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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

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***Abstract* - In January 2024 a 7.0 magnitude earthquake struck along the China-Kyrgyzstan border. The earthquake felt also in Kazakhstan in the city of Almaty. In this regard, being aware about the achievements of the author in retrofitting of different types of existing buildings, the author was contacted by the scared residents of a 19-story apartment building located on the Dostyk ave. 138 in the City of Almaty. The request was to consider upgrading the earthquake resistance of the mentioned building by implementation of one of the author's technologies on retrofitting of this building by base isolation. Previously the author has developed retrofitting designs using invented by him base isolation technology (Patent of the republic of Armenia №579) for the existing buildings from 2 to 9 stories in Armenia, Russia, Romania and Nagorno Karabakh. This paper is focused on the description of the developed conceptual solution for retrofitting of the 19-story apartment building, of which 2 floors are used as the basement and the rest 17 floors are residential. To develop the design, in response to the request of the dwellers, the local cadaster drawings were used. Some other needed information was obtained from internet. These drawings are included in the building's technical passport which was prepared in 2017.**

Keywords: Base Isolation Strategy, Retrofitting, Apartment Building, Monolithic, Bearing Walls, Kazakhstan.

I. Introduction

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 (base and roof) isolation of structures are becoming the more common strategies 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 technology was implemented in Russia as well as in Nagorno Karabakh and a retrofitting design was accomplished for implementation in Romania and approved by the corresponding governmental body of this country. It is worth noting that the mentioned seismic isolation strategies have great potential for rehabilitation of existing ordinary civil structures such as apartment blocks and critical facilities such as schools, hospitals. In case of base isolation, 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 (Naeim & Kelly, 1999). By reducing the seismic forces transmitted, isolation protects the contents and secondary structural features as well as the main structure.

From 1994 the author has started development of different retrofitting technologies for the existing buildings using seismic isolation systems. These were base and roof isolation technologies for the existing buildings with various structural systems, namely, with:

- Stone load-bearing walls;
- Reinforced concrete (R/C) bearing frames;
- R/C bearing frames with shear walls;
- R/C large-panel load-bearing walls;
- R/C monolithic load-bearing walls.

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To date more than 10 retrofitting designs were elaborated for various countries of which 8 existing buildings have already been retrofitted in different years (Fig. 1).

Figure 1: Retrofitting or protection of existing buildings in Armenia, Russia, Romania and Nagorno Karabakh using developed by the author base or roof isolation technologies

(a) 5-story existing stone apartment building retrofitted in Armenia by base isolation for the first time in the world without moving people out from their apartments; (b) and (c) 9-story existing apartment R/C frame buildings with shear walls protected in Armenia by roof isolation system – Additional Isolated Upper Floors (AIUF) acting as vibration dampers; (d) 3-story existing stone school building retrofitted in Armenia by base isolation; (e) 4-story existing stone bank building retrofitted in Russia by base isolation; (f) 2-story existing stone Iasi City Hall building in Romania designed for retrofitting by base isolation; (g) 5-story existing R/C frame hotel building retrofitted in Armenia by base isolation; (h) 9-story (including one basement floor) existing hematology center hospital R/C frame building with shear walls retrofitted in Armenia by base isolation; (i) 9-story existing R/C large-panel apartment building retrofitted in Nagorno Karabakh by base isolation; (j) 4-story existing stone College building in Armenia designed for retrofitting by base isolation.

In Armenia the projects (a), (b), (c) and (h) were financed by the World Bank and project (d) - by the "Caritas Switzerland". Project (g) was financed by the private company "Fredex Services" LLC. In Nagorno Karabakh project (i) was financed by the local authorities. The retrofitting design for the Iasi City Hall building (f) in Romania was financed by the World Bank and for the College building (j) in Armenia - by the Yerevan State Pedagogical University.

Thus, by creating the above mentioned seismic retrofitting technologies and implementing them in different existing buildings, the author has accumulated rich experience. It is necessary to stress that retrofitting by base isolation of a 5-story stone apartment building (Figure 1a) in Armenia was made without resettlements of the occupants (Melkumyan, 1997). World practice provides no similar precedent in retrofitting of apartment buildings. 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 (earthquake protection) was implemented for two existing R/C 9-story standard design frame buildings (Figures 1b and 1c) also in Armenia (Melkumyan, 2007).

The other project in Armenia relates to retrofitting of the 60 years old non-engineered 3-story stone school building which has historical meaning as well as a great architectural value (Figure 1d). Unique operations were carried out in order to install the isolation system within the basement of this building and to preserve its architectural appearance (Melkumyan *et al.*, 2003a,

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2003b). Then by the end of nineties, another project initiated by Prof. Eisenberg (Smirnov *et al.*, 2000) on retrofitting of about 100 years old 3-story stone bank building was implemented in Russia with increasing of the number of stories up to 4 (Figure 1e). It was emphasized that for retrofitting of the existing bank building using base isolation the method developed in (Melkumyan, 1997) was implemented and the author of this paper provided Russian colleagues with all the needed drawings, photos, video film related to the retrofitting works carried out in Armenia.

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 of about 180 years old 3-story historical building of the Iasi City Hall by base isolation (Figure 1f). The structural concept, including the new approach on installation of seismic isolation rubber bearings was developed and the design of retrofitting was accomplished in cooperation with the Romanian company MIHUL S.R.L. (Melkumyan *et al.*, 2011, Melkumyan, 2011).

The next project on retrofitting by base isolation of the existing 4-story industrial R/C frame building and its conversion into a 5-story hotel in Armenia (Figure 1g) is interesting by the fact that for the first time this retrofitting project was financed by the private company (Melkumyan, 2014). The other project which also deserves the attention is the 9-story (including one basement floor) existing hematology center hospital R/C frame building with shear walls retrofitted in Armenia by base isolation (Melkumyan, 2015). Initially it was planned to strengthen this building using old conventional approach. However, the author of this paper has proved that significant cost-savings will take place in case of application of the developed by him base isolation technology. Together with that the building will get the high reliability and architectural solutions in reconstruction of superstructure will have flexibility and much more free spaces at different floors.

