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International
Journal
Of Modern Engineering Research (IJMER)

Base Isolation Design of the 7-Story "Chullo" Residential Building in the City of Arequipa (Peru)

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Abstract
Brief information is given in the article on development and application of the created by the author seismic isolation systems in Armenia and on its leading position in this field. In this regard, the willingness of the scientific centers, design institutions, universities, academies of different countries to adopt the experience of Armenia is mentioned. As an illustration of the stated above, the information on the author's visit to the city of Arequipa (Peru) by the invitation of the San Pablo Catholic University is mentioned. Here the author delivered the lectures, conducted the "master class" and held the press-conference. Together with that a genuine aspiration of the young Peruvian specialists to implement seismic isolation technologies is stated and the structural solution for construction of the new seismic isolated 7-story residential building designed by the author is given.
Keywords: *seismic isolation in Armenia, development and application, visit to Peru, transfer of the experience, seismic isolated building, structural solution, design.*

Date of Submission: 01-04-2024 Date of acceptance: 13-04-2024

I. Introduction

Armenia is the only country among the developing countries in which, as a result of the scientific and practical works of the author of this article, seismic isolation of buildings has been widely used and recognized by the international professional community [1, 2, 3]. At present, Armenia occupies a leading position in the world (second after Japan) in terms of the number of seismic isolated buildings (newly constructed or retrofitted) per capita [4, 5]. As noted in [6, 7], Armenia is a pioneer in the use of seismic isolation among developing countries.

Seismic isolation technology is widely used here in the construction of new and retrofitting of existing residential buildings, schools, hospitals, hotels, business centers and other structures. At the same time, Armenia is the first country in the world where the retrofitting of existing buildings was carried out using seismic isolation devices at the base or at the roof levels of buildings without interruption of the use of these buildings [8, 9]. The number of buildings, in which seismic isolation systems are used, in the country has already reached 60. Some of them are shown in Figures 1 and 2. The number of Seismic Isolation Laminated Rubber-Steel Bearings (SILRSBs) produced and tested in Armenia, and already installed in buildings has exceeded 5500 pieces [10, 11].

The above brief information makes clear the desire of specialists from different countries to adopt the experience of Armenia, as it was done, for example, in Irkutsk [12], when the author, in order to retrofit the 100-year-old bank building by seismic isolation, handed over to Russian colleagues drawings, photographs, video materials on retrofitting of the existing building in Vanadzor, the third biggest city in Armenia. The Russian specialists on the spot were also familiarized in detail with the author's technology [13] and received all the necessary explanations and comments. The same was done during the author's visit to the city of Arequipa (Peru) by the invitation of the San Pablo Catholic University where, as one of the results, the author developed structural design for construction of the new base isolated 7-story "Chullo" residential building.

First existing 5-story apartment building retrofitted by base isolation in 1996 in the city of Vanadzor and fragments of its isolation system. This building with stone load-bearing walls was retrofitted using technology invented by the author (Patent of the Republic of Armenia №579) for the first time in the world without interruption of its use. During retrofitting works people were not moved out of the building. Dimensions of the building - 52×15 m. 60 high damping rubber bearings were used to create the base isolation system within the building's basement.

Two 4-story apartment buildings in the Huntsman Village of the city of Gyumri and fragment of their isolation system. These buildings with R/C masonry load-bearing walls were constructed in 2001. Dimensions of each building - 34×20 m. 110 medium damping rubber bearings were manufactured by Yerevan Factory of Rubber Technical Articles (YFRTA) for both buildings and were used to create the base isolation systems within the buildings' basement.

3-story existing school building retrofitted by base isolation in the city of Vanadzor and fragments of its isolation system. The building with stone load-bearing walls was retrofitted in 2002. It has historical and architectural value and was also retrofitted without interruption of its use. At the time of retrofitting the building was 60 years old. Dimensions of the building - 38×21 m. 41 medium damping rubber bearings were manufactured by YFRTA, and were used to create the base isolation system within the building's basement.

3-story clinic building in the city of Stepanakert and fragment of its isolation system. The building with R/C bearing frames and shear walls was constructed in 2003. Dimensions of the building - 47×20 m. 48 medium damping rubber bearings were manufactured by YFRTA, and were used to create the base isolation system within the building's basement.

