city of Irkutsk. The existing bank building in this city was built in 1934. The building did not meet the current Russian Seismic Building Code (SBC) requirements in respect of its dimensional and structural layout. Seismic strengthening of the building was needed [21]. The retrofit targets included: ensuring earthquake resistance of the building to satisfy SBC requirements in effect, re-planning premises and adding one or two stories to the superstructure as to convert the whole structure into a four-storied building (Fig. 27).

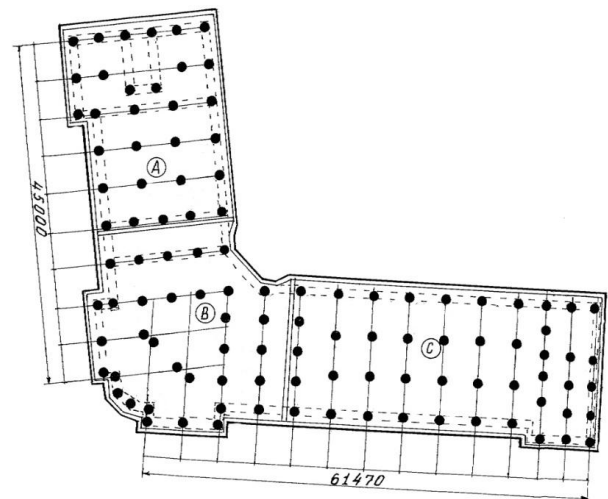


**Figure 27. View of the bank building retrofitted by base isolation in the city of Irkutsk**

The existing (prior to retrofit) 17-19 m wide building had a broken-line configuration in plan. The building consists of three blocks: Western (A), Central (B) and Northern (C). The Western and the Northern parts of the building are 45 and 62 m long, respectively, and are situated at an angle of approximately 100° to each other. On the main façade the blocks are connected by about 9 meters long wall of the Central part, which is also broken line in plan. The number of stories of the building is variable (3 - 4 stories) plus the basement floor. The Central part does not have a basement floor.

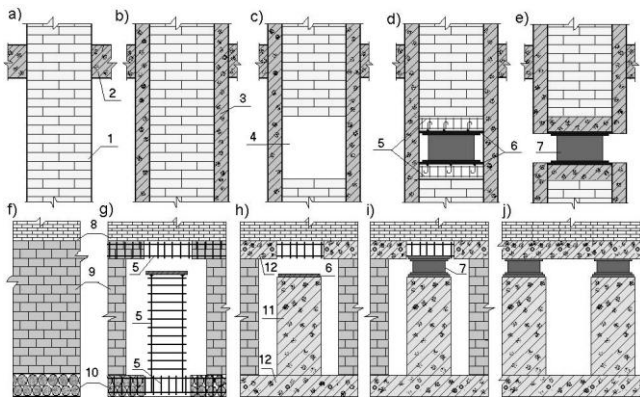
The height of the above-ground floors is from 3.5 to 5.2 m, the basement floor height is 3 m. The external brick walls, internal transverse walls, and two longitudinal rows of brick columns in the Western and the Northern blocks comprise the load-bearing structures of the building. The distance between the transverse bearing walls varies from 5 to 35 m. The ceiling above the basement floor is of monolithic reinforced concrete rib type. Given that the building is an architectural and historical monument, as well as considering its value, retrofit time, and the possibility to eliminate seismic load in above-ground part of the building, a decision was made to use seismic isolation in the building's foundations. According to the reconstruction project the seismic isolation bearings were to be arranged under all walls, piles, and columns at the level of the basement floor. The foundations must be accordingly strengthened with consideration of the values of base shear forces.

According to the author's technology a decision was made to install seismic lead rubber bearings at the mid-level of the basement floor to provide effective seismic isolation of the existing walls and building's columns. The total number of seismic bearings (produced by Vibro-Tech Industrial and Development Co. Ltd. Shantou, China) to be installed was 108. The plan of location of bearings is shown in Figure 28. Every bearing was designed for 2500 kN vertical load. All bearings had the same dimensions: diameter – 510 mm, height – 216 mm.



**Figure 28. Plan of the rubber bearings' location at the basement floor level of the bank building in the city of Irkutsk**

The retrofitting method by base isolation described above in Section 2 was used which, as it is shown in Figure 29, was implemented in the following sequence for brick and reinforced concrete piles: pile surface is prepared for concreting (Fig. 29a); timbering and reinforcement cage are installed, then concrete is poured into timbering. Reinforced concrete casing thickness is 100 mm (Fig. 29b). After concrete reaches design strength, the middle part of piles is cut through to make openings. The vertical load of the building is transferred at this time to the concrete casings (Fig. 29c). Then lower reinforcement frame is installed, and the part below isolator is concreted. The seismic bearing is placed. Upper reinforcement frame is installed, and the part above the bearing is concreted (Fig. 29d). After all the bearings are mounted in their places, the concrete casing is cut in proper areas, and the vertical load is transferred on seismic bearings (Fig. 29e).



