MONITORING AND EVALUATION OF TECHNICAL CONDITIONS OF SEISMIC ISOLATION SYSTEMS IMPLEMENTED IN ARMENIA

Global Facility for Disaster Risk Reduction
“Armenia: Institutional Arrangements for Disaster Risk Management and Reduction”

February 2009
**ACRONYMS AND ABBREVIATIONS**

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<td>Seismic Isolation Laminated Rubber-Steel Bearings</td>
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<td>GFDRR</td>
<td>Global Facility for Disaster Reduction and Recovery</td>
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<td>ISDR</td>
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The Global Facility for Disaster Reduction and Recovery (GFDRR) is a partnership of the World Bank, the International Strategy for Disaster Reduction (ISDR) and bilateral donors to support the implementation of the Hyogo Framework for Action (HFA). GFDRR was established to help developing countries enhance their capacity for disaster prevention, emergency preparedness and recovery. It also promotes awareness building on technical know-how and specific risk-reduction technologies and on best practice experiences in disaster risk reduction and management.

One of the objectives of a GFDRR funded project in Armenia (Institutional Arrangements on Disaster Risk Management and Reduction) is awareness building among the decision makers, professional engineering and construction community, and local self-governments on the modern, anti-seismic technologies successfully developed and implemented in Armenia.

In early 90s seismic isolation technologies were developed in Armenia by Prof. Mikayel Melkumyan. Since 1994 these technologies (base and roof isolation) were implemented on 32 buildings, including application of seismic isolation both for new construction as well as for retrofitting of the existing buildings and structures. The main advantages of the seismic isolation technology are: i) high earthquake resistance of the seismically isolated structures; ii) low cost of construction or retrofitting in Armenia in comparison with the traditional methods of new construction or strengthening of existing structures; iii) possibility of retrofitting of existing structures without interruption of the functioning of the buildings and without evacuation of the tenants; iv) possibility of preserving the historical and architectural value of the cultural heritage buildings/monuments without damaging them while retrofitting; v) significant speeding-up the process of strengthening; vi) provides the only practical way of reducing simultaneously interstory drifts and floor accelerations; vii) provides the necessary flexibility, with the displacements concentration mainly at the isolation level, etc.

The concept of base isolation is quite simple. The system decouples the building or structure from the horizontal components of the ground motion by interposing structural elements with low horizontal stiffness between the structure and the foundation. This gives the structure a fundamental frequency that is much lower than both its fix-base frequency and the predominant frequencies of the ground motion. The first dynamic mode of the isolated structure involves deformation only in the isolation system, the structure above being to all intents and purposes rigid. The higher modes that produce deformation in the structure are orthogonal to the first mode and, consequently, to the ground motion. These 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 structure. The isolation system does not absorb the earthquake energy, but rather deflects it through the dynamics of the system; this effect does not depend on damping, but a certain level of damping is beneficial to suppress possible resonance at the isolation frequency.

The seismic isolation laminate rubber-steel bearings (SILRSB) in the above mentioned 32 buildings are mainly of Armenian production, with the exception of a number of isolators in three buildings, which were of Malaysian production. The greatest achievements in the field of seismic isolation in Armenia were: i) for first time in the history of the norms of seismic resistant construction the development and inclusion of a chapter on the Seismic Isolation of Buildings and Structures in the National Seismic Code in 2005; ii) the development at the American University of Armenia by the order of the Ministry of Urban Development of the State Standard on Production of the Seismic Isolators, as well as of the Guidelines on Design and Construction of Seismic Isolated Buildings and their adoption by the government of Armenia in 2006.
By the number of applications of seismic isolated structures per capita Armenia now stands among the world leaders in this field, like Japan, USA, Italy and China. However, for a long time some resistance was observed by the construction and engineering community, as well as decision makers in the construction industry to acknowledge and to use the seismic isolation technologies. The hesitance and reluctance mainly was conditioned by the lack of awareness and necessary understanding of the technology and its advantages. The prevailing conservative mindset among the older generation of engineers as well as the absence of new and relevant syllabus on earthquake engineering in the universities also contributed to the resistance and in some cases of rejection of the technology. Some doubts were expressed about the quality of the locally produced seismic isolators.

To raise awareness on the seismic isolation technology it was decided to first evaluate the functioning of all seismic isolation systems in the already constructed buildings in Armenia. Then based on the carried out observations to analyze the results, to draw lessons from the findings and to present the conclusions and recommendations to the wider engineering and construction community, as well as to the decision makers in the construction industry. For that purpose monitoring and evaluation of the technical conditions of the seismic isolation systems in the buildings which were seismically isolated for more than a decade ago was carried out. This initiative was very useful, as it helped to answer to the frequently asked questions and concerns on the sustainability and effectiveness of the technology, of the seismic isolators. It also helped to draw lessons and recommend solutions for improving their construction and maintenance practices.

Overall eleven seismically isolated buildings were identified and investigated in Yerevan, Vanadzor, Gyumri and Spitak. Among those eleven buildings the first application of base isolation was performed 14 years ago.

As a result of visual and instrumental investigations and subsequent analysis a number of conclusions and recommendations were made.

The following findings were made:

- In all buildings the seismic isolators remain in good technical conditions with their vertical deformations and their rubber hardness in compliance with the design requirements and with the allowable values corresponding to the standards;
- In all buildings the bearing structures below and above the seismic isolators are in good technical conditions;
- In some buildings violations of the design requirements in relation to the seismic isolation systems have taken place during the construction period;
- In some buildings unacceptable arbitrary alterations to the seismic isolation structures have been made by the tenants at further exploitation stages;
- There is no legal framework regulating the maintenance and exploitation of the seismic isolated buildings;
- There is a lack of understanding of the simple rules for maintenance and exploitation of the seismic isolated systems among the tenants, local self-government bodies and developers;
- The construction supervision lacks the necessary quality control mechanisms to ensure the compliance of the constructed structures to the design requirements.
These violations may impede the full functioning of the buildings as seismically isolated structures during earthquakes, may cause unpredictable deformations, damages and destructions of different level in the bearing structures of the buildings.