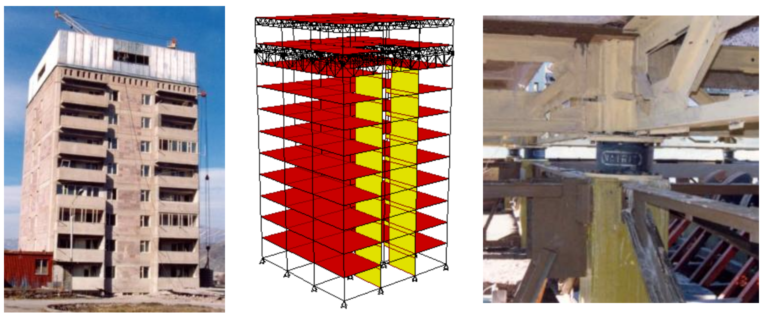
7-story commercial center/hotel building in the city of Yerevan and its design model. The building is of L-shape with non-symmetric plan. It has R/C bearing frames and shear walls and was constructed in 2007. Non-symmetry was neutralized due to the author's approach on installation of clusters of rubber bearings. Overall dimensions of the building - 45×37 m. 113 medium damping rubber bearings were manufactured by KHACHVAR (Armenia), and were used to create the base isolation system within the building's basement/parking floor.

Figure 1. Some of the medium-rise base isolated buildings constructed or retrofitted in Armenia starting from 1995

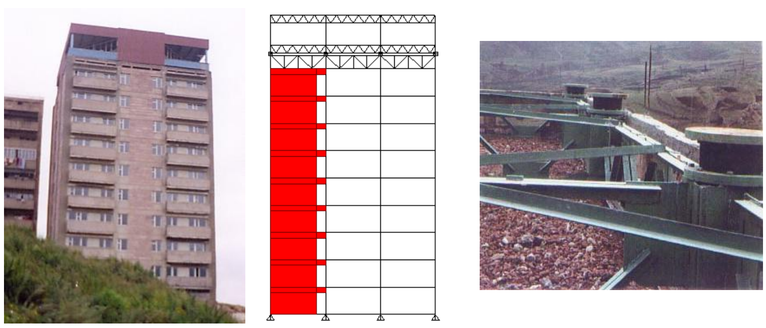
4-story existing industrial building with R/C bearing frames retrofitted by base isolation in the city of Yerevan and fragment of its isolation system. This building was converted into hotel and was retrofitted in 2015 in parallel with reconstruction works going on in all floors Dimensions of the building - 81×18 m. 158 high damping rubber bearings were manufactured by RETINE NORUYT (Armenia), and were used to create the base isolation system within the building's basement.

4-story building of medical center in the city of Vanadzor and fragment of its isolation system. The building of □-shape in plan with R/C bearing frames and shear walls was constructed in 2016. Dimensions of the building - 86×69 m. 260 high damping rubber bearings were manufactured by RETINE NORUYT, and were used to create the base isolation systems within the building's basement.

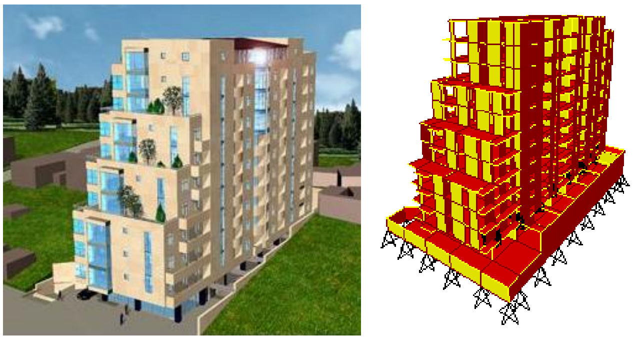
Figure 1 (continued). Some of the medium-rise base isolated buildings constructed or retrofitted in Armenia starting from 1995



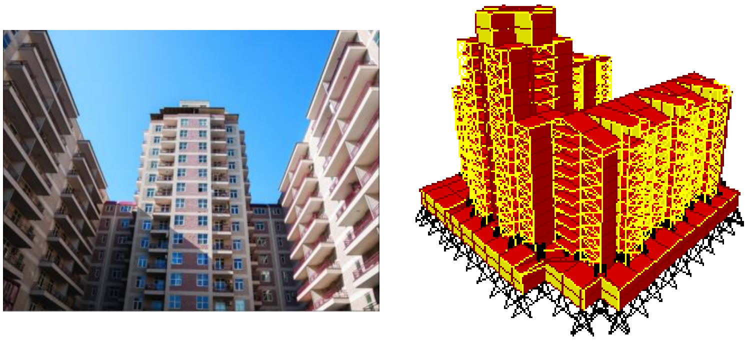
9-story existing apartment building retrofitted by roof isolation (invented by the author method of Additional Isolated Upper Floor - AIUF) in the city of Vanadzor, its design model and fragment of its isolation system. This building was retrofitted in parallel with reconstruction works going on in all floors. The building with R/C bearing frames and shear walls was retrofitted in 1997. Dimensions of the building - 19×19 m. 16 medium damping rubber bearings were manufactured by NAIRIT (Armenia), and were used to create the roof isolation system between the AIUF and the main building.