**Figure 29. Stages of the isolator's installation procedure**

**1 - brick masonry column; 2 - reinforced concrete beam; 3 - external reinforced concrete cage; 4 - cut-through portion of column; 5 - steel bar; 6 - steel plate; 7 - seismic isolator; 8 - brick masonry wall of the first story; 9 - block masonry wall of the basement story; 10 - stone and concrete strip foundation; 11 - reinforced concrete pile; 12 - upper and lower portion of beams**

The sequence on installation of bearings in exterior stone block walls is the following. Earth is removed from the external and internal sides of the basement floor wall and upper part of the continuous footing (Fig. 29f). The timbering for reinforced concrete beams is installed on the external and internal side at the level of foundation top and basement floor wall bottom. Reinforcement frames and embedded parts for beam bracing are installed after concrete reaches its design strength. The upper beams are concreted in a way that leaves open recesses in the areas where seismic bearings are to be located (Fig. 29g). The lower beams are concreted simultaneously with the piles for seismic bearings (Fig. 29h).

The bearings are installed on reinforced concrete piles. Embedded parts are placed on the bearing, and the upper recess above the bearing is concreted (Fig. 29i). Finally, the remaining parts of the basement floor wall between the isolators are dismantled, and the vertical load from the walls is transferred on the lead rubber bearings (Fig. 29j).

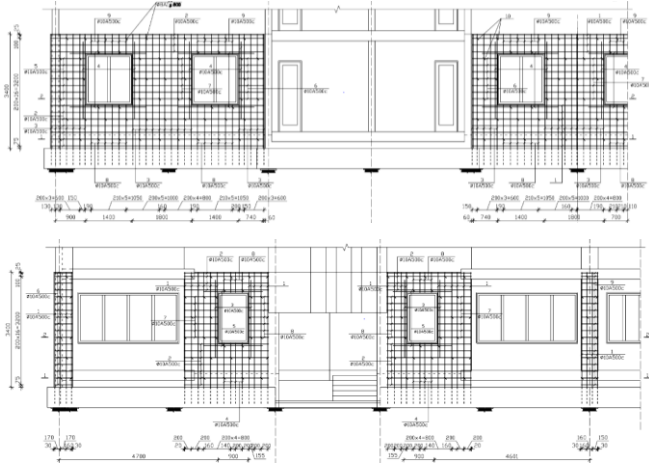
*B. Implementation of base isolation for retrofitting of an existing 9-story apartment large-panel building in Azerbaijan*

The next retrofitting design of an existing damaged 9-story apartment large-panel building constructed in 1988 was implemented in Azerbaijan in 2020 using technology invented by the author (Fig. 30). This is the first application of base isolation to a building with large panel bearing system. Structural concept of retrofitting was developed for this building based on the already acquired experience. Special attention in the design is given to strengthening of the first floor's damaged large panel walls by R/C jackets (Fig. 31 and 32). Base isolation interface for this building is designed at the level of basement floor [22].

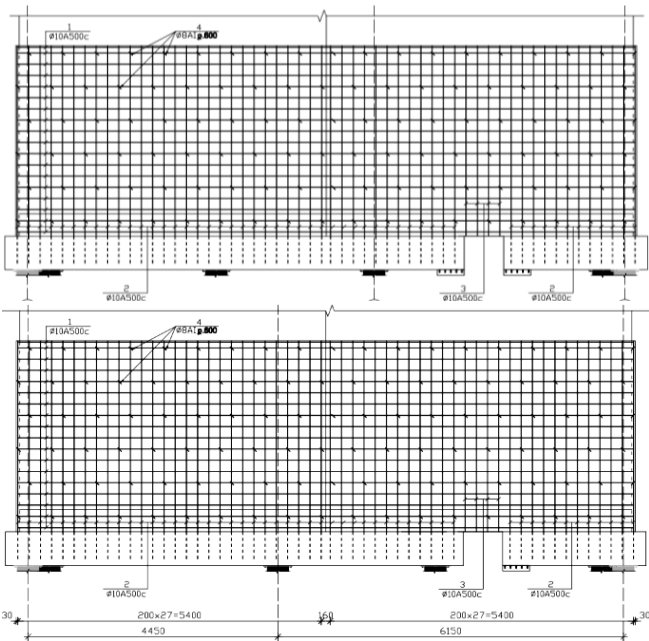


**Figure 30. View of the existing 9-story large-panel apartment building retrofitted by base isolation in Azerbaijan**

Figures 31 and 32 show all four façades (two longitudinal and two transverse) of the building with indication 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 entrances to the building. However, in transverse façades the jackets are envisaged to cover the whole exterior surfaces of the walls.



**Figure 31. R/C jackets designed for local strengthening of the existing longitudinal exterior large-panel load-bearing walls of the first floor of 9-story apartment building**

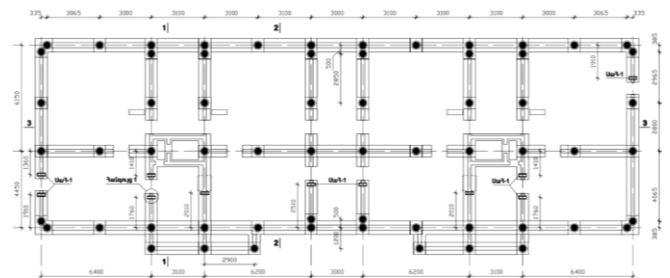


**Figure 32. R/C jackets designed for local strengthening of the existing transverse exterior large-panel load-bearing walls of the first floor of 9-story apartment building**

For design of isolation system along all exterior and interior load-bearing walls of the large-panel building again the method of retrofitting by base isolation according to the above-mentioned Patent of the Republic of Armenia #579 was used.