And finally, again for the first time unprecedented work was carried out in Nagorno Karabakh on retrofitting by base isolation of the 9-story existing R/C large-panel apartment building (Figure 1i) without resettlements of the occupants (Melkumyan, 2020). This building, as all other retrofitted in Armenia buildings briefly described above, was constructed during the Soviet era and has extremely low level of earthquake resistance. However, after retrofitting using suggested unique seismic isolation strategies, all these buildings became highly reliable.

II. Description of the Existing 19-Story (including two basement floors) Apartment Building with Monolithic Load Bearing Walls

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 (Figure 2) have contacted the author of this paper being aware about his achievements in retrofitting of different types of existing buildings.

Figure 2: View of the existing 19-story (including two basement floors) apartment building located on the Dostyk ave. 138 in the city of Almaty (Kazakhstan) to be retrofitted by base isolation

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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. In response to the request of the dwellers the retrofitting design was elaborated, and its structural concept is given below. Implementation of this design will depend on the collection of funds by the local authorities or building's residents. In any case this is the first time when the author has elaborated design for application of base isolation retrofitting technology to a 19-story building with monolithic load bearing walls. Structural concept of retrofitting was developed for this building based on the already acquired experience. 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 (Figure 3).

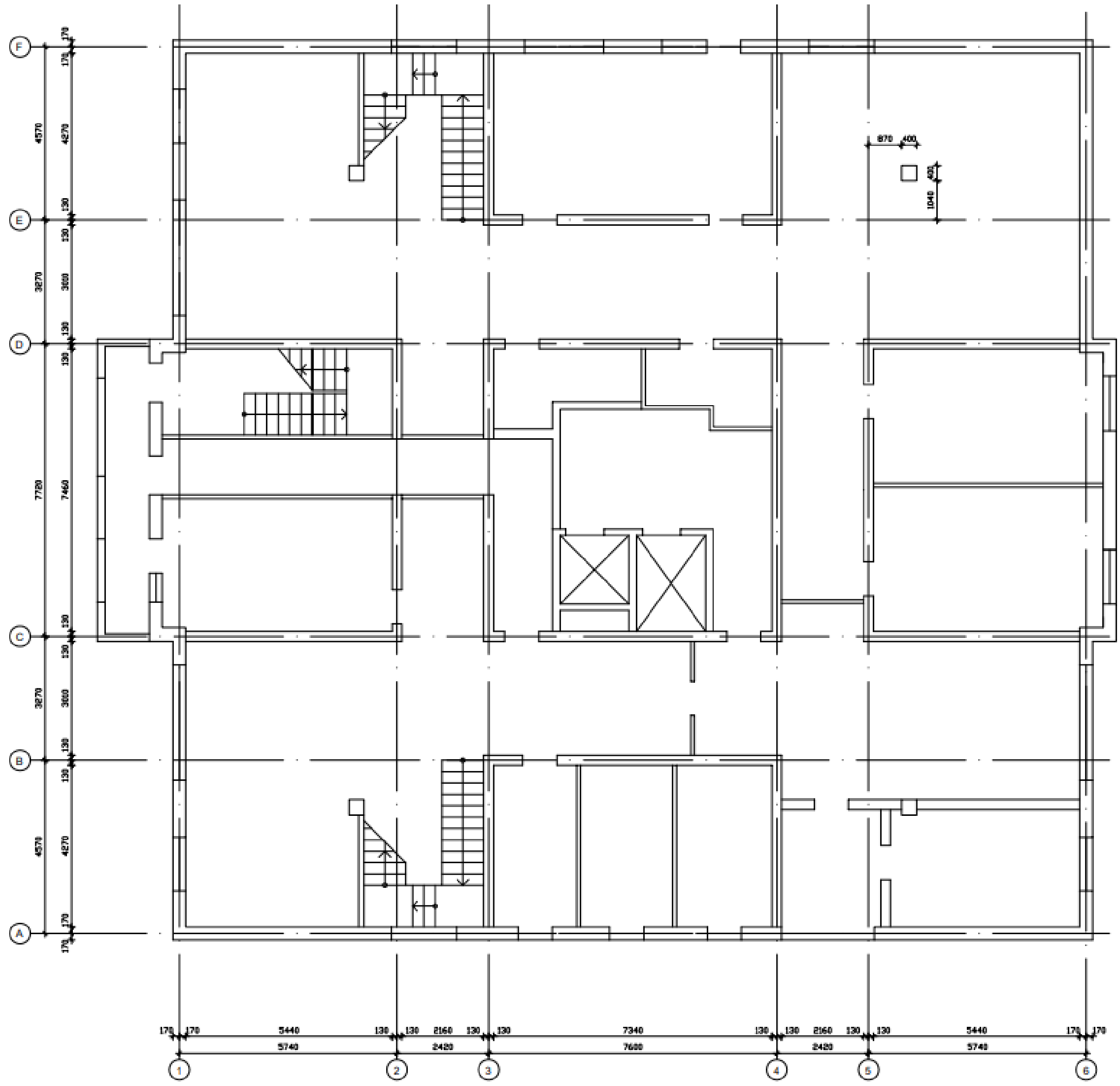

Figure 3: Plan of the basement floor at the mark -3.70 where the base isolation interface is designed between the marks -0.30 and -1.30

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. Plan of the first floor (Figure 4) differs from the other sixteen living floors (Figure 5). In all these drawings the outside facing layer of the building's façades conditionally is not shown. 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 in Chapter 3.