9-story existing apartment building retrofitted also by the method of AIUF in the city of Vanadzor, its design model and fragment of its isolation system. This building was also retrofitted in parallel with reconstruction works going on in all floors. The building with R/C bearing frames and shear walls was retrofitted in 1997. Dimensions of the building - 19×19 m. 16 high damping rubber bearings were used to create the roof isolation system between the AIUF and the main building.

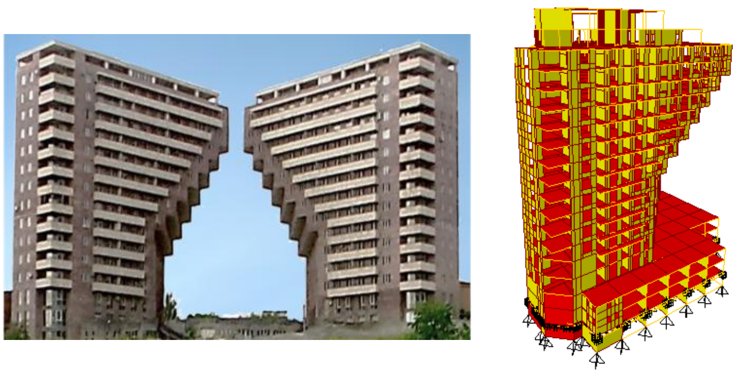


11-story building of the multifunctional residential complex "Cascade" in the city of Yerevan and its design model. The building with R/C bearing frames and shear walls was constructed in 2005. Dimensions of the building - 45×17 m. 128 medium damping rubber bearings were manufactured by RETINE NORUYT, and were used to create the base isolation system above one parking and one commercial floors.



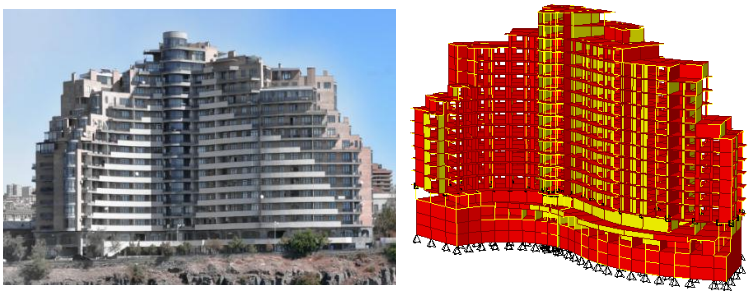
16- and 10-story buildings of the multifunctional residential complex "Our Yard" in the city of Yerevan and their design models. The buildings with R/C bearing frames and shear walls were constructed in 2005. Dimensions of two 10-story buildings - 58×21 m and of 16-story building - 32×23 m. Total 464 medium damping rubber bearings were manufactured by RETINE NORUYT, and were used to create the base isolation systems above the two parking floors.

16- and 14-story buildings of the multifunctional residential complex "Arami" in the city of Yerevan and their design models. The buildings with R/C bearing frames and shear walls were constructed in 2006. Dimensions of 14-story building - 33×32 m and of 16-story building - 52×33 m. Total 371 medium damping rubber bearings were manufactured by RETINE NORUYT, and were used to create the base isolation systems on top of four floors (two underground parking and two above ground commercial floors).