In order to avoid such undesirable occurrences and to ensure the safe exploitation of the seismically isolated buildings the following recommendations were made:

- It is necessary to ensure the strict compliance of the constructed structures to the designs;
- It is necessary to improve the quality of technical supervision of construction works;
- In some of the buildings it is necessary to dismantle all non-structural elements that have been arbitrarily created in violation of the design requirements and which do not allow the buildings to function of full value as seismically isolated structures;
- It is necessary to develop and adopt the corresponding legal framework regulating the exploitation and maintenance of seismic isolated buildings;
- It is advisable to distribute the regulations among local self-governance bodies, private developers, and tenants in order to increase their awareness on the principles and behavior of seismic isolated buildings;
- It is advisable to conduct seminars for the tenants of the seismic isolated buildings explaining the main rules of maintenance of seismic isolation systems.
- It is advisable to organize special seminars and workshops for construction companies, private investors, developers and local self-government bodies in order to explain the concept of the seismic isolation, the benefits and advantages over conventional methods of construction and retrofitting of the buildings and structures.
PART 1

OBSERVATIONS, ANALYSIS AND CONCLUSIONS ON THE TECHNICAL CONDITIONS OF SEISMIC ISOLATORS AND OF STRUCTURAL ELEMENTS ABOVE AND BELOW THE SEISMIC ISOLATION SYSTEMS

Technical conditions of seismic isolators and of structural elements above and below the seismic isolation systems in eleven buildings were observed visually and instrumentally. Of these four buildings were observed in Yerevan, four buildings in Vanadzor, two buildings in Gyumri and one building in Spitak. The obtained results for each building are given below.

A. “Cascade” Complex, Demirchyan street, Yerevan

The building is newly constructed. Presently the main construction works are completed and the inside and outside finishes are in the final stage. The seismic isolators were installed in 2005.

The general view of the building from the south-west side

The building is seismically isolated by installation of SILRSBs between the two parking floors and the ten residential floors. 140 SILRSBs were envisaged by the design and installed under the columns by clusters of four, five, six and seven pieces in the seismic isolation zone in transverse and longitudinal directions of the building. SILRSBs are produced in Armenia and at the unloaded state have 202.5mm height and 18-20mm thick recess rings. The design period of vibrations of the building in transverse direction is equal to $T_x=1.91$ sec and in longitudinal direction – $T_y=1.90$ sec.

In the present loaded condition using seismo-metric equipment the frequencies and the periods of free vibrations of the building in X and Y directions were determined and were equal accordingly to $\omega_x=1.4 \text{ Hz}$, $\omega_y=1.4 \text{ Hz}$, $T_X=0.71 \text{ sec}$, $T_Y=0.71 \text{ sec}$ (the results obtained during the seismometric measurements are given in Part 2).
The height between the upper and lower recess rings of SILRSBs as well as the rubber hardness for every fourth SILRSB was also measured. The obtained results of these measurements are given in the Table 1.1 (Annex 8).

From the visual and instrumental observations it was revealed:

- The steel plates above and below SILRSBs bolted to the recess rings were not painted and were corroded in some parts.
- In the seismic isolation zone the gap between the lower and upper parts of the building in some parts was filled with foam-plastic tiles which, however, will not essentially hinder the free movement of the mentioned parts of the building in relation to each other.
- There were some fractions within the gap which were filled by plywood fixed to the lower and upper bearing structures of the isolation system.
- In those parts where the elevator shafts are constructed the gaps are filled by concrete blocks using cement mortar. No horizontal deformation joints are left at the upper part of the concrete blocks. The leads of the elevators are continuous and do not have the necessary cuts.
- In the zone of the gaps between the coating tiles of the stairs the envisaged by the design deformation joint does not exist. The mentioned in-fills, the absence of the deformation joint, the absence of the cuts in the leads are design violations and may impede the free movement of the parts of the building in relation to each other.
- At the facade of the building in the crossing point of the axes “G” and “8”, a water pipe is installed between the SILRSBs, which barricade the access to the bearings during the inspections. In case of any accident it will bring to the moistening of the joint’s bearing structures.
- No cracks, caving and other types of deformations and damages were observed in the structural elements adjacent to the joints where the seismic isolators are installed.

The mentioned deficiencies and unacceptable arbitrary applied solutions are shown in the photos in Annex 1.

Based on the carried out on the visual and instrumental investigations it is concluded and recommended:

- There is a relationship between the design value of the period of vibrations of the building and the period corresponding to the initial stiffness of SILRSBs according to the existing standards \( T_{\text{design}} / \sqrt{10} \approx T_{\text{initial}} \). However, it was revealed that \( T_{\text{initial}} \approx 0.6 \text{sec} \) is smaller by 1.18 times than the measured actual value \( T_x = T_y = 0.71 \text{sec} \). Most probably the weight of the superstructure (the part of the building above the seismic isolation system) is bigger by around 40% than its design value, which caused the above inconsistency. The main reasons for the increased weight are the increased mass of the building’s coating layers and the floors’ smoothing layers.
- The average height of the loaded SILRSBs between the recess rings is equal to \( h_{\text{average}} = 159.8 \text{mm} \).
- The average value of the rubber hardness, which was measured for every fourth rubber bearing is equal to \( A_{\text{average}} = 77.2 \).
- The heights between the recess rings of SILRSBs and the magnitudes of their rubber hardness are in compliance with the design requirements and with the allowable values corresponding to the standards.
• In the zone of seismic isolation gap it is necessary to remove the construction rubbish and to paint the steel plates above and below SILRSBs bolted to the recess rings or to cover them with anticorrosion materials.

• It is necessary to change the location of the water pipe at the crossing point of the axes “G” and “8” by moving it off from the mentioned joint.

• It is necessary to remove the fixed in the seismic gap plywood and to dismantle the arbitrary installed concrete blocks of the elevator shafts within the seismic gap so that to comply with the design requirements.

• When choosing any options for mounting the seismic gap it is necessary to allow access to the seismic isolators for periodical inspections and measurements.
ANNEX 1. Photos illustrating some of the observed deficiencies and unacceptable arbitrary solutions in the seismic isolation zone.

Fig. 1. The part of the seismic gap adjacent to the elevator shaft filled in with concrete blocks.

Fig. 2. The part of the seismic gap filled in by the plywood.
Fig. 3. The unacceptable arbitrary solution of the coating tiles of the stairs at the seismic gap.

Fig. 4. The water pipe installed between the rubber bearings.
B. “Our Yard” Complex, Zavaryan and Rostomi streets, Yerevan

The complex consists of three buildings with a “IT” shape location in the plan.

The general view of the complex from south-west side.

The complex is newly constructed. Presently the main construction works are completed and the inside and outside finishes are in the final stage. Seismic SILRSBs were installed in 2005.