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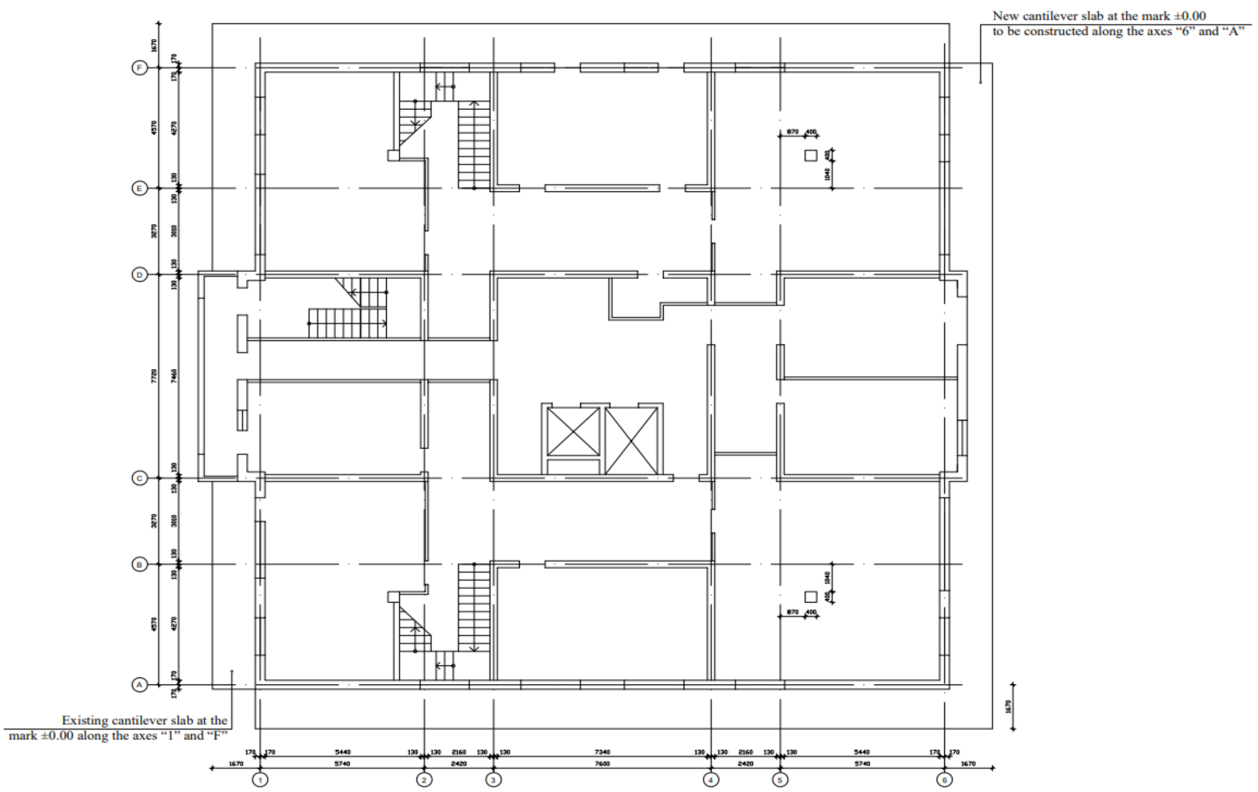

Figure 4: Plan of the first floor at the mark ±0.00 immediately above the base isolation interface