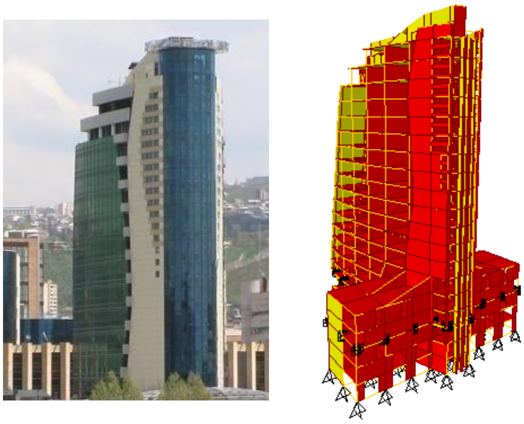


18-story buildings/twins of the multifunctional residential complex "Northern Ray" in the city of Yerevan and the design model of one building. The buildings with R/C bearing frames and shear walls were constructed in 2007. Dimensions of each building - 74×39 m. Total 904 medium damping rubber bearings were manufactured by RETINE NORUYT, and were used to create the base isolation system on top of the first parking floor.

Figure 2. Some of the high-rise base and roof isolated buildings constructed or retrofitted in Armenia starting from 1997



Multifunctional residential complex "Dzorap" in the city of Yerevan consists of 16- and 13-story parts divided by the anti-seismic vertical gap and their design models. The buildings with R/C bearing frames and shear walls were constructed in 2007. Dimensions of 13-story part - 32×33 m and of 16-story part - 67×29 m. Total 312 medium damping rubber bearings were manufactured by RETINE NORUYT, and were used to create the base isolation system on top of four floors (two underground parking and two above ground commercial floors).



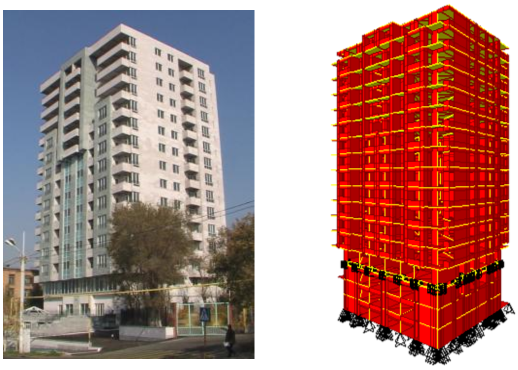
20-story building of business center "Elite Plaza" in the city of Yerevan and its design model. The building with R/C bearing frames and shear walls was constructed in 2007. Dimensions of the building - 42×36 m. 246 medium damping rubber bearings were manufactured by RETINE NORUYT, and were used to create the base isolation system above the two parking and one commercial floors.

17-story building of the multifunctional residential complex "Baghramian" in the city of Yerevan and its design model. The building with R/C bearing frames and shear walls was constructed in 2008. Dimensions of the building - 41×36 m. 271 medium damping rubber bearings were manufactured by RETINE NORUYT, and were used to create the base isolation system above the two parking and one commercial floors.

Figure 2 (continued). Some of the high-rise base and roof isolated buildings constructed or retrofitted in Armenia starting from 1997

The international recognition and high appreciation of the work performed is confirmed not only by the publications of well-known scientists from different countries, but also by the desire of many specialists to get acquainted in more detail with the seismic isolation technologies developed and implemented in Armenia and discuss them directly with the author of these works. This explains the frequent invitations from research centers, design institutes, universities, and academies. From the recent presentations by the author the following lectures should be mentioned: at the Japan Society for Seismic Isolation, at the Institute of Civil Engineering and Technology of the Vienna University of Technology, at the International Balkan University of the R. North Macedonia, at the University of Aberdeen, Scotland, UK, at the Satbayev Kazakh National Research Technical University of Kazakhstan, etc.

15-story building of the multifunctional residential complex "Avan" in the city of Yerevan and its design model. The building with R/C bearing frames and shear walls was constructed in 2011. Dimensions of the building - 40×28 m. 247 medium damping rubber bearings were manufactured by R.M.I.A. (Armenia), and were used to create the base isolation system above the ground commercial floor.



17-story building of the multifunctional residential complex "Sevak" in the city of Yerevan and its design model. The building with R/C bearing frames and shear walls was constructed in 2012. Dimensions of the building - 30×30 m. 184 medium damping rubber bearings were manufactured by R.M.I.A. (Armenia), and were used to create the base isolation system above the two parking and one commercial floors.

9-story existing large-panel apartment building retrofitted by base isolation in the city of Stepanakert and fragment of its isolation system during carrying out construction works. The building with R/C load-bearing walls was retrofitted in 2023. Dimensions of the building - 34.6×11.2 m. 62 medium damping rubber bearings were manufactured by "Shahnazaryans" LLC, and were used to create the base isolation system within the building's basement. It also includes 11 bearings which can carry the vertical load and allow horizontal displacement, but they do not have horizontal stiffness and called as bearings with no horizontal stiffness.

