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Steps of Creation of Seismic Isolation Strategies for Sustainable Development of Construction Industry in Armenia

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1. INTRODUCTION

Earthquake engineering is one of the rather complicated fields of human activities. There is too much uncertainty in this discipline, from the earthquake phenomenon to the properties of building structures that have to withstand it. Despite notable achievements in this field, we have to admit that the humankind is still far from solving the puzzles of the Nature that it opens to us little by little with each new earthquake.

Armenia is located in a collision zone between the Arabian and Eurasian plates [1]. This causes very strong and frequent seismic activities in the country. For example, in 893 (M=6.0) and 1319 (M=5.9) earthquakes completely destroyed Dvin and Ani, the capital cities of ancient Armenia. Based on some historical data the following destructive earthquakes also can be mentioned: Vayots Dzor in 906, M=6.1; Garni in 1679, M=6.3; Ararat in 1840, M=6.7; Zangezour in 1931, M=6.3 [2].

The December 7, 1988 Spitak earthquake (M=7.0) took place in Northern Armenia, causing extensive damage and loss of lives. It was estimated that the lives of 800,000 people had been disrupted as a result of this earthquake. About 52,000 people died in the earthquake and approximately 530,000 persons were left homeless. In addition, 40 percent of the country's manufacturing capacity was destroyed just before the country achieved independence. Leninakan (Gyumri), population 270,000, Kirovakan (Vanadazor), population 185,000, Stepanavan, population 30,000 and Spitak, population 25,000, as well as more than 80 villages were paralyzed [3]. According to announcements by government leaders in Moscow and Yerevan, the disaster zone should have been completely reconstructed in two years. However, thirty-five years have elapsed already after the disastrous earthquake, but even today we still call the affected territory a "disaster zone" and it is far away to be called as completely reconstructed.

After the destructive 1988 Spitak earthquake the seismic hazard on the territory of Armenia has been revised and increased. The size of earthquakes set practically on all of the territory of Armenia now ranges up to M = 7.1 with the focal depth of 10 km, in average. All sources are located on active faults. The average recurrence interval of large earthquakes ($M \geq 5.5$) is about 30-40 years. For developing countries where the seismic risk is not only very high but is also increasing due to urbanization, the problem that mostly lacks solutions is the absence of state policy with respect to reduction of seismic risk [4]. However, the 21st century strategy for reducing the seismic risk should be based upon prioritizing preparedness over the recovery. The earthquakes on almost all the area of Armenia are now expected with an acceleration of 0.4g. At the same time, the great majority of buildings constructed before the Spitak earthquake were designed for seismic action of about 0.1-0.2g, according to the former design codes of the Soviet Union. Since the hazard was considerably underestimated in the past, the seismic resistance of buildings and structures, by which the whole republic is built up, turned out to be significantly below the level required for the real seismic hazard.

Extensive works on searching for new solutions which could strengthen houses, buildings and structures against the attacks of the underground element have been launched in 1993 by the initiative and efforts of the author of this paper. However, mass-scale strengthening of buildings does not seem feasible even for the developed countries. With this in mind, a scheme of seismic mitigation was developed, which presupposed that the buildings were to be strengthened in turns, beginning with the most vulnerable ones [5].

2. INITIAL STEPS OF CREATION OF SEISMIC ISOLATION STRATEGIES

Now, it is safe to say that solutions leading to revolutionary transformations in the field of earthquake engineering in the country have been found. These solutions are based on the application of seismic isolation systems using chloroprene rubber produced locally. The task to study thoroughly the experience accumulated for such systems worldwide and to start developing step-by-step Armenian seismic isolation technologies has been set already in 1992. As a result, the new technologies for upgrading earthquake resistance and retrofitting the existing buildings, as well as for construction of new buildings with application of seismic isolation systems were developed, and these technologies represented new directions of earthquake engineering in Armenia.