This innovative technology envisages making openings with certain spacing in the basement load-bearing walls to accommodate lower reinforcement frames with seismic isolators' sockets. It is very important that two adjacent openings in the walls are not made simultaneously.

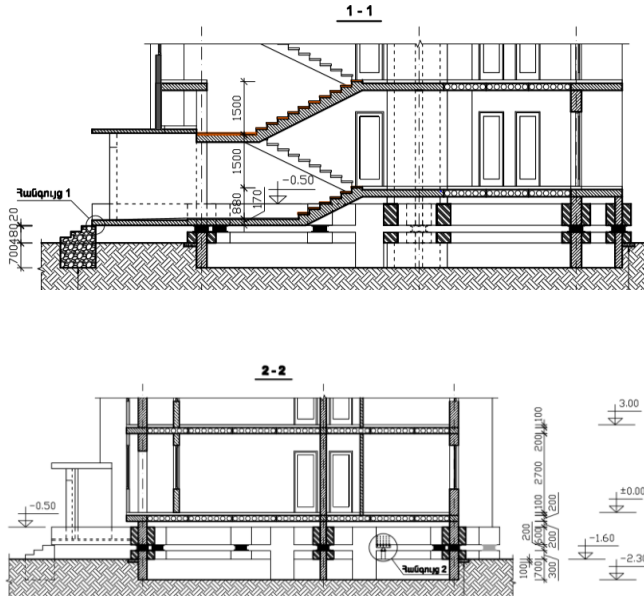
HDRBs of the same type and sizes were used to make the seismic isolation system. Total 62 neoprene bearings have an aggregate horizontal stiffness equal to  $0.81 \times 62 = 50.22$  kN/mm. These are manufactured in Armenia according to the Republic of Armenia Standard HST 261-2007 with the sizes and physical/mechanical parameters given in [12 and 22]. Together with the mentioned HDRBs the seismic isolation system includes 11 bearings which can carry the vertical load and allow horizontal displacement, but they do not have horizontal stiffness (BNHS) shown in Figure 33.



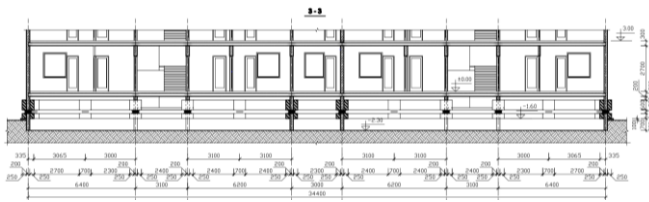
**Figure 33. Plan of location of HDRBs and BNHS in the seismic isolation interface of existing 9-story large-panel apartment building**

Parts of walls existing between 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 HDRBs during cutting of the walls. Figures 34 and 35 show vertical elevations of the isolated building in transverse and in longitudinal directions, respectively.

From these drawings one can see that the base isolation system consists of the lower continuous beams with the height of 300 mm to be constructed below the isolation interface, the gap (200 mm) where the HDRBs are located and the upper continuous beams with the height of 600 mm to be constructed above the isolation interface. 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.



**Figure 34. Vertical elevations 1-1 and 2-2 of the base isolated 9-story large-panel building in transverse direction**



**Figure 35. Vertical elevation 3-3 of the base isolated 9-story large-panel building in longitudinal direction**

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. Figure 36 shows a fragment of seismic isolation system during the process of its realization.



**Figure 36. One of the stages of installation of seismic isolation in the basement of existing 9-story large-panel building in accordance with the Patent of the Republic of Armenia № 579**

#### IV. APPLICATION OF DEVELOPED BY THE AUTHOR INNOVATIVE BASE ISOLATION TECHNOLOGIES IN RETROFITTING DESIGNS FOR EXISTING BUILDINGS OUTSIDE ARMENIA

##### *A. Retrofitting design of base isolation for existing 2-story stone City-Hall building in Romania*

Experience accumulated in Armenia in retrofitting of existing buildings including those of historical and architectural value created a good basis for participation in the international competition announced by the Government of Romania for development of the design on retrofitting at least 179 years old (at the time of the competitive bidding) historical building of the Iasi City Hall by base isolation. The structural concept and detailed results of the earthquake response analysis were presented to the client. Obtained results indicate the high effectiveness of the isolation system and the structural concept proposed for the given historical building.

The design for retrofitting of City Hall (Fig. 37) was to be implemented within the framework of the Romania Hazard Risk Mitigation and Emergency Preparedness Project. The design was accomplished under the leadership of the author in cooperation with the Romanian company MIHUL S.R.L. and was finally approved by the Technical Committee for Seismic Risk Reduction (TCSRR, a body specially created by the Government of Romania) on June 1, 2009.