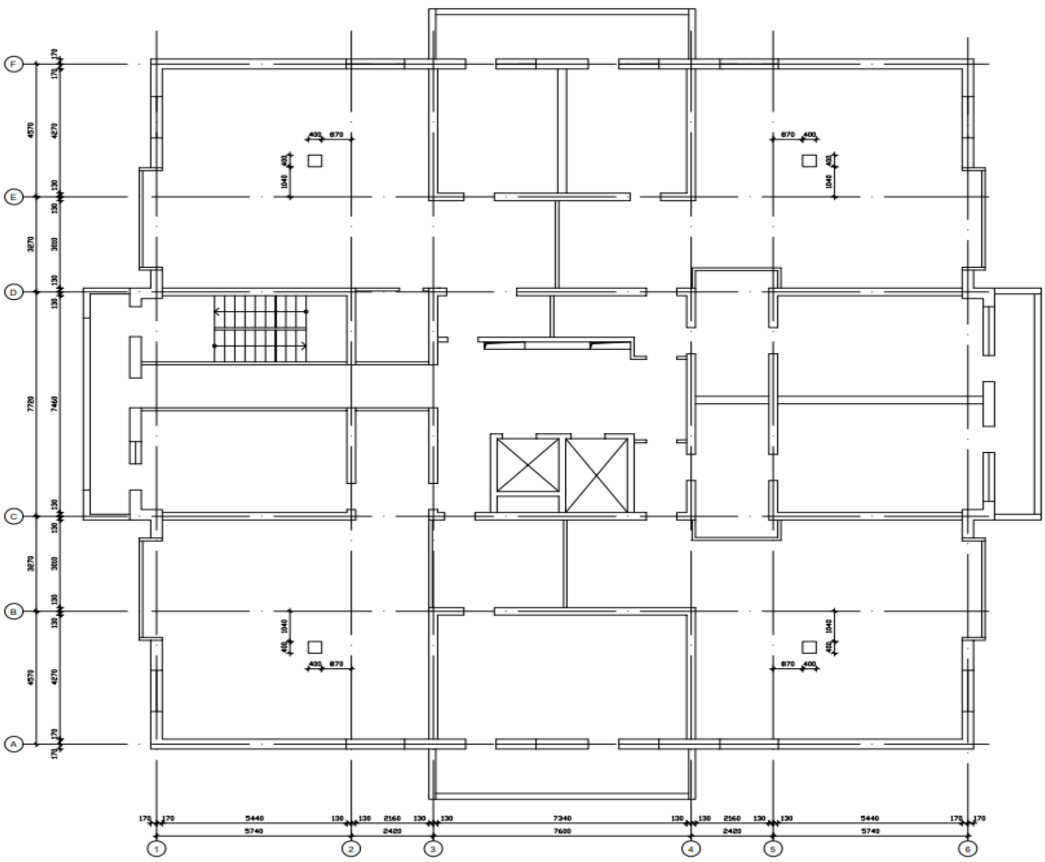

Figure 5: Plan of the second typical living floor at the mark +3.00

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Parking space for this building is located along the axes "A" and "6" outside of its basement floors. Along the mentioned axes some part of the parking's upper slab will be dismantled, and this part will be covered by the cantilever slab, which is a structural element of the isolation system (see below the Chapter 3). The purpose of such a solution is again to provide the free horizontal displacement of the seismic isolators.

III. Strategy for Retrofitting by Base Isolation of the Existing 19-Story (including two basement floors) Apartment Building with Monolithic Load Bearing Walls

Structural concept of retrofitting using suggested by the author base isolation technology and results of analysis of the considered building are described below. The sequence of implementation of base isolation system in the existing bearing walls is shown in Figure 6.

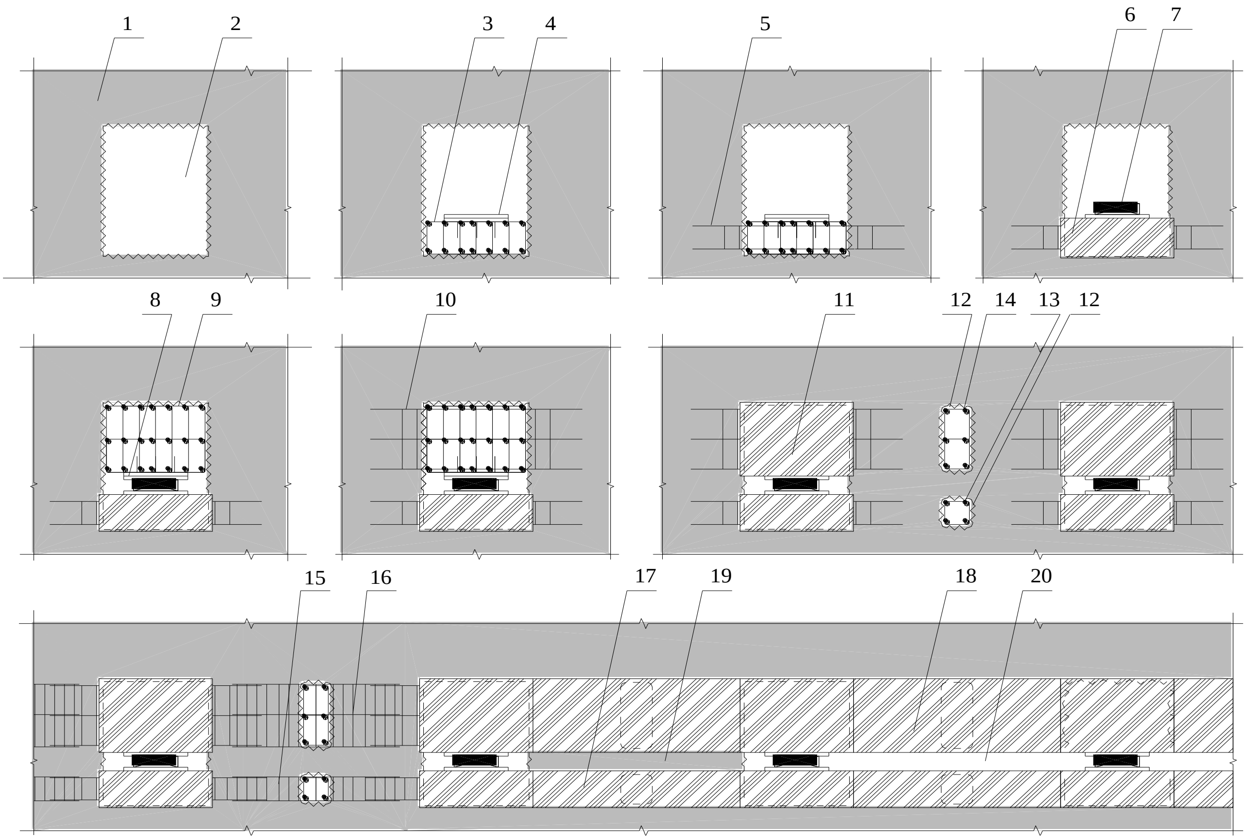

Figure 6: Stages of installation of seismic isolation in the existing buildings with load bearing walls

According to the innovative technology developed by the author of this paper (Patent of the Republic of Armenia №579), openings 2 with certain spacing are made in the basement bearing walls 1 to accommodate lower reinforcement frames 3 with seismic isolator sockets 4. Binding reinforcement lower frames 5 are passed along both sides of the bearing walls 1 through reinforcement frames 3. Then the latter are concreted to form lower pedestals 6. The next step is to place seismic isolators 7 in the lower sockets 4. Upper sockets 8 and upper reinforcement frames 9 are placed on the isolators 7 passing along both sides of the bearing walls upper binding reinforcement frames 10, through the upper reinforcement frames 9. Then the latter are concreted to form the upper pedestals 11. When concreting the frames, ends of the binding reinforcement frames 5 and 10 are left free beneath and above the seismic isolators 7. In the parts of walls between the seismic isolators, openings 12 are made and short binding reinforcement frames 13 and 14 are placed through them. The latter tie additional reinforcement frames 15 and 16 of the adjacent seismic isolators. Then the parts between pedestals are concreted thus forming lower 17 and upper 18 continuous beams along all bearing walls of the building. The parts 19 of the existing walls 1 which at this point still remain between seismic isolators 7 are removed creating gaps 20 and the building is hence separated from its foundation, being linked to it only by the seismic isolators. It is very important that two adjacent openings in the walls are not made simultaneously; parts of walls existing between seismic isolators should be cut off beginning from the middle of the building plan.