Very soon a pilot project on design of an experimental four-story building with seismic isolation and manufacture of the first laminated rubber bearing (LRB) using the cold fastening technique [6] was launched. So, the first attempt to independently analyze and design of LRB for seismic isolation was accomplished and the bearing was ready in autumn 1993. This historic event marked the start of development and introduction of unique projects in the reality of earthquake engineering practice in the country. The mentioned bearing was successfully tested (Fig. 1) in the presence of renowned experts from more than 20 countries of the world who had come to Armenia to participate in the International Conference held in Yerevan in commemoration of the 5th anniversary of the 1988 Spitak earthquake.

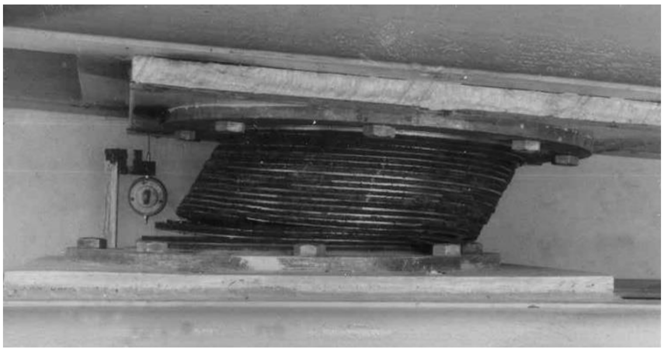

Figure 1. View of the first laminated rubber bearing manufactured in Armenia under testing

It became apparent that we were able to have our own seismic isolation structures and apply them efficiently to address the main challenges of seismic risk reduction, as well as sustainable development of construction industry in Armenia. These structures may play a critical role in the country that is situated in high seismic activity zone and is a country living through the transition period of its economic development with acute housing problems. Hence, conventional earthquake resistance upgrading techniques applied for existing buildings most probably are not acceptable in Armenia insofar as they require re-settlement of residents, and, consequently, providing them with temporary shelters, that in turn entails additional investments.

After this successful start, many other projects were developed and implemented. However, the projects at the beginning of the seismic isolation era in Armenia within the framework of Earthquake Zone Reconstruction Project (EQZRP) implemented under the World Bank Credit [7, 8] deserve special mentioning. The author of this book was appointed by the government of Armenia as Project director.

Efforts to recover from the earthquake were thwarted by political and economic upheaval that followed the breakup of the Soviet Union. International rescue efforts began in December 1988, and early 1989 were followed rapidly by reconstruction projects led by a specially created committee, which mobilized material and labor from the Soviet Republics in a concerted campaign of rebuilding. The work continued till mid-1991, but the collapse of the Soviet Union disrupted the organized reconstruction plans of the central government. The work crews were withdrawn back to their newly independent home countries without fulfilling their commitments. A total of 40 countries, in addition to all the republics of the Soviet Union, participated in the reconstruction program. And yet, when 1991 came around, the volunteer builders from other countries left, because of lack of construction materials and a collapsed infrastructure. This left vast areas of partially completed apartment blocks, factories, and infrastructure projects, and even more damaged buildings and infrastructure to be cleared and restored [8].

In the first two years less than 10% of the residences planned for reconstruction were successfully completed. During the second year, however, construction by volunteer units from many countries provided additional living space, as well as facilities for schools and hospitals. Some examples of the contribution by volunteer units are as follows: a school for 400 students (United Kingdom); a 90-bed hospital (France); a construction materials factory (Austria); a rubble processing factory (Germany); a village with a school (Italy); a hospital (Norway); a rehabilitation center (Finland); a school for 480 students (Czech Republic); 24 cottages and a kindergarten (Denmark); a housing building complex (USA); an outpatient clinic (Poland), etc. These examples illustrate the volunteer efforts for reconstruction that brought hope and feeling of gratitude to the disaster region [9].