**Figure 37. View of the 2-story Iasi City Hall building with stone bearing walls**

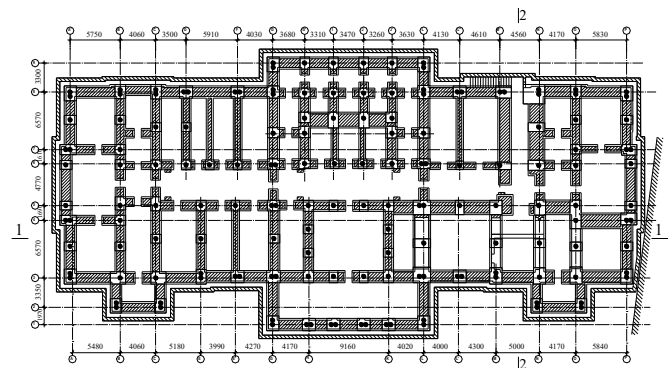
The TCSRR has requested to accept the peak ground acceleration (PGA) for retrofitting design of the Iasi City Hall building equal to 0.28 g. Taking into account that the Iasi City Hall building has historical and architectural value, evidently the conventional (traditional) methods of strengthening (reinforced concrete jacketing, construction of additional shear walls and frames, etc.) are not applicable to this building. There are known cases, when the application of conventional methods of strengthening to similar type of buildings has brought to significant disfiguration of their façades and interiors. The above upholds that the City Hall should be retrofitted using innovative base isolation technologies. In this case the first dynamic mode of the isolated building involves deformation only in the isolation system, the building above being to all intents and purposes rigid. The higher modes do not participate in the motion so that the high energy in the ground motion at these higher frequencies cannot be transmitted into the building [7].

The key objective of the given work was to develop a structural concept and design for retrofitting the Iasi City Hall building, which will ensure cost-effectiveness of the construction works, high reliability of the structure and preservation of the historical and architectural value of the building.

There is no basement in most of the area under the City Hall building. Only a partial basement exists under the building and, therefore, based on the accumulated experience on retrofitting similar buildings by base isolation, it was proposed to extend the basement throughout the whole built surface of the building.

This requires excavating the soil inside of the building's basement and to bare the existing foundation walls. Obviously, before creation of the isolation system these walls must be thoroughly cleaned and washed from the remainders of soil and then adequately strengthened. The proposed structural solution provides for jacketing of the natural stone walls of the foundations.

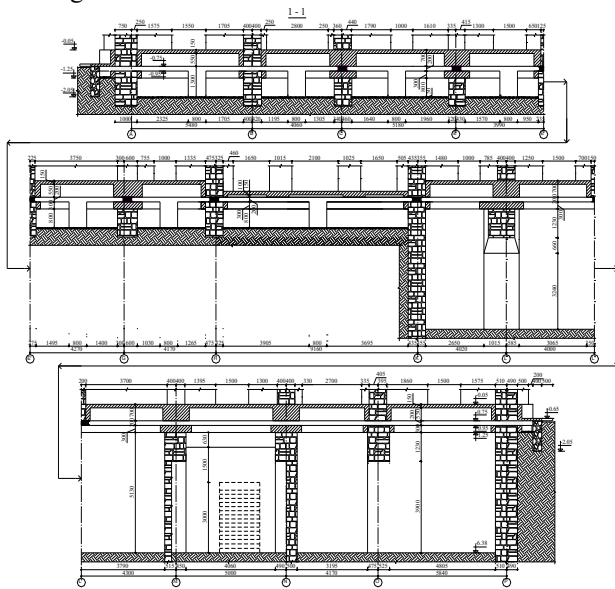
The new approach on installation of the clusters of seismic isolators [23] successfully implemented in many buildings in Armenia was also proposed for retrofitting the Iasi City Hall building (Fig. 38). It was also proposed to lay a 150 mm thick reinforced concrete slab immediately above the seismic isolation plane to cover the basement. This approach would significantly increase the reliability of the whole structure (i.e. the building itself plus the isolation system), lead to an increased rigidity of the superstructure and would result in a more uniform distribution of seismic forces on isolators.



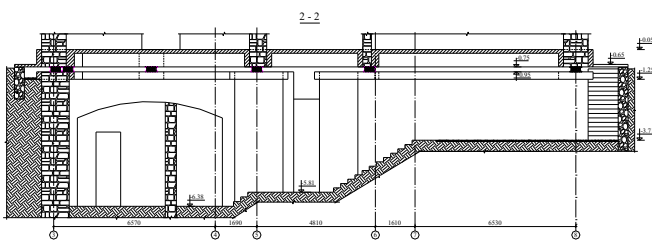
**Figure 38. Plan of location of seismic isolators on the level of the newly created basement highlighting the lower pedestals under the isolators and the lower continuous beams along the whole perimeter of the bearing walls**

Thus, suggested base isolation method involves creating a new basement. The height of such basement under the slab is 1.85 m, however under the upper beam of the isolation system it is 1.3 m (Fig. 39 and 40). The height of the basement is limited by the depth of the foundation walls.

Analysis of this building without base isolation shows that because of the amplification phenomenon, the input acceleration of 0.28g will reach in average 1.11g on the top of the building. In retrofitting by base isolation there is no reason to plan any additional measures related to the superstructure, as for a base isolated building the input acceleration significantly declines from 0.28g to 0.09g. This is practically the same throughout the height of the building.