Figure 2 (continued). Some of the high-rise base and roof isolated buildings constructed or retrofitted in Armenia starting from 1997

At the end of October – beginning of November 2016, the author was invited to Peru by the Catholic University of San Pablo in Arequipa, where he conducted two lectures and held a "master class" on the following topics for students and teachers of the Faculty of Civil Engineering (Fig. 3):

First lecture:

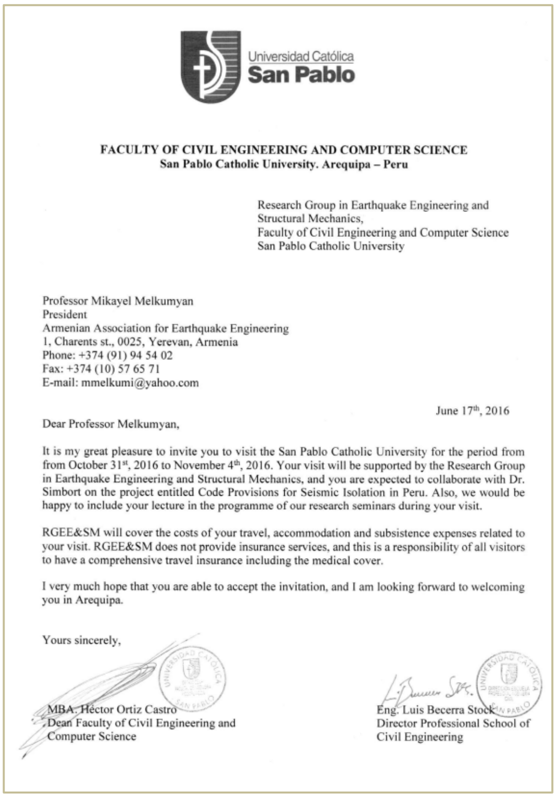
1. Seismic (base and roof) isolation - idea, innovation, development and further application in Armenia;
2. Implementation of seismic isolation for construction of new medium- and multi-story buildings.

Master class:

3. Unique retrofitting base isolation technologies for existing frame and braced-frame hospital buildings;
4. Unique roof isolation technology for upgrading earthquake resistance of existing frame buildings;
5. Creation and application of new method of seismic isolation rubber bearings' location by clusters.

Second lecture:

6. Seismic risk of destruction of existing buildings in Armenia - reasons and consequences;
7. Unique retrofitting base isolation technology for existing stone-masonry apartment and school buildings.



Universidad Católica San Pablo

FACULTY OF CIVIL ENGINEERING AND COMPUTER SCIENCE
San Pablo Catholic University. Arequipa – Peru

Research Group in Earthquake Engineering and Structural Mechanics,
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June 17th, 2016

Dear Professor Melkumyan,

It is my great pleasure to invite you to visit the San Pablo Catholic University for the period from from October 31st, 2016 to November 4th, 2016. Your visit will be supported by the Research Group in Earthquake Engineering and Structural Mechanics, and you are expected to collaborate with Dr. Simbort on the project entitled Code Provisions for Seismic Isolation in Peru. Also, we would be happy to include your lecture in the programme of our research seminars during your visit.

RGEE&SM will cover the costs of your travel, accommodation and subsistence expenses related to your visit. RGEE&SM does not provide insurance services, and this is a responsibility of all visitors to have a comprehensive travel insurance including the medical cover.

I very much hope that you are able to accept the invitation, and I am looking forward to welcoming you in Arequipa.

Yours sincerely,

MBA. Héctor Ortiz Castro
Dean Faculty of Civil Engineering and Computer Science

Eng. Luis Becerra Stock
Director Professional School of Civil Engineering

Universidad Católica San Pablo

CERTIFICATE OF APPRECIATION

The Faculty of Civil Engineering and Computer Science of the San Pablo Catholic University in the city of Arequipa, Peru certifies that Prof. Dr. Mikayel Melkumyan in accordance with our invitation has carried out two lectures and a master class from October 31 to November 4, 2016 on the following topics.