In 1992 Armenia joined the World Bank and requested the Bank assistance in re-mounting the reconstruction effort. World Bank judged that International Development Association (IDA) involvement was justified to alleviate the pressing economic and social problems and to provide a unique opportunity to support implementation of basic economic reforms in housing and infrastructure. It was acknowledged that the volume of reconstruction needed was well beyond the scope of a single operation. However, the project was intended to provide an opportunity for the government to reaffirm its commitment to the reconstruction effort and provide the physical basis and a coherent plan for continuing the process. Although it came some five years after the earthquake, the World Bank's EQZRP - an IDA credit - was the first significant donor activity in Armenia in the post-Soviet era [8].

EQZRP pursued three objectives: a) to provide improved housing and living conditions to the residents of the earthquake zone; b) to reconstruct the basic infrastructure, which will contribute to the creation of jobs; and c) to support a longer term sustainable program for rehabilitation in the earthquake zone. The Project comprised of four components:

1. Housing, including completion of unfinished apartment buildings; repair and strengthening of damaged buildings; and land development and construction of serviced plots and starter houses for single family ownership and self-help expansion.
2. Municipal services, including provision of selected water supply and sewerage sub-projects in Spitak, Vanadzor and Gyumri; and community facilities.
3. Factory shells, including the completion of those for existing profitable industries.
4. Technical Assistance, Training, Equipment and Studies.

The credit of SDR 20.1 million was disbursed locally. This was estimated to be equal to USD 28.0 million. Disbursement followed the projected profile totaling at closing USD 29.75 million, thanks to SDR appreciation. Moreover, additional civil works valued at about USD 600,000 were achieved through the use of contractor penalties, for a total value of USD 30.3 million. The Project was highly ranked by the World Bank and was implemented in about 20 cities and villages of the earthquake zone (Fig. 2). Construction of 2,862 apartments, 10 factories, 6 schools, 2 hospitals, 11 bathhouses, a stadium, community center, kindergarten and library, as well as 40 km of water pipes has been accomplished. At this step of development of seismic isolation strategies construction, retrofitting or protection of four buildings were financed by the World Bank (Fig. 3).

The earthquake engineering approaches have principally changed after the Spitak earthquake. Construction of prefabricated multi-story frame buildings in the earthquake zone was renounced. Erection of mainly monolithic, up to 5-story buildings was started in the cities, while rural areas started applying up to 2-story stone masonry buildings in complex with reinforced concrete monolithic elements. Construction of large-panel buildings comprised a small percentage. Along with the construction of new buildings, attention has been paid to seismic protection of the existing buildings that have survived Spitak earthquake. Significant transformations in Armenia were related specifically to that field.

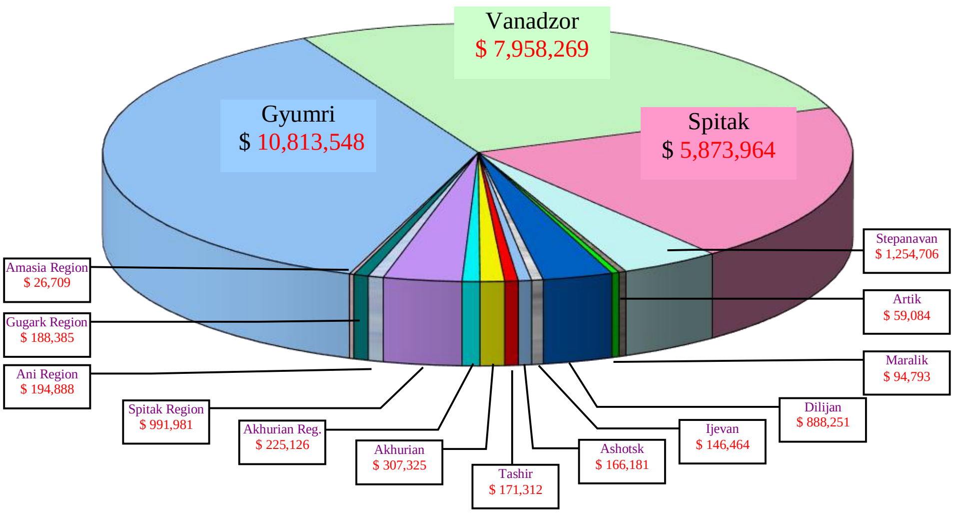

Figure 2. Distribution of credit funds by cities and regions of the earthquake zone