**Figure 39. Longitudinal (1-1) vertical elevations of the basement and isolation system of the building according to the developed structural solution**



**Figure 40. Transverse (2-2) vertical elevations of the basement and isolation system of the building according to the developed structural solution**

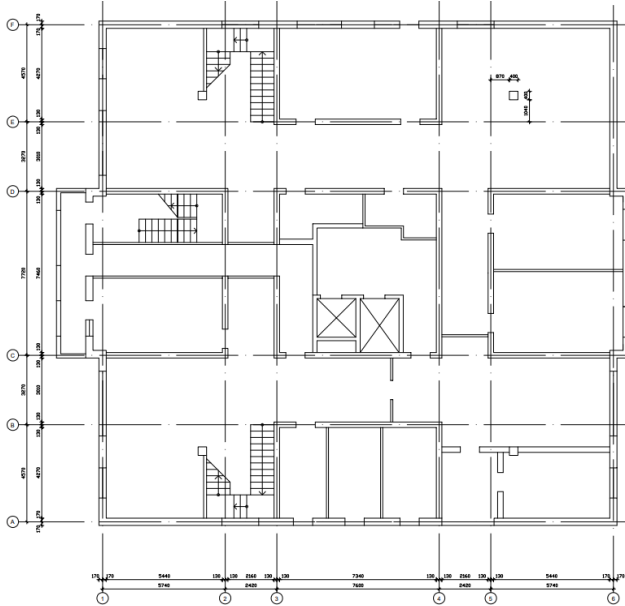
*B. Base isolation strategy for retrofitting of the existing 19-story (including two basement floors) apartment building with monolithic load bearing walls in Kazakhstan*

After the earthquake of magnitude 7.0 in January 2024 along the China-Kyrgyzstan border the scared residents of a 19-story apartment building located on the Dostyk ave. 138 in the City of Almaty (Fig. 41) have contacted the author of this paper being aware about his achievements in retrofitting of different types of existing buildings [24].



**Figure 41. View of the existing 19-story (including two basement floors) apartment building located on the Dostyk ave. 138 in the city of Almaty to be retrofitted by base isolation**

The request was to consider upgrading the earthquake resistance of the mentioned building by implementation of the author's technology on retrofitting using base isolation systems. This is the first time when design was elaborated for application of base isolation retrofitting technology to a 19-story building with monolithic load bearing walls. Base isolation interface for this building is designed at the upper level of basement floor. The building under consideration has symmetric rectangular plan with main dimensions of 24.3×23.7 m (Fig. 42). It has 340 mm thick exterior and 260 mm thick interior load bearing walls. The floors' slabs consist of precast reinforced concrete hollow-core panels of the thickness equal to 220 mm.



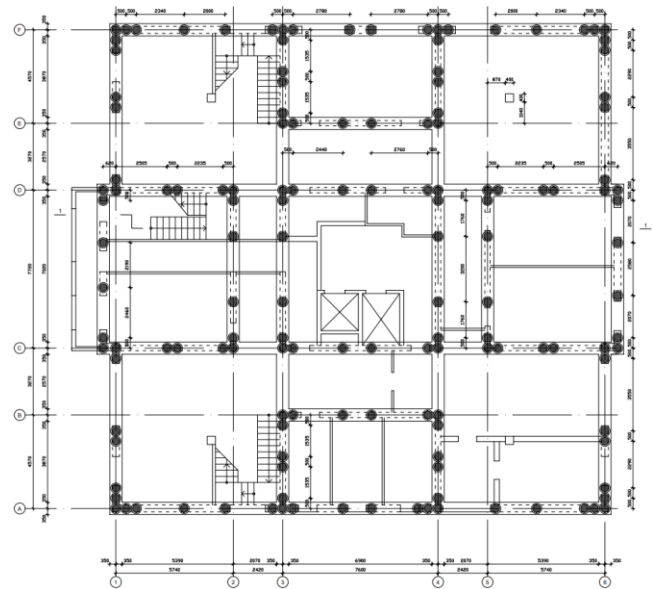
**Figure 42. Plan of the basement floor at the mark -3.70 where the base isolation interface is designed between the marks -0.30 and -1.30**

There are three staircases in the building. The main one between the axes “C”-“D” and “1”-“2” is envisaged along the whole height of the building starting from the basement floors. The other two staircases are envisaged only for connecting two basement floors with the first above ground floor. At the horizontal plane where all three staircases are crossing the seismic isolation interface the corresponding stair flights must be reconstructed providing the gaps to ensure unhindered movement of the building supported by seismic isolators. Related joint and some descriptions on this matter are given below.

Seismic isolation system for this building is designed at the upper level of its basement (Fig. 43) between the marks -0.30 and -1.30, and HDRBs are installed here also by clusters. Structural concept of retrofitting using invented base isolation technology is the same as was described above for buildings with load-bearing walls.

Vertical elevation 1-1 of the seismic isolation system given in Figure 44 shows that the base isolation system consists of the lower continuous beams with the height of 300 mm to be constructed below the isolation interface, the gap (200 mm) where the HDRBs are located and the upper continuous beams with the height of 500 mm to be constructed above the isolation interface.

The width of the lower and upper continuous beams from the both sides of the existing load-bearing walls is different and equal for the exterior walls to 180 mm and for the interior walls – to 220 mm (see Fig. 44 the Joint-2). 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.