The buildings are seismically isolated by installation of SILRSBs between the three parking floors and the upper residential floors. 152 SILRSBs were envisaged by the design and installed under the columns by clusters of two, three, four, and five pieces in the seismic isolation zone in transverse and longitudinal directions of the 1st and 3rd buildings that have ten residential floors. In the 2nd building, which has sixteen residential floors, 160 SILRSBs were installed by clusters of three, four, five, six and seven pieces, including some single bearings installed separately from the clusters. In these buildings SILRSBs were produced in Armenia. At the unloaded state SILRSBs have 202.5mm height and 18-20mm thick recess rings. The design periods of vibrations of the buildings correspondingly are equal to:
- for the 1st building - $T_x1=2.04$ sec and $T_y1=2.08$ sec
- for the 2nd building - $T_x2=2.06$ sec and $T_y2=2.17$ sec
- for the 3rd building - $T_x3=2.04$ sec and $T_y3=2.08$ sec

In the present loaded condition using seismo-meteric equipment the frequencies and the periods of free vibrations of the buildings in X and Y directions were determined and were equal accordingly to:
- for the 1st building - $\omega_x1=1.55$ Hz, $\omega_y1=1.55$ Hz, and $T_x1=0.64$ sec, $T_y1=0.64$ sec
- for the 2nd building - $\omega_x2=3.1$ Hz, $\omega_y2=2.15$ Hz, and $T_x2=0.32$ sec, $T_y2=0.47$ sec
- for the 3rd building - $\omega_x3=1.5$ Hz, $\omega_y3=1.5$ Hz, and $T_x3=0.67$ sec, $T_y3=0.67$ sec

(the results obtained during the seismometric measurements are given in Part 2).
The height between the upper and lower recess rings of SILRSBs as well as the rubber hardness for every fourth SILRSB was also measured. The obtained results of these measurements are given for each building in the Tables 2.1, 2.2 and 2.3 (Annex 8).

From the visual and instrumental observations it was revealed:

- The steel plates above and below SILRSBs bolted to the recess rings were not painted and were corroded in some parts;
- In the seismic isolation zone the gaps between the lower and upper parts of the buildings were not cleaned from the construction waste and accumulated rubbish.
- Along the exterior perimeter of all buildings a cantilever slab is envisaged by the design and the deformation joint between this slab and the fencing structure below it should be created. However, in some parts the deformation joint is filled-in by cement mortar and in other parts the coating touches the cantilever slab directly.
- The sloping slabs going to the inside yards also have direct structural contact with the cantilever slabs.
- The observed in-fills in the deformation joints and the direct contacts of the nonstructural elements with the cantilever slabs may impede the free movement of the upper and lower parts of the buildings in relation to each other.
- In some places the cantilever slabs are severely damaged. In these parts uncovered reinforcement was observed which also shows that the reinforcement is located in the compressed zone of the concrete. This means that the cantilever slabs are reinforced incorrectly with the violation of design requirements.
- In the adjacent to staircases and elevators parts the gaps of seismic isolation systems are filled-in and blocked.
- The leads of the elevators are continuous and do not have the necessary cuts, which is also an impediment to the free movement of the parts of the buildings in relation to each other.

The mentioned deficiencies and unacceptable arbitrary applied solutions are shown in the photos in Annex 2.

Based on the carried out visual and instrumental investigations it is concluded and recommended that:

- There is a relationship between the design value of the period of vibrations of the building and the period corresponding to the initial stiffness of SILRSBs according to the existing standards $T_{design}/\sqrt{10} \approx T_{initial}$. However, it was revealed that for the 2nd building (16-story) $T_{initial} \approx 0.65$ sec is by about 2 times bigger than the measured actual value $T_r=0.32$ sec. This inconsistency is conditioned by the above mentioned unacceptable violations. As a result this building does not fully function as a base isolated structure.
- The average heights of the loaded SILRSBs between the recess rings are equal to $h_{average1}=159.2$ mm, $h_{average2}=160.0$ mm, and $h_{average3}=159.5$ mm. The average values of the rubber hardness are equal to $A_{average1}=80.8$, $A_{average2}=84.9$, and $A_{average3}=80.8$. The heights between the recess rings of SILRSBs and the magnitudes of their rubber hardness are in compliance with the design requirements and with the allowable values corresponding to the standards.
- No cracks, caving and other types of deformations and damages were observed in the structural elements adjacent to the joints where the SILRSBs are installed. From the
technical point of view the structural elements of the isolation system are in a good condition.

- In the zone of seismic isolation gap it is necessary to remove the construction rubbish and to paint the steel plates above and below SILRSBs bolted to the recess rings or to cover them with anticorrosion materials.
- It is necessary to dismantle the parts of the exterior coating and of the going to the inside yards sloping slabs, which have direct structural contact with the cantilever slabs.
- It is necessary to free the horizontal deformation joints between the cantilever slabs and fencing structures to comply with the design requirements.
- It is necessary to reconstruct and to strengthen the damaged parts of the cantilever slabs.
- When choosing any options for mounting the seismic gap it is necessary to allow access to the seismic isolators for periodical inspections and measurements.
ANNEX 2. Photos illustrating some of the observed deficiencies and unacceptable arbitrary solutions in the seismic isolation zone.

Fig. 1-3. Blocked parts of the deformation joints of the adjacent to the building and of going to the yard sloping slabs and a damaged part of the cantilever slab.
Fig. 4-6. Blocked parts of the deformation joints between the external fencing elements and cantilever slabs in the seismic isolation zone.
Fig. 7-9. Parts of the deformation joints between the external fencing elements and cantilever slabs blocked by coating in the seismic isolation zone.
Fig. 10. Filled in and blocked part of the seismic gap adjacent to the elevator shaft.

Fig. 11. A part of the seismic gap not cleaned from the construction waste.
C. School building #4, Vanadzor

The school building is a three story structure with a basement. The building was constructed about 65 years ago.

The building is seismically isolated by installation of SILRSBs between the basement and the three upper floors. The base isolation was implemented in 2002. 41 SILRSBs were envisaged by the design and installed under the bearing walls in transverse and longitudinal directions of the building. SILRSBs were produced in Armenia. At the unloaded state the SILRSBs have 202.5mm height and 18-20mm thick recess rings. The design period of vibrations of the building in both, transverse and longitudinal directions is equal to $T_x = T_y = 2.0\text{sec}$.