(a) (b) (c) (d)

Figure 3. Construction, retrofitting or protection of four buildings financed by the World Bank
(a) View of the bath-house under construction and details of its base isolation system; (b) View of the existing 5-story stone apartment building retrofitted for the first time in the world by base isolation without moving people out from their apartments and fragments of its isolation system; (c) and (d) Views of the two existing R/C frame 9-story apartment buildings protected by roof isolation system – Additional Isolated Upper Floors (AIUF) acting as vibration dampers

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 [10] "…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 [11] 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 [12] 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 [13] 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".

These technologies were successfully implemented under the first and second components of the mentioned EQZRP. This Project funded retrofitting of an occupied 5-story apartment building by means of base isolation system without requiring temporary resettlement of the tenants, something that had heretofore not been accomplished anywhere in the world. The same is true for another low-cost seismic protection technology named Additional Isolated Upper Floor (or roof isolation), also funded by EQZRP and implemented on two 9-story apartment buildings. The works also won the attention of the United Nations Industrial Development Organization (UNIDO), an influential international agency, which finances similar projects under its programs. The result of negotiations was an agreement that UNIDO will finance manufacturing of 60 LRBs for retrofitting an existing five-story building, as well as will organize special three months training for Armenian specialists in the UK based Malaysian Rubber Producers' Research Association, which was one of the world's leading centers on development and introduction of seismic isolation systems.

Thus, in a short period of time actual implementation of seismic isolation has started in the country. Citing the advanced research level and practical value of these works along with their extreme importance for the country, the Engineering Academy of Armenia has recommended the Government to provide prerequisites for large-scale application of the newly developed systems on the territory of Armenia. Moreover, the Academy has sent recommendations to international financial organizations offering to take advantage of the unique experience gained in the country and to make use of it not only within Armenia, but in other earthquake-prone countries as well.

2. Further Steps of Creation of Seismic Isolation Strategies

Further development and application of seismic (base) isolation strategy in construction of new and retrofitting of existing medium- and high-rise buildings took place owing to projects financed by Huntsman Corporation, Caritas Switzerland, Hayastan All-Armenian Fund, "Tufenkian Hospitality" LLC, "Elite Group" CJSC, "ITARKO Construction" CJSC, "Fredex Services" CJSC, Governmental program for providing apartments for young families, and the Healthcare Project Implementation Unit of the Ministry of Health, as well as private individuals who were constructing their own houses (Figure 4).

The author is absolutely confident that seismic isolation strategies are the way to provide sustainable development of construction industry in Armenia. The matter is that seismic isolation solves the problem of reducing simultaneously inter-story drifts and floor accelerations at each level of the buildings. This is easy to understand looking at the deformations of the buildings along their height. Results of calculations for the buildings in Figure 4 based on the Armenian Seismic Code show that inter-story drifts in base isolated building are smaller than in fixed base building by 2.6 times in average and horizontal shear forces are smaller by 2.3 times in average. Time history analyses bring to even much bigger differences. In base isolated building reduction of 0.4g input acceleration takes place along the height of superstructure by 2.6 times in average, but in fixed base building vice versa amplification of 0.4g input acceleration takes place along the height of structure by 2.25 times. Similar results were received by the author when carrying out comparative analyses for many other base isolated and fixed base buildings [14]. Due to his huge efforts Armenia now is the second country in the world after Japan by the number of seismic isolated buildings per the number of residents.