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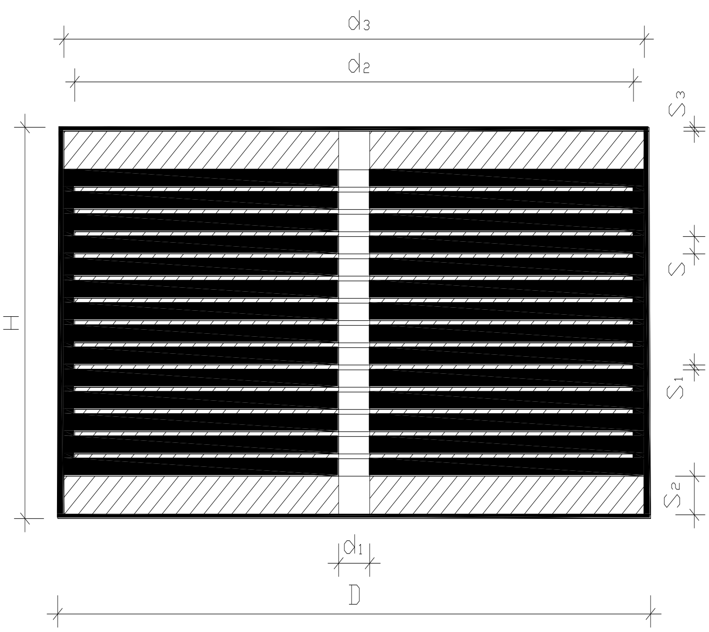
For the building under consideration the high damping rubber bearings (HDRBs) with the damping of about 13-15% from neoprene have been designed by the author of this paper (Figure 7). High damping rubber bearings are a simple, economical means of providing isolation. They have the low horizontal stiffness 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 earthquake. 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 dissipation devices are needed. The service life of the bearings is expected to be several decades (Fuller & Roberts, 1997), and they should require no maintenance. Many projects throughout the world have installed seismic isolation systems based on such type of bearings (Kelly, 1995, Akiyama, 1993). HDRBs of the same type and sizes were used to make the seismic isolation system. Total 144 bearings were used with aggregate horizontal stiffness equal to 0.81×144=116.64 kN/mm. This type of bearings is manufactured in Armenia according to the Republic of Armenia Standard HST 261-2007.



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 (S_1): (2.5 ± 0.1) mm;
External diameter of the upper and lower flanges (d_3): (376 ± 0.5) mm;
Thickness of the upper and lower flanges (S_2): (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 280 mm, 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%.

Figure 7: Dimensions and physical/mechanical parameters of the seismic isolation laminated rubber-steel bearing

Seismic isolation system for this building is designed at the upper level of its basement (Figure 8) between the marks -0.30 and -1.30. Figure 8 shows that HDRBs are installed by clusters. This approach suggested by the author of this paper on installation of the cluster of small rubber bearings instead of a single large bearing is not a typical one for the buildings with isolation systems. The advantages of this approach are summarized below:

- Increased seismic stability of the buildings;
- More uniform distribution of the vertical dead and life loads as well as additional vertical seismic loads on the rubber bearings;
- Small bearings can be installed by hand without using any mechanisms;
- Easy replacement of small bearings, if necessary, without using any expensive equipment;
- Easy casting of concrete under the steel plates with anchors and recess rings of small diameter for installation of bearings;
- Neutralization of rotation of buildings by manipulation of the number and location of bearings in the seismic isolation plane, etc. (Foti & Mongelli, 2011, Melkumyan, 2011).