In the present loaded condition using seismo-metric equipment the frequencies and the periods of free vibrations of the building in X and Y directions were determined and were equal accordingly to $\omega_x = 2.8\text{Hz}$, $\omega_y = 2.45\text{Hz}$, $T_x = 0.36\text{sec}$, $T_y = 0.41\text{sec}$ (the results obtained during the seismometric measurements are given in Part 2).

The height between the upper and lower recess rings of SILRSBs as well as the rubber hardness for every fourth SILRSB was also measured. The obtained results of these measurements are given in the Table 3.1 (Annex 8).

From the visual and instrumental observations it was revealed:

- The gap of the seismic isolation zone is not fully cleaned from the construction rubbish. Along the exterior walls the gap is obstructed by sacks filled-in by glass fiber cotton wool.
- In the parts of the sport hall and the toilets the gap is covered by light plastic material.
- The mentioned obstructions and coatings of the seismic isolation gap do not essentially hinder the free movement of the mentioned parts of the building in relation to each
other; however, they partially or completely block the access to the isolators necessary for inspections and/or measurements.

- There is a gap created around the whole perimeter of the building by construction of a small retaining wall, which is covered by tinplate.
- There are no access holes to allow inspection of the technical conditions of the structural elements from the outside of the building.
- In the structural wall below the seismic isolator #13 horizontal and inclined cracks of 3 mm width were observed.

The mentioned deficiencies and the partially damaged wall under the seismic isolator #13 and other unacceptable arbitrary applied solutions are shown in the photos in Annex 3.

Based on the carried out on the visual and instrumental investigations it is concluded and recommended:

- There is a relationship between the design value of the period of vibrations of the building and the period corresponding to the initial stiffness of SILRSBs according to the existing standards $T_{\text{design}}/\sqrt{10} \approx T_{\text{initial}}$. However, it was revealed that $T_{\text{initial}} = 0.63 \text{sec}$ is bigger by 1.75 times than the measured actual value $T_x = 0.36 \text{sec}$. This inconsistency is conditioned by and can be explained by the possible presence of obstacles in the seismic gap between the building and retaining wall around it. This can be revealed after obtaining the necessary access to that zone.
- The average height of the loaded SILRSBs between the recess rings is equal to $h_{\text{average}} = 158.3 \text{mm}$ and the average value of the rubber hardness is equal to $A_{\text{average}} = 75$.
- The heights between the recess rings of SILRSBs and the magnitudes of their rubber hardness are in compliance with the design requirements and with the allowable values corresponding to the standards.
- Besides the partially damaged wall under the seismic isolator #13 no cracks, caving and other types of deformations and damages were observed in the structural elements adjacent to the joints where the SILRSBs are installed.
- From the technical point of view the structural elements of the isolation system are in a good condition.
- In the zone of seismic isolation gap it is necessary to remove the construction rubbish.
- The partially damaged wall under the seismic isolator #13 should be cleaned from the plaster and be strengthened by reinforced concrete jacket.
- Access holes to allow inspection of the technical conditions of the structural elements from the outside of the building should be created as needed in the corresponding places.
- When choosing any options for mounting the seismic gap it is necessary to allow access to the seismic isolators for periodical inspections and measurements.
ANNEX 3. Photos illustrating some of the observed deficiencies and unacceptable arbitrary solutions in the seismic isolation zone.

Fig. 1-2. The solutions applied for covering by tinplate the gap created around the whole perimeter of the building.
Fig. 3-4. The gap of the seismic isolation zone along the exterior wall obstructed by sacks filled-in by glass fiber cotton wool.
Fig. 5-6. The construction waste present in the seismic gap.
Fig.7-9. The seismic gap covered by light plastic material in the sport hall and the toilets.
Fig.10-11. The damaged part of the wall under the seismic isolator #13.
D. Building #4, Isahakyan str and Building #1, Cherkassi str, Vanadzor

The mentioned buildings are 9 story buildings with basement floors and one entrance. They were constructed before 1988 Spitak Earthquake by the typical design of series 111.

The general view of the Isahakyan #4 building from north-west with the application of additional isolated upper floor.

The view of the main façade of Cherkassi #1 building with the application of additional isolated upper floor.
In order to increase the seismic resistance of these buildings additional upper 10th flexible floors were constructed on the top of the buildings connected to the main buildings by SILRSBs. The SILRSBs were installed respectively in 1996 and 1997 between the 9th and additionally constructed 10th floors on the parts of the columns coming out above the slabs of the 9th floors. These parts of the columns were correspondingly strengthened and connected to each other by steel trusses in order to provide rigidity to the structures below the isolation system for proper interaction between the building and the isolated upper floor.

In the zone of the seismic isolation of each building 60 SILRSBs are installed symmetrically related to the axes of the buildings. In each of the support joints one bearing is installed. The SILRSBs installed in Isahakyan #4 building are of Armenian production, and the ones in Cherkassi #1 building are of Malaysian production. The periods of vibrations of the isolated upper floors are the same in both buildings and are equal to $T_x = T_y \approx 1.14 \text{sec}$.

In the present loaded condition using seismo-metric equipment the frequencies and the periods of free vibrations of the buildings in X and Y directions were determined at the levels of the 9th and additional upper isolated (flexible) floor slabs and were correspondingly equal to: i) for Isahakyan #4 building $\omega_x=1.6\text{Hz}$, $\omega_y=1.4\text{Hz}$, $T_x=0.63\text{sec}$, $T_y=0.71\text{sec}$; ii) for Cherkassi #1 building $\omega_x=1.8\text{Hz}$, $\omega_y=1.4\text{Hz}$, $T_x=0.56\text{sec}$, $T_y=0.71\text{sec}$ (the results obtained during the seismometric measurements are given in Part 2).

The height between the upper and lower recess rings of SILRSBs as well as the rubber hardness for every second SILRSB was also measured. The obtained results of these measurements are given in the Table 4.1 (Annex 8).

From the visual and instrumental observations it was revealed:

- In the seismic isolation zones between the 9th and upper 10th flexible floors the pipes envisaged for ventilation are used by the tenants as chimneys, in some parts there are piles of appliances, blockages created by the tenants.
- Because of the smoke penetrating to the seismic isolation zone the structural elements almost completely are covered by soot. Several seismic isolators are in similar conditions.
- In some places the paint cover of the steel structures is destroyed.
- Easily inflammable materials exist adjacent to the ventilation pipes.
- Some fencing steel elements are missing in the seismic isolation zone, as a result of which the SILRSBs are under atmospheric precipitation actions and the flanges of some bearings are corroded.
- In the bearing #10 of the Isahakyan #4 building a swelling/bloating of the rubber for about 0.5mm is observed around the perimeter of the site surface of the bearing like a ring with the thickness of 10mm.