Figure 4. Views of some newly constructed and retrofitted base isolated buildings in Armenia with seismic isolation systems located at different levels

(a) 16- and 10-story buildings of the multifunctional residential complex "Our Yard", (b) 20-story business center "Elite Plaza", (c) 16- and 14-story buildings of the multifunctional residential complex "Arami", (d) 18-story buildings of the multifunctional residential complex "Northern Ray", (e) 17-story building of the multifunctional residential complex "Baghramian", (f) 16- and 13-story buildings of the multifunctional residential complex "Dzorap", (g) 4-story apartment building with reinforced masonry bearing walls in Huntsman Village of Gyumri city,

(h) 3-story private house in the village Jrvezh, (i) 3-story retrofitted existing school building in Vanadzor city.

Projects from (a) to (f) and project (q) on construction of 14 new multi-story buildings were financed by “Elite Group” CJSC. Project (g) on construction of 2 new low-story buildings was financed by Huntsman Corporation. Project (h) and similar 3 projects on construction of new private houses were financed by their owners. Project (i) on retrofitting of existing school building was financed by Caritas Switzerland.

Figure 4. (Continued)

(j) 9-story retrofitted existing hematology center hospital building, (k) 9-story retrofitted existing apartment building in Stepanakert, (l) 5-story retrofitted existing hotel building (m) 15-story building of the multifunctional residential complex “Avan”, (n) 17-story building of the multifunctional residential complex “Sevak”. (o) 3-story clinic building in Stepanakert, (p) 7-story hotel/commercial center building, (q) 11-story building of the multifunctional residential complex “Cascade”, (r) 4-story hospital building in Vanadzor

Project (i) on retrofitting of existing hematology center hospital building was financed by the Healthcare Project Implementation Unit of the Ministry of Health. Project (k) on retrofitting of existing apartment building was financed by the Ministry of Urban Development of Artsakh. Project (l) on retrofitting of existing hotel building was financed by the “Fredex Services” CJSC. Project (m) on construction of new multi-story building was financed by the Governmental program for providing apartments for young families. Project (n) on construction of new multi-story building was financed by “ITARKO Construction” CJSC. Project (o) on construction of new 3-story clinic building was financed by Hayastan All-Armenian Fund. Project (p) on construction of new 7-story hotel/commercial center building was financed by “Tufenkian Hospitality” LLC. Project (r) on construction of new 4-story hospital building was financed by the World Bank and the Healthcare Project Implementation Unit of the Ministry of Health

Given the local manufacturing of different types of rubber bearings, seismic isolation techniques developed in Armenia lead to significant savings in construction costs. This fact attracts the attention of different institutions and private investors. Construction of ordinary (apartment) buildings and critical facilities (schools, hospitals, etc.) using seismic isolation costs 30-40% less in comparison with the conventionally designed buildings. Much higher savings were attained in retrofitting of an apartment building and a school building. In these cases, due to seismic isolation the cost of retrofitting was about 3-5 times less in comparison with the cost of conventional retrofitting.

There are several reasons for the mentioned savings. One of them is that rubber bearings manufactured in Armenia cost significantly less than bearings manufactured elsewhere in the world. This is conditioned by the lower labor cost, availability of rubber components in the country, as well as existence of several competing factories capable of manufacturing high quality rubber bearings with low (LDRB), medium (MDRB) and high (HDRB) damping. Also, the provisions of the Armenian Seismic Code for seismically isolated structures are much more progressive in comparison with, for example, the USA Code in terms of analysis and design of superstructures of base isolated buildings. As a result, a huge amount of reinforcement could be reduced in superstructures of R/C base isolated buildings designed in accordance with the Armenian Code. In addition, cross-sections of the bearing structures (columns, beams, shear walls) are smaller, and there is no need to apply high strength concrete for them. Therefore, large amounts of concrete and cement may also be saved in superstructures.