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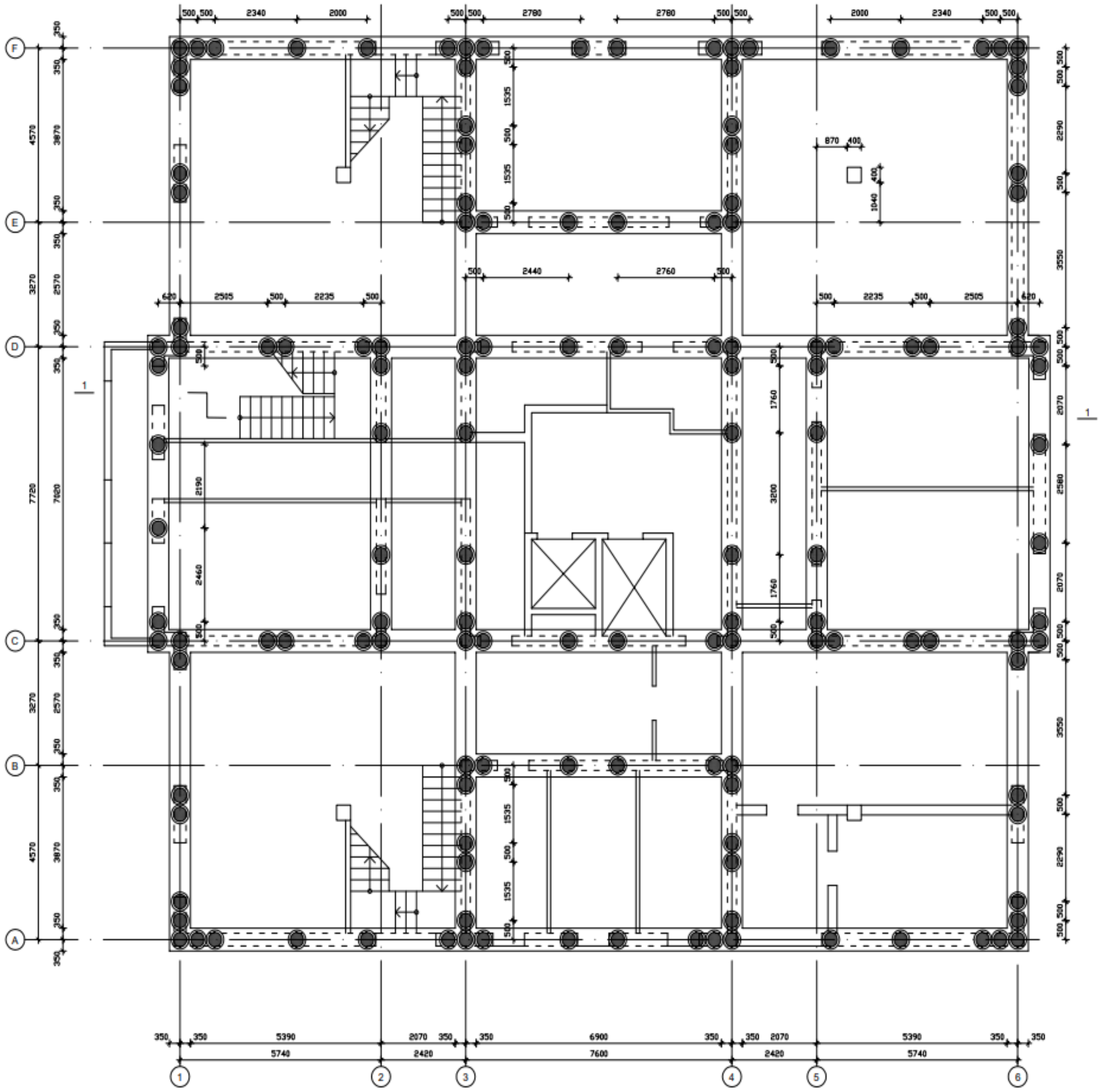

Figure 8: Plan of location of HDRBs in the seismic isolation interface of 19-story (including two basement floors) apartment building in accordance with the developed retrofitting design

Vertical elevation 1-1 of the seismic isolation system given in Figure 9 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. 9 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.

In Figure 9 the Joint-1 shows the structural solution of the stair flight with the gap at the level of the seismic isolation interface. As it mentioned above these gaps are envisaged to ensure unhindered movement of the building supported by seismic isolators. Thus, instead the old stair flights the new ones will be constructed having the stairs in the form of cantilever elements coming out from the lower and upper continuous beams of the seismic isolation system.

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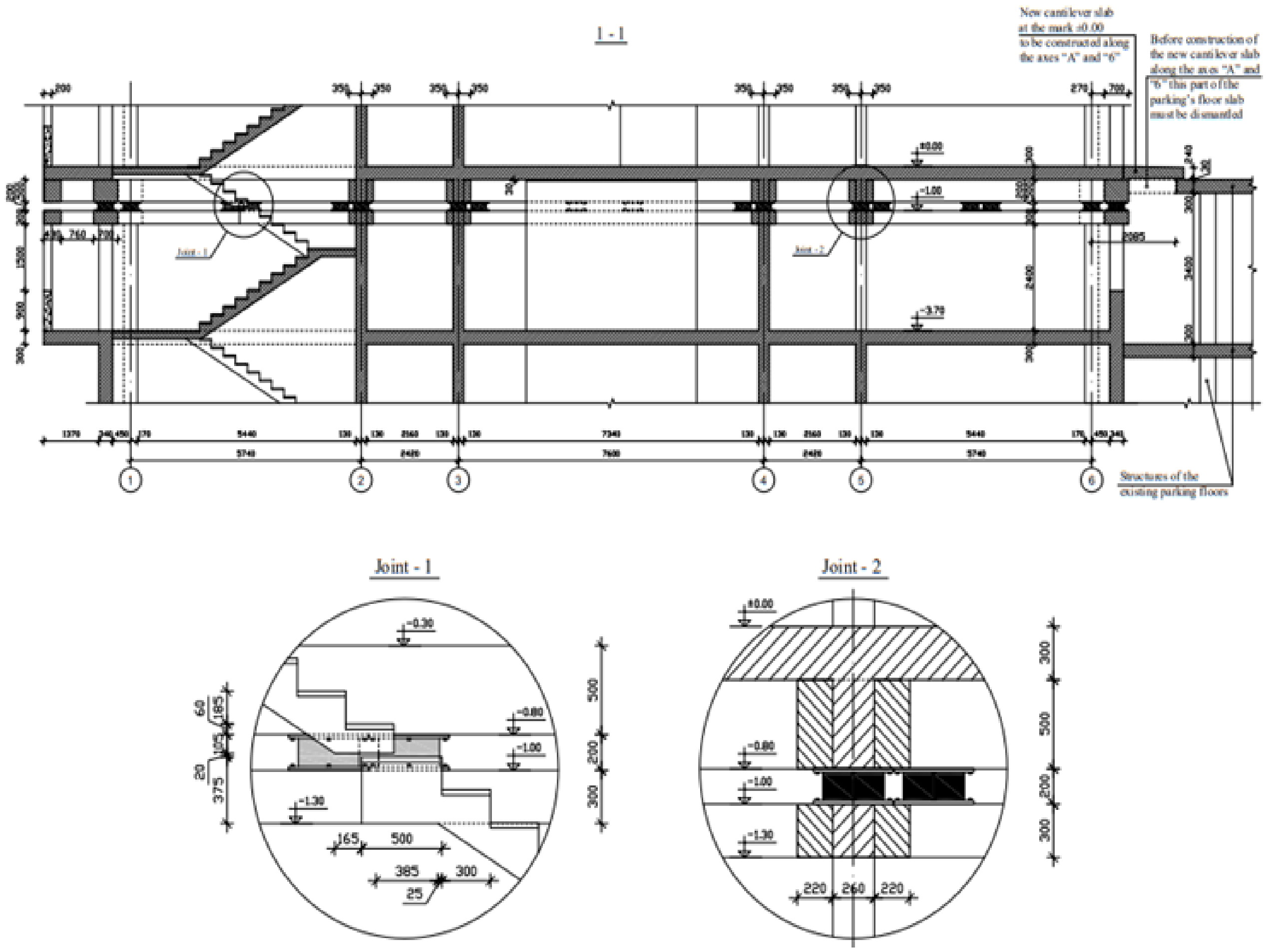