The mentioned deficiencies and other unacceptable arbitrary applied solutions are shown in the photos in Annex 4.

Based on the carried out the visual and instrumental investigations it is concluded and recommended:

- There is a relationship between the design value of the period of vibrations of the upper isolated floors and the period corresponding to the initial stiffness of SILRSBs according
to the existing standards $T_{\text{design}}/\sqrt{10} \approx T_{\text{initial}}$. However, in this case the free vibrations of the buildings influence the periods of vibrations of the upper floors. It was revealed that the $T_{\text{initial}} \approx 0.36$ sec and is bigger by 1.6-2.0 times than the measured actual value $T_x=0.56$ sec and $T_y=0.71$ sec, as well as $T_x=0.63$ sec and $T_y=0.71$ sec. This difference is within the acceptable range, taking into account the above mentioned influence of free vibrations of the buildings.

- The average height of the loaded SILRSBs between the recess rings is equal to $h_{\text{average}}=180.7$ mm and $h_{\text{average}}=152.5$ mm respectively. The average value of the rubber hardness is equal to $A_{\text{average}}=78.5$ and $A_{\text{average}}=80.2$ respectively.

- The heights between the recess rings of SILRSBs and the magnitudes of their rubber hardness are in compliance with the design requirements and with the allowable values corresponding to the standards.

- No cracks, caving and other types of deformations and damages were observed in the structural elements adjacent to the joints where the seismic isolators are installed.

- From the technical point of view the structural elements of the isolation system are in a good condition.

- In the zone of seismic isolation gap it is necessary to prohibit the arbitrary use of ventilation pipes by the tenants as chimneys taking into account the anti-fire security requirements and the fact that the created soot brings to the deterioration of the technical conditions of the structural elements.

- The observed in the bearing #10 (Isahakyan #4 building) swelling/bloating of the rubber should be considered as a manufacturing deficiency, because its $h_{\text{average}}=181.7$ mm and $A_{\text{average}}=79.0$ values are in compliance with the standard requirements.

- It is necessary to clean up the corroded parts of some steel elements of the isolators, to paint them and at the same time to restore the missing and damaged exterior fencing steel elements in order to avoid the direct influence of atmospheric precipitations on the seismic isolators.
ANNEX 4. Photos illustrating some of the observed deficiencies in the seismic isolation zone.

Fig. 1-3. The view of the structural elements adjacent to the ventilation pipes used as chimneys in the seismic isolation zone.
Fig. 4-6. The view of the seismic isolators and adjacent structural elements covered by the soot or corroded.
Fig.7-8. The parts where the exterior fencing steel elements envisaged for protecting the seismic isolators from atmospheric precipitations are missing or damaged.
E. Building #149, Yerevanyan str, Vanadzor

The building was constructed before the 1988 Spitak earthquake. It’s a five story building with 3 entrances and was built according to the typical design of series 1A-450.

The view of the building from the north-east side.

After the earthquake in 1995 the building was base isolated by installation of SILRSBs in the cellar under the first floor between the foundation and the upper part of the building.

In the seismic isolation zone 60 SILRSB are installed symmetrically related to the axes of the building. In each of the support joints one bearing is installed. The SILRSBs are of Malaysian production. In unloaded condition the SILRSBs have the height equal to 196mm. The recess rings of these bearings have a thickness of 18-20 mm.

The design periods of vibrations of the buildings are equal to \( T_x = T_y = 2.0 \text{sec} \).

In the present loaded condition using seismo-metric equipment the frequencies and the periods of free vibrations of the building in X and Y directions were determined and were correspondingly equal to \( \omega_x = 2.0 \text{Hz}, \omega_y = 2.0 \text{Hz}, \quad T_x = 0.5 \text{sec}, \quad T_y = 0.5 \text{sec} \) (the results obtained during the seismometric measurements are given in Part 2).

The height between the upper and lower recess rings of SILRSBs as well as the rubber hardness for every fourth SILRSB was also measured. The obtained results of these measurements are given in the Table 5.1 (Annex 8).

From the visual and instrumental observations it was revealed:
Along the exterior perimeter of the building the envisaged by the design horizontal deformation joint between the monolithic reinforced concrete cantilever slab and the retaining wall is generally free and open except the part next to the first entrance of the building. This part between outside asphalt and the cantilever slab is filled-in by soil.

The door leading to the cellar space and seismic isolation zone does not function because of household garbage accumulated in front of it and the damaged lock. The only passage adjacent to the second entrance of the building can be used to enter the cellar space.

In the cellar of the building the gap of the seismic isolation zone along the exterior perimeter is arbitrary blocked by tenants using different materials and solutions probably in order to protect from cold. In some parts of the cellar the accumulations of the piles of appliances exist.

The mentioned obstructions do not essentially hinder the free movement of the parts of the building in relation to each other; however, they partially or completely block the access to the isolators necessary for inspections and/or measurements.

In some parts the cantilever slab and retaining wall are damaged which leads to the penetration of the precipitation water through the deformation joint to the cellar space resulting in periodic moistening of these structural elements.

In some parts the damages of the concrete surface of the cantilever slab due to freezing were observed.

The mentioned deficiencies are shown in the photos in Annex 5 (in the seismic isolation zone no photos could be taken because of the absence of the light and all measurements and observations were made using lantern).

Based on the carried out the visual and instrumental investigations it is concluded and recommended:

There is a relationship between the design value of the period of vibrations of the building and the period corresponding to the initial stiffness of SILRSBs according to the existing standards $T_{\text{design}}/\sqrt{10} \approx T_{\text{initial}}$. However, it was revealed that $T_{\text{initial}} \approx 0.63$ sec is bigger by 1.26 times than the measured actual value $T_x = T_y = 0.5$ sec, which is generally within the acceptable range, but at the same time witnesses that some obstructions definitely hinder the free movement of the parts of the building in relation to each other.

The average height of the loaded SILRSBs between the recess rings is equal to $h_{\text{average}} = 150.7$ mm and the average value of the rubber hardness is equal to $A_{\text{average}} = 70.35$, which are in compliance with the design requirements and with the allowable values corresponding to the standards.

No cracks, caving and other types of deformations and damages were observed in the structural elements adjacent to the joints where the seismic isolators are installed.

From the technical point of view the structural elements of the isolation system are in a good condition.