Thus, successful implementation of seismic isolation technologies in the last 30 years, the presence of industry capable of local manufacture of seismic isolators, the presence of capable scientific and engineering brainpower for local development and design of seismic isolation systems, the possibility of retrofitting by seismic isolation without interruption of the use of the facilities, the low cost of retrofitting and new construction with seismic isolation, and the possibility of speeding up the retrofitting process fully justify further practical application of the advanced seismic isolation technologies in Armenia. Furthermore, worldwide experience proves that seismic isolation is the most reliable technology. Excellent examples demonstrating the effectiveness and high reliability of seismically isolated buildings during the destructive Hanshin-Awaji earthquake in 1995 (Japan) [15] and the Great Sichuan Earthquake in 2008 (China) [16] are well known.

It is also known that the growth in the number of seismically isolated buildings is still quite slow, with the exception of some countries such as Japan, Italy, China and currently Armenia. A serious reason for this is the lack of provisions in the seismic codes for analysis and design of such type of buildings [17]. This problem, however, was solved in Armenia and, thus, successful application of seismic isolation in the country is also conditioned by availability of relevant legal and technical documentation, including: a chapter on *Buildings and Structures with Seismic Isolation Systems* in the National Design Code for Earthquake Resistant Construction, the *Guidelines for Design and Construction of Buildings with Application of Laminated Rubber-Steel Bearings*, and the *Standards (Specifications) on Manufacturing of Seismic Isolation Laminated Rubber-Steel Bearings*. All these documents were developed by the order of the Ministry of Urban Development, adopted by the Government of Armenia and are in force since 2006 [18].

3. Statistics on Buildings with Application of Seismic Isolation Strategies from 1994 to 2023

It should be emphasized that Armenia was experiencing extremely hard times in 1993 when the works on development and research of seismic isolation technologies were initiated by the author of this paper. Since then, during a period of 30 years about 67 buildings and structures have been designed in Armenia with application of base or roof isolation systems. Of these designed buildings the total number of already constructed and retrofitted buildings or those currently under construction has reached 60. About 5500 rubber bearings were manufactured in Armenia tested locally and sent to construction sites.

Among the seismic isolated buildings there are bathhouses, private residences, school buildings, clinic and hospital buildings, business and commercial centers, apartment buildings, hotels, and Zvartnots International airport buildings. Above is mentioned that number of seismically isolated buildings per capita in Armenia is one of the highest in the world [19]. This is evidenced in [20], where it is stated: “*It is worthwhile stressing that Armenia remains second, at worldwide level, and has the largest number of building applications of seismic isolation per number of residents, in spite of the fact that it is still a developing country*”.

Detailed statistics on constructed and retrofitted buildings in Armenia designed by the author of this book with application of seismic isolation technologies for the mentioned period of time is given in the Tables 1-5 [21, 22, 23].

Table 1. Statistics on buildings with application of seismic isolation technologies from 1994 to 2003

Building	Bathhouse with two 10 t water tanks in the attic space	Existing apartment building with stone bearing walls	Existing apartment building with R/C bearing frames and shear walls	Apartment building with R/C bearing walls
Type of seismic isolation	Base isolation	Base isolation	Additional Isolated Upper Floor (AIUF, roof isolation)	Base isolation