**Figure 43. Plan of location of HDRBs in the seismic isolation interface of 19-story (including two basement floors) apartment building in accordance with the developed retrofitting design**

From the given drawings one can see that there are cantilever slabs around the building at the mark  $\pm 0.00$ . The existing cantilever slabs along the axes “1” and “F” were constructed during construction of the building to cover outside stairs leading to the entrances of the basement floors. The cantilever slabs along the axes “6” and “A” will be newly constructed after dismantling the parts of the existing slabs of outside parking. The matter is that currently the mentioned parking’s slabs are adjoined to the building, and they will not permit the free movement of the latter being supported by the seismic isolators. In fact, these newly constructed cantilever slabs will cover the created gap between the building and the existing slabs of the parking and, thus, the horizontal displacement of the building’s isolation system will be accommodated freely during any earthquake impact.

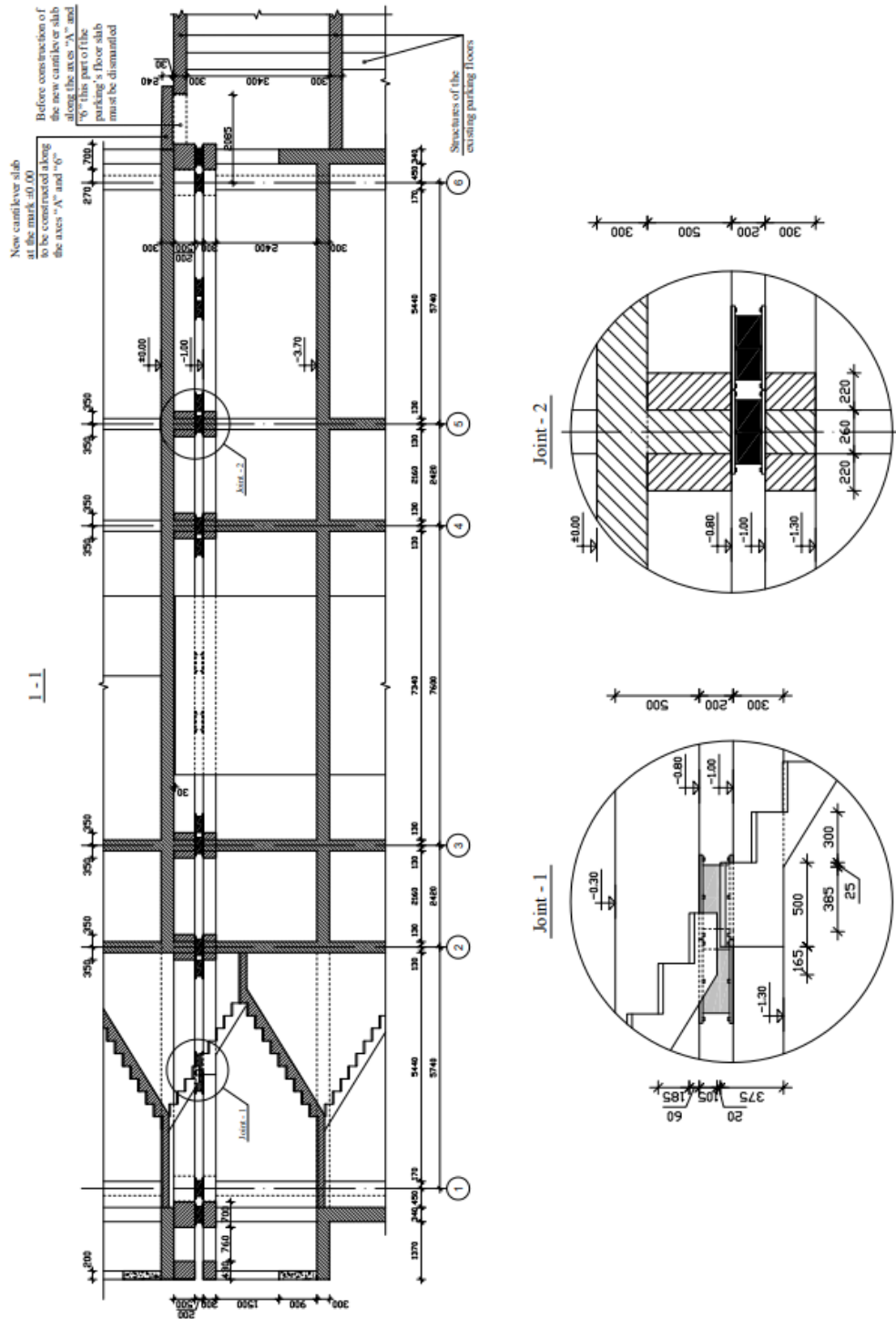
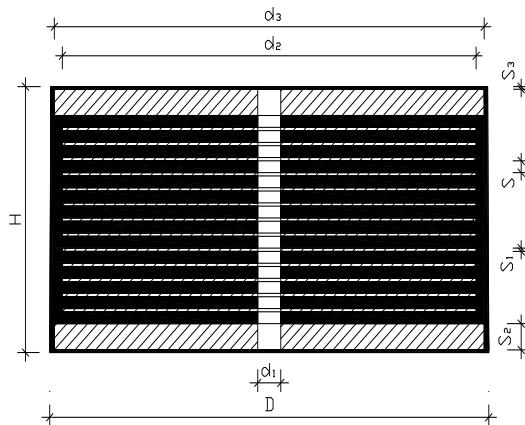


Figure 44. Vertical elevation 1-1 of the seismic isolation system

Total 144 bearings were used with aggregate horizontal stiffness equal to  $0.81 \times 144 = 116.64$  kN/mm. As it is mentioned above, this type of bearings (Fig. 45) is manufactured in Armenia according to the Republic of Armenia Standard HST 261-2007. The service life of the bearings is expected to be not less than 150 years; they should require no maintenance and were used in the most of the newly constructed or retrofitted buildings in or outside Armenia where the author's seismic isolation technologies were applied.