It is necessary to clean up the entrance leading to the zone of seismic isolation and to ensure the functioning of the door and also to clean up the seismic isolation gap from the arbitrarily created by the tenants obstacles.

It is necessary to clean up the horizontal deformation joint between the monolithic reinforced concrete cantilever slab and the retaining wall with the restoration of some damaged parts of these structures.

When choosing any options for mounting the seismic gap it is necessary to allow access to the seismic isolators for periodical inspections and measurements.
ANNEX 5. Photos illustrating some of the observed deficiencies in the seismic isolation zone.

Fig. 1-2. The view of the blocked entrance leading to the cellar.
Fig. 3-5. The view of the cantilever slab and outside surface of the building in different parts.
Fig. 6. The view of the deformation joint adjacent to the second entrance of the building (the deformation joint is not blocked).

Fig. 7. The view of the deformation joint adjacent to the first entrance of the building (the deformation joint is blocked).
Fig. 8-9. The damaged parts of the monolithic reinforced concrete cantilever slab and retaining wall of the seismic isolation zone.
F. Buildings #9/3, #9/4, Garegin Njdeh str, Gyumri

Both buildings were constructed after the 1988 Spitak earthquake by the same design.

The view of the buildings #9/3, #9/4 at Garegin Njdeh street from south-east side.

The buildings are base isolated on the level of the basement. SILRSBs were installed in 2000 within the vertical structural elements connected from one side to the foundation and from the other side to the upper 4 residential floors.

In the seismic isolation zone 55 SILRSBs are installed symmetrically related to the axes of the building. In each of the support joints one bearing is installed. The SILRSBs are of Armenian production. In unloaded condition the SILRSBs have the height equal to 202.5mm. The recess rings of these bearings have a thickness of 18-20 mm. The design periods of vibrations of the buildings are equal to $T_x = T_y = 2.0 \text{ sec}$.

In the present loaded condition using seismo-metric equipment the frequencies and the periods of free vibrations of the building in X and Y directions were determined and were correspondingly equal to: i) for the #9/3 building $\omega_x = 2.8 \text{ Hz}$, $\omega_y = 3.1 \text{ Hz}$, and $T_x = 0.36 \text{ sec}$, $T_y = 0.32 \text{ sec}$; ii) for the #9/4 building $\omega_x = 3.9 \text{ Hz}$, $\omega_y = 2.9 \text{ Hz}$, and $T_x = 0.26 \text{ sec}$, $T_y = 0.34 \text{ sec}$ (the results obtained during the seismometric measurements are given in Part 2).

The height between the upper and lower recess rings of SILRSBs as well as the rubber hardness for every third SILRSB was also measured. The obtained results of these measurements are given in the Table 6.1 (Annex 8).

From the visual and instrumental observations it was revealed:

- The works on the exterior asphalt surface adjacent to the buildings were performed by violations of design requirements and application of arbitrary solutions:
  - Along the exterior perimeter of the buildings the envisaged by the design horizontal deformation joints between the monolithic reinforced concrete cantilever slabs and the retaining walls are filled-in by the asphalt layer which directly touches the cantilever slabs.
o The edges of the hatchways adjacent to the buildings directly touch the cantilever slabs by arbitrary applied solutions different from the design.

o The monolithic concrete stairs constructed in front of the entrances touch the building without providing of the necessary deformation joint.

The mentioned design violations significantly obstruct the free movement of the lower and upper parts of the buildings in relation to each other.

- In the basements of the buildings the residents have constructed store-rooms, the walls of which are mainly made of one-layer tuff stones using cement mortar.
- The dividing walls of the store-rooms in longitudinal and transverse directions in many places touch the bearing structures of the buildings without providing the necessary gaps. The mentioned arbitrary and wrong solutions also obstruct the free movement of the lower and upper parts of the buildings in relation to each other.
- Some of the SILRSBs turned out within the store-rooms and cannot be accessed. Some other SILRSBs are also not accessible because of the disorderly accumulated piles of appliances and other materials.

The mentioned deficiencies are shown in the photos in Annex 6.

Based on the carried out the visual and instrumental investigations it is concluded and recommended:

- There is a relationship between the design value of the period of vibrations of the building and the period corresponding to the initial stiffness of SILRSBs according to the existing standards $T_{\text{design}} / \sqrt{10} \approx T_{\text{initial}}$. However, it was revealed that $T_{\text{initial}} \approx 0.62$ sec is bigger by 2-2.4 times than the measured actual value $T_x = 0.26$ sec and $T_y = 0.32$ sec. This inconsistency is conditioned by the mentioned design violations of the exterior surfaces and unacceptable solutions applied in the basements. Actually these buildings do not fully function as base isolated structures.
- The average heights of the loaded SILRSBs between the recess rings are correspondingly equal to $h_{\text{average}} = 161.2$ mm and $h_{\text{average}} = 161.0$ mm, the average values of the rubber hardness are equal to $A_{\text{average}} = 84.0$ and $A_{\text{average}} = 87.5$, which are in compliance with the design requirements and with the allowable values corresponding to the standards.
- No cracks, caving and other types of deformations and damages were observed in the structural elements adjacent to the joints where the seismic isolators are installed. From the technical point of view the structural elements of the isolation system are in a good condition.
- It is necessary to bring the exterior asphalt surface and the walls of store-rooms in the basements to the design solutions and requirements and to clean up the obstacles that hinder the free movement of the parts of the buildings in relation to each other.
ANNEX 6. Photos illustrating some of the observed deficiencies in the seismic isolation zone.

Fig. 1-3. The blockages of the horizontal deformation joints between the monolithic reinforced concrete cantilever slabs and retaining walls by the exterior asphalt layer and by the edges of the hatchways adjacent to the buildings.
Fig. 4-6. The blockages of the deformation joints at the entrances of the buildings by asphalt layers and stair slabs.
Fig. 7-9. The arbitrary constructed walls touching the bearing structures in the basement of the buildings without preservation of the necessary deformation joints
G. Building #1, S. Avetisyan str, Spitak

The building was constructed after the 1988 Spitak earthquake. It has two entrances, four stories and a basement floor. The SILRSBs were installed during the construction of the building in 1997.

![The general view of the building from the north-west side.](image)

The building is base isolated by installation of SILRSBs between the basement floor and the upper 4 residential floors. In the seismic isolation zone 39 SILRSBs are installed symmetrically related to the axes of the building. In each of the support joints one bearing is installed.