Dimensions (m) of buildings in plan	21×12	52×15	19×19	33×14
Number of stories	1	5	9	4
Years of design	1994	1994-1995	1995	1996
Years of implementation	1994-1995	1995-1996	1996-1997	1997-1998
Number of buildings	6	1	2	1
Newly constructed or retrofitted	Newly constructed	Retrofitted	Retrofitted	Newly constructed
Place of implementation	Spitak (2), Gyumri (2), Vanadzor (2)	Vanadzor	Vanadzor	Spitak
Number and type of rubber bearings	126, LDRB*	60, HDRB**	32, HDRB	39, HDRB
Manufacturer of rubber bearings	NAIRIT, Armenia	TARRC, UK; Min Rubber Products and Sime Engineering Rubber Products, Malaysia	NAIRIT, Armenia; Min Rubber Products, Malaysia	Min Rubber Products, Malaysia
Building	Apartment building with R/C masonry bearing walls	Single-family house with stone bearing walls	Existing school building No.4 with stone bearing walls	Clinic building with R/C bearing frames and shear walls
Type of seismic isolation	Base isolation	Base isolation	Base isolation	Base isolation
Dimensions (m) of buildings in plan	34×20	15×15	38×21	47×20
Number of stories	4	2	3	3
Years of design	1999-2000	2001	2001	2002
Years of implementation	2000-2001	2001-2002	2002	2003
Number of buildings	2	1	1	1
Newly constructed or retrofitted	Newly constructed	Newly constructed	Retrofitted	Newly constructed
Place of implementation	Huntsman Village, Gyumri	Proshyan Village	Vanadzor	Stepanakert
Number and type of rubber bearings	110, MDRB***	16, MDRB	41, MDRB	48, MDRB
Manufacturer of rubber bearings	YFRTA, Armenia	YFRTA, Armenia	YFRTA, Armenia	YFRTA, Armenia

***MDRB - Medium damping rubber bearing (8-10%)

Table 2. Statistics on buildings with R/C bearing frames and shear walls with application of seismic isolation technologies from 2003 to 2006

Building	Residential house with dynamic damper	Apartment building in "Our Yard" complex	Apartment building in "Our Yard" complex	Apartment building "Cascade"
Type of seismic isolation	Base isolation	Base isolation	Base isolation	Base isolation
Dimensions (m) of buildings in plan	14×14	58×21	32×23	45×17
Number of stories	2	10	16	11
Years of design	2003-2004	2004-2005	2004-2005	2005
Years of implementation	2004-2005	2005	2005	2005
Number of buildings	1	2	1	1
Newly constructed or retrofitted	Newly constructed	Newly constructed	Newly constructed	Newly constructed
Place of implementation	Jrvezh	Yerevan	Yerevan	Yerevan
Number and type of rubber bearings	16, MDRB	304, MDRB	160, MDRB	128, MDRB
Manufacturer of rubber bearings	GTMC, Armenia	Retine Noruyt, Armenia	Retine Noruyt, Armenia	Retine Noruyt, Armenia

Building	Business center "Elite Plaza"	Apartment building in "Arami" complex	Apartment building in "Arami" complex	Apartment building in "Dzorap" complex	Apartment building in "Dzorap" complex
Type of seismic isolation	Base isolation	Base isolation	Base isolation	Base isolation	Base isolation
Dimensions (m) of buildings in plan	42×36	33×32	52×33	32×33	67×29
Number of stories	20	14	16	13	16
Years of design	2005	2005	2005	2005-2006	2005-2006
Years of implementation	2005	2005	2005	2006	2006
Number of buildings	1	1	1	1	1
Newly constructed or retrofitted	Newly constructed	Newly constructed	Newly constructed	Newly constructed	Newly constructed
Place of implementation	Yerevan	Yerevan	Yerevan	Yerevan	Yerevan
Number and type of rubber bearings	246, MDRB	147, MDRB	224, MDRB	73, MDRB	239, MDRB
Manufacturer of rubber bearings	Retine Noruyt, Armenia	Retine Noruyt, Armenia	Retine Noruyt, Armenia	Retine Noruyt, Armenia	Retine Noruyt, Armenia

Table 3. Statistics on buildings with R/C bearing frames and shear walls with application of seismic isolation technologies from 2006 to 2009

Building	Apartment building in "Northern Ray" complex	Commercial center/hotel	Apartment building "Baghramian"	Hotel building
Type of seismic isolation	Base isolation	Base isolation	Base isolation	Base isolation
Dimensions (m) of buildings in plan	74×39	45×37	41×36	56×26
Number of stories	18	7	17	6
Years of design	2005-2007	2007-2008	2007-2008	2007-2008
Years of implementation	2007	2007	2008	2009
Number of buildings	2	1	1	1
Newly constructed or retrofitted	Newly constructed	Newly constructed	Newly constructed	Newly constructed
Place of implementation	Yerevan	Yerevan	Yerevan	Dilijan
Number and type of rubber bearings	904, MDRB	113, MDRB	271, MDRB	102, MDRB
Manufacturer of rubber bearings	Retine Noruyt, Armenia	Khachvar, Armenia	Retine Noruyt, Armenia	Khachvar, Armenia