External diameter of the bearing (D):  $(380 \pm 2.0)$  mm;  
 Internal diameter of the bearing's central hole (d1):  $(19 \pm 1.0)$  mm;  
 Height of the bearing (H):  $(202.5 \pm 2.5)$  mm;  
 Thickness of the rubber layers (S):  $(9 \pm 0.1)$  mm;  
 Diameter of the steel shim plates (d2):  $(360 \pm 0.5)$  mm;  
 Thickness of the steel shim plates (S1):  $(2.5 \pm 0.1)$  mm;  
 External diameter of the upper and lower flanges (d3):  $(376 \pm 0.5)$  mm;  
 Thickness of the upper and lower flanges (S2):  $(20 \pm 0.2)$  mm;  
 Thickness of the upper and lower flanges' protective layer (S3):  $(2 \pm 0.1)$  mm;  
 Mass of the bearing:  $(77.5 \pm 2.5)$  kg;  
 The bearing must withstand a maximum (design) permissible vertical loading of 1500 kN;  
 Shear modulus of the bearing's rubber must be  $(0.97 \pm 0.15)$  MPa;  
 Vertical stiffness of the bearing: no less than 300 kN/mm;  
 Horizontal stiffness of the bearing:  $(0.81 \pm 0.1)$  mm;  
 The bearing must withstand a maximum (design) permissible horizontal displacement of 280 mm, without causing cracks greater than 3 mm deep and 6 cm long;  
 Shore A hardness of the bearing:  $70 \pm 5$  points;  
 Damping coefficient of the bearing: 13-15%.

**Figure 45. Dimensions and physical/mechanical parameters of the seismic isolation laminated rubber-steel bearing**

## V. CONCLUSIONS

Seismic hazard in Armenia is very high and most of the existing buildings constructed in the country during about 100 years (70 years of Soviet period and about 30 years since Armenia gets its independence) will not be able to resist earthquakes of such a high intensity. Investigations have shown that if the design level earthquake (0.4g) struck the city of Yerevan, then 80% of the existing building will be destroyed and 300,000 people will die. Consequently, new technologies, for upgrading the earthquake resistance of the existing buildings and for construction of new buildings were essential and were developed by the author using seismic isolation strategies.

For the first time, in a single article, the author presents his works on retrofitting of existing buildings in Armenia and beyond using invented and developed by him various seismic isolation systems.

Description of retrofitting technologies for six buildings in Vanadzor and Yerevan (Armenia) is given. Among them four buildings (from 3 to 8 floors) were retrofitted by application of base isolation systems and two 9-story buildings were protected by application of roof isolation technology.

Unique, modern and cost-effective seismic (base and roof) isolation strategies were implemented with high efficiency in existing buildings, making them earthquake proof. These strategies can be realized in very short periods of time, and without interruption of the use of the buildings. They were demonstrated on existing buildings with different structural systems, such as reinforced concrete frame buildings with and without shear walls and buildings with stone and large-panel load-bearing walls.

Outside Armenia the author's seismic isolation retrofitting strategies were implemented in Irkutsk (Russia) for existing 4-story stone bank building and in Azerbaijan for 9-story large-panel apartment building. Also, retrofitting designs were developed by the author for 2-story City Hall stone building in Iasi (Romania) and for 19-story (including two basement floors) apartment building with monolithic load-bearing walls in Almaty (Kazakhstan).

## REFERENCES

- [1] Melkumyan M. "Non-Linear Behavior of Reinforced Concrete Structures under Seismic Actions (Dedicated. to 25th Anniversary of 1988 Spitak Earthquake)". - "Lusabats" Publishing House, Yerevan, 2013, 230 p. (in Russian).
- [2] Pusch Ch. "Preventable Losses: Saving Lives and Property through Hazard Risk Management". - Working Paper Series №9, The World Bank, October 2004, 88 p.
- [3] Balassanian S., Melkumyan M., Arakelyan A., Azaryan A. "Seismic Risk Assessment for the Territory of Armenia and Strategy of its



**International Journal of Recent Development in Engineering and Technology**  
**Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 04, April 2026)**