The SILRSBs are of Malaysian production. In the unloaded condition the SILRSBs have the height equal to 196mm. The recess rings of these bearings have a thickness of 18-20 mm. The design periods of vibrations of the buildings are equal to $T_x = T_y = 2.0 \text{ sec}$.

In the present loaded condition using seismo-metric equipment the frequencies and the periods of free vibrations of the building in X and Y directions were determined and were correspondingly equal to $\omega_x = 3.2 \text{ Hz}$, $\omega_y = 3.0 \text{ Hz}$, and $T_x = 0.31 \text{ sec}$, $T_y = 0.33 \text{ sec}$ (the results obtained during the seismometric measurements are given in Part 2).

The height between the upper and lower recess rings of SILRSBs as well as the rubber hardness for every second SILRSB was also measured. The obtained results of these measurements are given in the Table 7.1 (Annex 8).

From the visual and instrumental observations it was revealed:
- The basement of the building was renovated and is used as a Museum of History of the Earthquake, as well as of History and Culture of the Spitak City
- Along the exterior perimeter of the building the seismic gap of the seismic isolation zone is totally covered from outside and inside. From outside the gap is arbitrarily filled-in by blocks with the thickness of 10cm and its upper horizontal joint is filled-in by mineral cotton. From inside the gap is covered by steel plates fixed to the lower and upper structural elements. In some parts of the gap water and sewerage pipes are installed.
By such a solution of the coverage of the gap the access to the seismic isolators is obstructed and it is impossible to make inspections and measurements. This solution partly hinders the free movement of the upper and lower parts of the building in relation to each other.

The concrete blocks installed in the gap from outside are of poor quality and in some places are damaged. This leads to the penetration of the precipitation water to the basement through the gap and to corrosion of the recess rings of some isolators.

During the renovation of the staircases at the entrances of the building the deformation joints envisaged by the design between the stairs and the stairs’ slab were destroyed and the mentioned structural elements were connected to each other which hinder the free movement of the upper and lower parts of the building in relation to each other.

No cracks, caving and other types of deformations and damages were observed in the structural elements adjacent to the joints where the seismic isolators are installed.

From the technical point of view the structural elements of the isolation system are in a good condition.

The mentioned deficiencies are shown in the photos in Annex 7.

Based on the carried out the visual and instrumental investigations it is concluded and recommended:

- There is a relationship between the design value of the period of vibrations of the building and the period corresponding to the initial stiffness of SILRSBs according to the existing standards T_{design}/\sqrt{10} \approx T_{initial}. However, it was revealed that T_{initial} = 0.63\,\text{sec} is bigger by about 2 times than the measured actual value T_x = 0.31\,\text{sec} and is bigger by 1.9 times than the actual value T_y = 0.32\,\text{sec}. This inconsistency is conditioned by the mentioned design violations of the exterior surfaces and unacceptable solutions applied in the basements. Actually this building does not fully function as a base isolated structure.

- The average height of the loaded SILRSBs between the recess rings are correspondingly equal to h_{average}=149.7\,\text{mm} and the average value of the rubber hardness is equal to A_{average}=76, which are in compliance with the design requirements and with the allowable values corresponding to the Standards.

- It is necessary to dismantle the non-structural elements in the seismic isolation zone by cleaning the gap and deformation joints and the corroded parts of the recess rings. It is necessary to paint or to cover them with anticorrosion materials.

- It is necessary to realize a new cover of the seismic isolation gap from outside and inside of the building in compliance with the design requirements.

- When choosing any options for mounting the seismic gap it is necessary to allow access to the seismic isolators for periodical inspections and measurements.
ANNEX 7. Photos illustrating some of the observed deficiencies in the seismic isolation zone.

Fig. 1-2. The view of the entrances where stairs and stair slabs are connected to each other by filling the deformation joint between them.
Fig. 3-7. The external view of the blocked seismic isolation gap and its present technical condition.
Fig. 8-10. The internal view of the blocked seismic isolation gap.
PART 2

INSTRUMENTAL DETERMINATION OF THE PERIODS OF FREE VIBRATIONS OF THE BUILDINGS WITH SEISMIC ISOLATION SYSTEMS

Eleven buildings with the application of seismic isolation systems in Yerevan, Spitak and Gyumri were examined. Nine of these buildings are base isolated structures and two are roof isolated (have flexible upper floors, constructed on the top of the buildings in the form of additional isolated upper floors).

The micro-vibrations of these buildings were measured and the periods of free vibrations in two mutually perpendicular horizontal directions were determined. In the buildings which have a rectangular plan the vibrations were measured in longitudinal and transverse directions, and in the buildings with square plan in the directions along the entrances and in perpendicular to those directions.

The periods of free vibrations were measured for four buildings in Yerevan, four buildings in Vanadzor, one building in Spitak and two buildings in Gyumri. Highly sensitive seismic equipment of Japanese production was used for measurements, which includes the following devices:

1. UP-255 three component block
2. UPS-UT three channel amplifier
3. FC-14 – four channel magnetic recorder
4. OMNLIGHT 8M – four channel analogue recorder
5. 7T265- signal processor

In the Cherkassi #1 and Isahakyan #4 buildings in Vanadzor the measurements were carried out on the level of the 9th floor slab and on the level of the slab of the additional isolated upper floor. In all other buildings which are base isolated the measurements were carried out right above the isolation systems on the level of the first floor slabs of superstructures.

All measurements were made by installation of seismic devices approximately in the middle of the plan of the buildings.

On Fig.1-Fig. 26 (Annex 9) sections of micro-vibrations records and obtained based on their integral analysis the Furier spectra are given. Using the Furier spectra the predominant frequencies (periods) of micro-vibrations are determined with high accuracy.

Using the determined ω frequency the corresponding value of the period can be calculated by the following formula: $T = 1/\omega$.