Table 4. Statistics on buildings with application of seismic isolation technologies from 2010 to 2016

Building	Apartment building with R/C bearing frames and shear walls	School building with stone bearing walls	School building with stone bearing walls	Apartment building "Avan" with R/C bearing frames and shear walls
Type of seismic isolation	Base isolation	Base isolation	Base isolation	Base isolation
Dimensions (m) of buildings in plan	23×25	33×15	37×16	40×28
Number of stories	13	2	2	15
Years of design	2010	2010	2010	2010
Years of implementation	2010	2010	2010	2011
Number of buildings	1	1	1	1
Newly constructed or retrofitted	Newly constructed	Newly constructed	Newly constructed	Newly constructed
Place of implementation	Yerevan	Vardakar Village	Akhurik Village	Yerevan
Number and type of rubber bearings	112, MDRB	36, MDRB	40, MDRB	247, MDRB
Manufacturer of rubber bearings	R.M.I.A, Armenia	R.M.I.A, Armenia	R.M.I.A, Armenia	R.M.I.A, Retine Noruyt, Armenia

Building	Apartment building “Sevak” with R/C bearing frames and shear walls	Medical center “Vanadzor” with R/C bearing frames and shear walls	Existing building with R/C bearing frames and shear walls of Yeolyan Hematology center	Existing industrial building with R/C bearing frames to be converted into hotel
Type of seismic isolation	Base isolation	Base isolation	Base isolation	Base isolation
Dimensions (m) of buildings in plan	30×30	86×69	38×26	81×18
Number of stories	17	4	9	6
Years of design	2011	2013	2013	2014
Years of implementation	2012	2014	2015	2016
Number of buildings	1	1	1	1
Newly constructed or retrofitted	Newly constructed	Newly constructed	Retrofitted	Retrofitted
Place of implementation	Yerevan	Vanadzor	Yerevan	Yerevan
Number and type of rubber bearings	184, MDRB	260, HDRB	117, HDRB	158, HDRB
Manufacturer of rubber bearings	R.M.I.A, Armenia	Retine Noruyt, Armenia	Retine Noruyt, Armenia	Retine Noruyt, Armenia

Table 5. Statistics on buildings with application of seismic isolation technologies from 2017 to 2022

Building	Two residential town-houses with stone bearing walls unified by one rigid base isolated R/C slab		Existing apartment building with R/C large panel bearing walls	Existing building with stone bearing walls to be converted into kindergarten
	town-house №1	town-house №2		
Type of seismic isolation	Base isolation		Base isolation	Base isolation
Dimensions (m) of buildings in plan	11×9.75	11×9.75	34.6×11.2	30.2×19.7
Number of stories	3	3	9	3
Years of design	2017-2018		2019	2022
Years of implementation	2019	2020	2021	2022
Number of buildings	1	1	1	1
Newly constructed or retrofitted	Newly constructed	Newly constructed	Under retrofitting	Under retrofitting
Place of implementation	Jrvezh		Stepanakert	Stepanakert
Number and type of rubber bearings	12, HDRB		62, HDRB	33, HDRB
Manufacturer of rubber bearings	Shahnazaryans, Armenia	Shahnazaryans, Armenia	Shahnazaryans, Armenia	Shahnazaryans, Armenia

Note: “Shahnazaryans” LLC is a successor of R.M.I.A. Ltd

In 2023 a base isolated 5-story R/C apartment building was designed by "Melkumyan Seismic Technologies" LLC as a gift to the people suffered from the Turkey-Syria Earthquake of February 6, 2023 for the multiple applications in the devastated areas.

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