Figure 9: Vertical elevation 1-1 of the seismic isolation system

From Figure 4 and Figure 9 one can see that there are cantilever slabs around the building at the mark ±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.

IV. Some Results of the Comparative Analyses for the Existing 19-Story (including two basement floors) Apartment Building with and without Seismic Isolation System

Earthquake response non-linear analysis of the considered building was carried based on the design model developed by application of different types of finite elements for the various bearing structures, as well as for seismic isolators. Non-linearity of seismic isolation rubber bearings was described by the same input parameters, and also, the same time histories were applied for calculations as accepted in (Melkumyan, 2022).

Horizontal displacement of the building's isolation system was also calculated based on the provisions of the International Standards (Fuller & Melkumyan, 1998). At the period of the isolated structure Ti equal to 2 sec, the damping factor of the isolation system – 15% and zone factor – 0.4 the horizontal displacement is equal to 160 mm. Results of calculations in terms of changes of the input acceleration at the top of the building for both cases of with and without seismic isolation are shown in Table 1.

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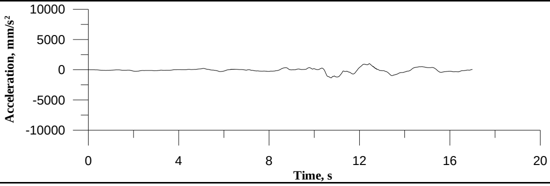
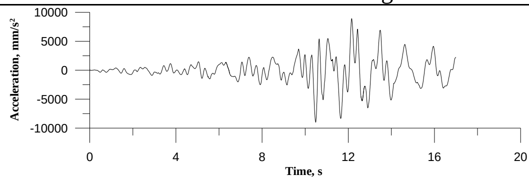
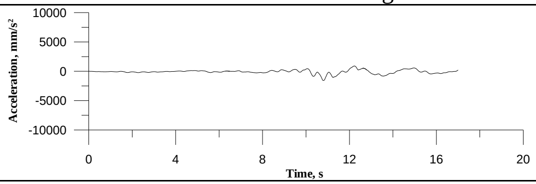
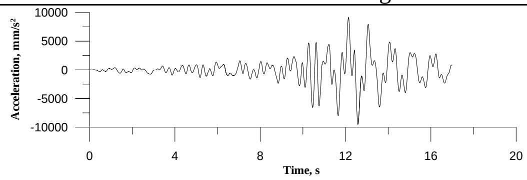
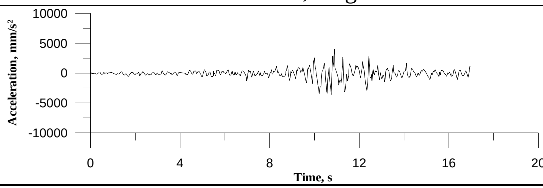
Table 1: Changes of input acceleration (1988 Spitak Earthquake accelerogram recorded at Ashotsk station) at the top of the existing 19-story (including two basement floors) base isolated and fixed base buildings in transverse (X) and longitudinal (Y) directions

<table>
<tr><td colspan="2">Response acceleration</td></tr>
<tr><td>Top of the isolated building, X direction
Max. acceleration = 0.14g</td><td>Top of the fixed base building, X direction
Max. acceleration = 0.91g</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Top of the isolated building, Y direction
Max. acceleration = 0.16g</td><td>Top of the fixed base building, Y direction
Max. acceleration = 0.95g</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">Foundation, 0.4g</td></tr>
<tr><td colspan="2">
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From the obtained results it follows that the first mode vibrations' period of the base isolated building is much longer than that for the fixed base building in transverse (X) and in longitudinal (Y) direction. Seismic isolation has reduced the maximum spectral acceleration over 2.7 times in average. On the contrary, for the fixed base building the input acceleration amplifies along the height of the building by a factor of 2.28 in transverse (X) direction and by a factor of 2.38 in longitudinal (Y) direction.

Thus, acceleration in the base isolated building is in average 6.2 times smaller than in the fixed base building. Results of calculations also show that inter-story drifts in the base isolated building are in average 4.85 times smaller than in the fixed base building and horizontal shear forces are smaller by 3.3 times in average. It is also worth mentioning that in none of the isolators the vertical force exceeds 1500 kN.

V. Conclusions

After the 7.0 magnitude earthquake along the China-Kyrgyzstan border in January 2024 the author was contacted by the scared residents of a 19-story apartment building located on the Dostyk ave. 138 in the City of Almaty with the request to consider upgrading the earthquake resistance of the mentioned building by implementation of one of the author's technologies on retrofitting of the existing buildings by base isolation.

Brief information is given in the paper on the projects carried out by the author from 1995 to 2023 on implementation of the created by him base and roof isolation technologies for the various types of the existing buildings. These were from 2 to 9-story buildings with the stone load-bearing walls, R/C bearing frames, bearing frames with shear walls, large-panel load-bearing walls, and monolithic load-bearing walls.