In the Table 8 the frequencies $\omega_x, \omega_y$, and periods $T_x, T_y$ determined based on the received records are given.
Table 8

The frequencies (Hz) and the periods (sec) of free vibrations of the buildings

<table>
<thead>
<tr>
<th>No.</th>
<th>Building address and number of stories</th>
<th>The level of measurement</th>
<th>ω, Hz</th>
<th>T, sec</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>1</td>
<td>“Cascade”Complex, Demirchyan street, Yerevan, 10 storey</td>
<td>1st floor</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>2</td>
<td>“Our Yard” Complex, building #1, Zavaryan and Rostomi streets, Yerevan, 10 storey</td>
<td>1st floor</td>
<td>1.55</td>
<td>1.55</td>
</tr>
<tr>
<td>3</td>
<td>“Our Yard” Complex, building #2, Zavaryan and Rostomi streets, Yerevan, 16 storey</td>
<td>1st floor</td>
<td>3.1</td>
<td>2.15</td>
</tr>
<tr>
<td>4</td>
<td>“Our Yard” Complex, building #3, Zavaryan and Rostomi streets, Yerevan, 10 storey</td>
<td>1st floor</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>School building #4, Vanadzor, 3 storey</td>
<td>1st floor</td>
<td>2.8</td>
<td>2.45</td>
</tr>
<tr>
<td>6</td>
<td>Building #4, Isahakyan str, Vanadzor, 9 storey</td>
<td>9th floor</td>
<td>1.65</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Isolated upper floor</td>
<td>1.6</td>
<td>1.4</td>
</tr>
<tr>
<td>7</td>
<td>Building #1, Cherkassi str, Vanadzor, 9 storey</td>
<td>9th floor</td>
<td>1.8</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Isolated upper floor</td>
<td>1.8</td>
<td>1.4</td>
</tr>
<tr>
<td>8</td>
<td>Building #149, Yerevanyan str, Vanadzor, 5 storey</td>
<td>1st floor</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>9</td>
<td>Building #9/3 Garegin Njdeh str, Gyumri, 4 storey</td>
<td>1st floor</td>
<td>2.8</td>
<td>3.1</td>
</tr>
<tr>
<td>10</td>
<td>Building #9/4, Garegin Njdeh str, Gyumri, 4 storey</td>
<td>1st floor</td>
<td>3.9</td>
<td>2.9</td>
</tr>
<tr>
<td>11</td>
<td>Building #1, S. Avetisyan str, Spitak, 4 storey</td>
<td>1st floor</td>
<td>3.2</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Results given in the table show that the application of the seismic isolation systems brings to the increase of the values of the fundamental periods of vibrations of the buildings.
PART 3

CONCLUSIONS AND RECOMMENDATIONS

From the carried out investigations of the buildings with seismic isolation systems where the seismic isolators were installed in Yerevan 2-3 years ago, in Vanadzor 8-14 years ago, in Gyumri 8-9 years ago and in Spitak 12 years ago, it is concluded:

- In all buildings the seismic isolators are in good technical condition.
- The bearing structures below and above the seismic isolators are also in good technical conditions.
- The vertical deformations of the seismic isolators and their rubber hardness are in compliance with the design requirements and with the allowable values corresponding to the standards.
- In most of the buildings during construction and further exploitation period violations of the design requirements and unacceptable arbitrary actions in relation to the seismic isolation system have taken place. This was revealed by seismo-metric measurements and by comparison of the obtained actual periods of vibrations with their design values by checking through the known formula $T_{\text{design}}/\sqrt{10} \approx T_{\text{initial}}$ according to the existing standards. Because of the revealed violations some of the buildings will not function of full value as seismically isolated structures.
- The obstructions and blockages of the seismic isolation gaps by different materials not only hinder the free movement of the parts of the buildings in relation to each other, but also complicate or exclude the access to the isolators and adjacent structural elements necessary for inspections and/or measurements.
- The revealed design violations and the arbitrary actions in case of a possible earthquake may cause unpredictable deformations, damages and destructions of different level in the bearing structures of the buildings.

In order to avoid such undesirable occurrences and to ensure the safe exploitation of the seismically isolated buildings it is required and recommended:

- In the process of construction the technical supervision of works on seismic isolation system should be carried out by strictly observing the design requirements.
- In the observed buildings in Yerevan which are in their final stage of construction (“Our Yard” and “Cascade” Complexes) it is necessary to dismantle all non-structural elements and ties which are made in violation of the design requirements and do not allow the buildings to function of full value as seismically isolated structures. It should be mentioned that the increased weight of superstructures of the buildings because of the excessively increased mass of the building’s coating layers and the floors’ smoothing layers brings to overloading of seismic isolators and to unfavorable conditions for their behavior during the design level earthquakes.
- In the base isolated buildings in Vanadzor (Yerevanyan street #149 building and school building #4) city it is necessary to take corresponding measures for removing arbitrary pilings of appliances, blockages created by the tenants in the seismic isolation zone. In these buildings it is also necessary to take measures for eliminating all observed deficiencies and their causes mentioned in the given report and which hinder the free movement of the parts of the buildings in relation to each other.
In the roof isolated buildings (Isahakyan street #4 and Cherkassi street #1 buildings) it is necessary to take measures for bringing the blast-pipes that are used as chimneys in accordance with anti-fire technical requirements.

In the buildings in Gyumri it is necessary to dismantle and to lower the marks of the outside asphalt surface bringing those to the level envisaged by the design in order to free the horizontal deformation joint between the cantilever slabs and the retaining walls. In the basements it is necessary to create horizontal deformation gaps between the arbitrarily constructed partitions and bearing structures of the buildings in order to provide free movement of the parts of the buildings in relation to each other.

In the building in Spitak it is necessary to dismantle the non-structural elements which cover from outside and inside the seismic isolation zone gap, and to construct new covers keeping the design requirements and eliminating other deficiencies mentioned in the given report. Between the entrance stairs and slab it is also necessary to provide the horizontal deformation joint as envisaged in the design.

It is necessary to develop corresponding legal framework regulating the maintenance and exploitation of seismic isolated buildings. The regulations should include guidelines on accurate execution of the coverage of seismic isolation zone gaps, on maintenance of the seismic isolation rubber bearings and on providing technical conditions for carrying out necessary measurements and inspections.

The regulations should prohibit the tenants to make partitions and dividers with arbitrary solutions in the basement floors and cellars, as well as to accumulate appliances and other materials in those areas so that to avoid creation of fire threat conditions.

Any construction works, repairs, structural changes aimed at usage of the free spaces of the seismic isolation zones should be carried out in accordance with the requirements of the existing norms and guidelines based on the approved designs.

The developed guidelines on exploitation of seismic isolated buildings should be distributed among local self-governance bodies, private developers, and tenants in order to increase their awareness on the principles and behavior of seismic isolated buildings, to guide them so that all parties could provide the necessary conditions for proper exploitation and maintenance.

It is advisable to organize special seminars for construction companies, private investors, developers and local self-government bodies in order to explain the concept of the seismic isolation, the advantages and specificities of the buildings constructed or strengthened by its application.