- Mitigation". - Natural Hazards, No. 20, Kluwer Academic Publisher. The Netherlands, 1999, pp. 43-45.
- [4] Republic of Armenia Building Code RABC-20.04. - Committee of Urban Development under the government of Armenia, 2020, 93 p.
- [5] Melkumyan M. "Assessment of the Seismic Risk in the City of Yerevan and its Mitigation by Application of Innovative Seismic Isolation Technologies". - Journal "Pure and Applied Geophysics". 2011, Vol.168, Nos.3-4, pp. 695-730.
- [6] Martelli A., Forni M., Arato G.-B., Spadoni B. "Overview and Summary of the 7th International Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control of Vibrations of Structures". - Preface to the Proceedings of the 7th Int. Seminar. Assisi, Italy, 2001, pp. i-xxxvii.
- [7] Naeim F., Kelly J. "Design of Seismic Isolated Structures. From Theory to Practice". - John Wiley & Sons Inc., 1999.
- [8] Miyamoto K., Gilani A. "Base Isolation for Seismic Retrofit of Structures: Application to a Historic Building in Romania". - Seismic Risk Reduction, Proceedings of the International Symposium. Bucharest, Romania, 2007, pp. 585-592.
- [9] Garevski M. "Development, Production and Implementation of Low-Cost Rubber Bearings". - Geotechnical, Geological and Earthquake Engineering. Vol.17, Earthquake Engineering in Europe. Editors: Mihail Garevski and Atilla Ansal. Springer. 2010, pp. 411-437.
- [10] Melkumyan M. "The methodology for the seismic evaluation of existing buildings and comparative analysis of rehabilitation of stone and frame buildings in Armenia". - Proceedings of the 11th World Conference on Earthquake Engineering, Acapulco, Mexico, 1996, paper No 700.
- [11] Melkumyan M. "Seismic Isolation of Civil Buildings in Armenia". - Journal "Progress in Structural Engineering and Materials". 2002, Vol.4, No. 4, pp. 344-352.
- [12] Melkumyan M. "The Use of High Damping Rubber Isolators to Upgrade Earthquake Resistance of Existing Buildings in Armenia". - Proceedings of the International Post-SMiRT Conference Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control of Seismic Vibrations of Structures, Taormina. Sicily, Italy, 1997, pp. 861-867.
- [13] World Bank Implementation Completion Report (ICR) No. 17255 of December 1997.
- [14] Melkumyan M. "Dynamic Tests of the 9-story R/C Full-Scale Building with an Additional Isolated Upper Floor Acting as Vibration Damper". - Proceedings of the 3rd European Conference on Structural Dynamics. Florence, Italy, 1996, Vol.1, pp. 557-560.
- [15] Melkumyan M., Inoue T., Kumazawa F., Nakano Y., Okada T. "Hysteresis Model for the Shear Behavior of R/C Multistory Frame Buildings with Diaphragms under Seismic Actions (Part 2) - Rules of Formation". - "SEISAN-KENKYU" Monthly Journal of Institute of Industrial Science, University of Tokyo. 1991, Vol.43, #4, pp. 28-31.
- [16] Melkumyan M., Käppeli G., Khalatyan R., Hovivyan H. "Application of Seismic Isolation for Retrofitting of Existing 3-story Stone Building of the School #4 in the City of Vanadzor, Armenia". - Proceedings of the 8th World Seminar on Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures. Yerevan, Armenia, 2003, pp. 557-565.
- [17] Report by the Ehrenkrantz Group, Burch Beall, E.W. Allen and Associates, Forell/Elsesser Engineers and SSD, Inc. "Base Isolation Study for the Renovation of the City and County Building, Salt Lake City, Utah", 1986.
- [18] Melkumyan M. "Seismic Isolation Retrofitting Experience in Armenia and New Structural Concept for an Existing 8-story Reinforced Concrete Hospital Building to be Retrofitted by Base Isolation". - Study of Civil Engineering and Architecture, Vol. 3, 2014, pp.78-92.
- [19] Melkumyan M. "Unique Retrofitting Technology for Base Isolation of an Existing 8-story R/C Hematology Center Hospital Frame Building with Shear Walls". - Journal of Civil Engineering and Architecture Research (JCEAR), Ethan Publishing Company, CA, USA, Vol. 2, No. 12, 2015, pp. 1153-1162.
- [20] Melkumyan M. "New Structural Concept for an Existing 4-story Reinforced Concrete Industrial Frame Building to be Retrofitted by Base Isolation and Simultaneously Reconstructed into a 6-story Hotel Building". - Engineering and Technology, Vol. 1, No. 1, 2014, pp.1-12.
- [21] Smirnov V., Eisenberg J., Zhou F., Chung Y., Nikitin A. "Seismoisolation for Upgrading of an Existing Historical Building in Irkutsk-City, Siberia-Russia". - Proceedings of the 12th World Conference on Earthquake Engineering. Auckland, New Zealand. 2000, Paper No. 0962.
- [22] Melkumyan M. "Base Isolation Retrofitting Design for the Existing 9-story Large-Panel Apartment Building". - 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](http://www.ijtsrd.com/papers/ijtsrd30937.pdf)
- [23] Melkumyan M. "New Approach in Design of Seismic Isolated Buildings Applying Clusters of Rubber Bearings in Isolation Systems". - Earthquakes and Structures. An International Journal, Vol. 4, No. 6, June 2013, pp. 587-606.
- [24] Melkumyan M. "Base Isolation Strategy for Retrofitting of the Existing 19-Story (including two basement floors) Apartment Building with Monolithic Load Bearing Walls in the City of Almaty, Kazakhstan". - International Current Journal of Engineering and Science (ICJES), ISSN: (Online) 2583-7257, Volume 3, Issue 6, (June) 2024, pp. 1-12