Existing 19-story apartment building with monolithic load-bearing walls which is supposed to be retrofitted by base isolation technology is described in detail. Plan of the basement floor where the seismic isolation system must be constructed into the existing structural elements is given. Also, the plan of the first floor at the mark ±0.00 immediately above the seismic isolation interface is presented to show all three staircases that connect it with the basement floors, as well as the existing and new cantilever slabs around the building. Geometrical dimensions of the second typical living floor at the mark +3.00 are given as well.

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Strategy for retrofitting by base isolation of the existing 19-story (including two basement floors) apartment building with monolithic load-bearing walls is described in detail based on the innovative technology developed by the author of this paper (Patent of the Republic of Armenia №579). Seismic isolation system for this building is designed at the upper level of its basement between the marks -0.30 and -1.30. The HDRBs in this interface are installed by clusters. This original approach suggested by the author has many advantages which are summarized in the paper.

The detailed vertical elevations of the seismic isolation system together with its joints are given in the paper. It is shown that structural solution of the stair flight envisages the gap at the level of the seismic isolation interface. These gaps are needed to ensure unhindered movement of the building supported by seismic isolators. The paper mentions that currently the outside parking's slabs are adjoined to the building along the axes "6" and "A" and they will not permit the free movement of the latter being supported by the seismic isolators. The developed strategy suggests dismantling of these parts of the existing slabs of outside parking and to cover the created gap between the building and the existing slabs of the parking by the newly constructed cantilever slabs. Thus, the horizontal displacement of the building's isolation system will be accommodated freely during any earthquake impact.

Earthquake response non-linear analysis of the considered building was carried based on the design model developed by application of different types of finite elements for the various bearing structures, as well as for seismic isolators. Horizontal displacement of the building's isolation system equal to 160 mm was calculated based on the provisions of the International Standards at the period of the isolated structure Ti equal to 2 sec, the damping factor of the isolation system – 15% and zone factor – 0.4.

Comparison of accelerations at the top of the existing 19-story (including two basement floors) in transverse (X) and longitudinal (Y) directions for two cases, namely, when building is base isolated and when it is a fixed base building was carried out. It is shown that seismic isolation has reduced the maximum spectral acceleration over 2.7 times in average. Acceleration in the base isolated building is in average 6.2 times smaller than in the fixed base building. Also, inter-story drifts in the base isolated building are in average 4.85 times smaller than in the fixed base building and horizontal shear forces are smaller by 3.3 times in average.

REFERENCES

[1] Naeim, F. & Kelly J. (1999). Design of seismic isolated structures. *From theory to practice, John Wiley & Sons Inc*.
[2] Melkumyan, M. (1997). The use of high damping rubber isolators to upgrade earthquake resistance of existing buildings in Armenia. *International Post-SMiRT Conference Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control of Seismic Vibrations of Structures, Taormina, Sicily, Italy*, 861-867.
[3] Melkumyan, M. (2007). Base and roof isolation for earthquake retrofitting and protection of existing buildings in Armenia, *International Symposium on Seismic Risk Reduction (the JICA Cooperation Project in Romania), Bucharest, Romania*, 593-600.
[4] Melkumyan, M., Käppeli, G., Khalatyan, R., & Hovivyan, H. (2003a). Application of seismic isolation for retrofitting of existing 3-story stone building of the school #4 in the city of Vanadzor, *Armenia, 8th World Seminar on Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures, Yerevan, Armenia*, 557-565.
[5] Melkumyan, M., Hovivyan, H., Movsessyan, L., & Terjanyan, S. (2003b). Technique of installation of seismic isolation bearings in an existing building with historical and architectural value, *8th World Seminar on Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures, Yerevan, Armenia*, 629-641.
[6] Melkumyan, M., Mihul, V., & Gevorgyan, E. (2011). Retrofitting by base isolation of existing buildings in Armenia and in Romania and comparative analysis of innovative vs. conventional retrofitting, *3rd International Conference on Computational Methods in Structural Dynamics and Earthquke Engineering, Corfu Island, Greece,* Paper No. 121.
[7] Melkumyan, M. (2011). New solutions in seismic isolation, *Yerevan, LUSABATS.*
[8] Melkumyan, M. (2014). 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 & Technology. J.*, vol.1, no.1, 1-12.
[9] Melkumyan, M. (2015). 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*, vol.2, no.12, 1153-1162.

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[10] Melkumyan, M. (2020). 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, vol.4, no.4, 199-209.

[11] Fuller, K.N.G. & Roberts, A. (1997) Longevity of natural rubber structural bearings, *Proceedings IRC 97, Kuala Lumpur*, 777-787.

[12] Kelly, J. (1995). New applications and R. & D. for isolated civil buildings in USA, *International Post-SMiRT Conference Seminar on Seismic Isolation, Passive Energy Dissipation and Control of Vibration of Structures, Santiago, Chile*.

[13] Akiyama, H. (1993). State-of-the-art in the world on seismic isolating of bearings based on the results of the international workshop held in Tokyo in April 1992 - most recent developments for buildings and bridges in Japan. *Isolation, energy dissipation and control of vibration and structures, International Post-SMiRT Conference, GLIS, Italy*, 3-26.

[14] Foti, D. & Mongelli, M. (2011). Isolatori sismici per edifice esistenti e di nuova costruzione, *Dario Flaccovio Editore*, (in Italian).

[15] Melkumyan, M. (2011). New solutions in seismic isolation. "*LUSABATS", Yerevan*.

[16] Melkumyan M. (2022). Unique Concepts and Features of Seismic Isolation Systems. "*B P International", First Edition, ISBN* 978-81-959913-0-3 (Print), ISBN 978-81-959913-6-5 (eBook), DOI: 10.9734/bpi/mono/978-81-959913-0-3, 563 p.

[17] Fuller, K.N.G. & Melkumyan, M. (1998). Development of Code for the Design of Seismic Isolation Systems, *11th European Conference on Earthquake Engineering, Paris, France.*

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