First lecture:
1. Seismic (base and roof) isolation - idea, innovation, development and further application in Armenia
2. Implementation of seismic isolation for construction of new medium- and multi-story buildings

Master class:
3. Unique retrofitting base isolation technologies for existing frame and braced-frame hospital buildings
4. Unique roof isolation technology for upgrading earthquake resistance of existing frame buildings
5. Creation and application of new method of seismic isolation rubber bearings' location by clusters

Second lecture:
6. Seismic risk of destruction of existing buildings in Armenia - reasons and consequences
7. Unique retrofitting base isolation technology for existing stone-masonry apartment and school buildings

We especially emphasize his high professionalism and invaluable information, which he provided for students and faculty during all presentations that were very well attended and raised huge interest among participants. Prof. Dr. Melkumyan's knowledge, rich experience and efforts in conducting the above are highly appreciated and will significantly contribute to the development of seismic isolation technologies in Peru.

Arequipa, November 2016

Mg. Héctor Ortiz Castro
Dean Faculty of Civil Engineering and Computer Science

Eng. Luis Beccerra Stock
Director Professional School Civil Engineering

Figure 3. Materials on invitation, lectures and "master class" conducted by the author at the Catholic University of San Pablo in Arequipa, Peru

The stay and different events at the Catholic University of San Pablo were widely covered in the press. Below are the articles from some newspapers.


ESPECIAL

noticias 11

AREQUIPA, viernes 04 de noviembre de 2016

ESPECILISTA LLEGÓ POR PRIMERA VEZ A AREQUIPA

Aislamiento sísmico para reducir la vulnerabilidad ante terremotos

Uno de los mayores expertos internacionales en movimiento telúricos llegó a la Ciudad Blanca.

Noticias

DATOS

Con la técnica del Dr. Melkumyan se ha mejorado 36 edificios ya construidos en Armenia y se están levantando otros 7 aplicando el aislamiento sísmico de base.

Dr. Mikayel Melkumyan, presidente de la Asociación de Ingeniería Sismoresistente de Armenia, llegó a Arequipa a fin de presentar una innovadora técnica de aislamiento sísmico en las construcciones la cual puede ser aplicada tanto en edificaciones nuevas como en edificios ya construidos. Utilizando esta técnica en las construcciones se reduciría la vulnerabilidad de las ciudades ante los terremotos porque se evitaría el colapso de las estructuras.

El especialista llegó a Arequipa gracias a la invitación de la Escuela de Ingeniería Civil de la UCSP (Universidad Católica San Pablo), a fin de dar una serie de charlas por la semana de aniversario de la Facultad de Ingeniería y Computación. Él es uno de los mayores expertos en técnicas de aislamiento sísmico a nivel internacional.

La técnica creada por el Dr. Melkumyan consiste en separar la edificación del suelo colocando en entre uno y otro, elementos flexibles a manera de amortiguadores llamados aisladores sísmicos. De este modo al ocurrir un movimiento sísmico, la estructura no se ve afectada. Es más las personas pueden permanecer dentro pues totalmente seguro.

Los aisladores colocados en la base se da en el caso de los edificios nuevos, para lo que ya están construidos se interviene en sus bases de modo paulatino a fin de ir colocando los amortiguadores en partes.

El especialista precisó que esta técnica es más económica que las tradicionales. El ahorro en caso de una construcción nueva puede ser de 30 a 35%. En los edificios ya construidos el costo es 3 a 5 veces menor que los sistemas de reforzamiento tradicionales.

Otra de las ventajas es que no se necesita desocupar el edificio para realizar los trabajos y se hace en un tiempo menor, de 3 a 5 meses. Por lo general, trabajos similares tardan entre año y medio a 2 años.

El caso de Arequipa y Perú

Aunque esta es la primera visita del Dr. Melkumyan a nuestro país dijo que es evidente que la calidad de las estructuras es deficiente porque no tienen un buen diseño, ni una buena construcción y no se aplica la tecnología. Ante esta situación exhortó a los profesionales y a las autoridades tener en cuentas nuevas técnicas como la que ha presentado ya que así se puede proteger a la población.

"No se debe esperar a que pase una catástrofe sino que se tiene que actuar antes. En Perú se debe aplicar el aislamiento sísmico principalmente en edificaciones públicas como hospitales y colegios, porque tiene una gran afluencia de personas. Al inicio va a ser costoso e incluso va a haber oposición, pero al ver los resultados van a ver que es importante y necesario aplicar estos nuevos métodos. Eso es lo que pasó en Armenia", comentó.

La técnica del Dr. Melkumyan también es propicia para Arequipa pues puede ser aplicada en monumentos históricos tal como ya lo ha hecho en países de Europa y en el suyo propio. La ventaja es que al aplicarla no se altera en nada la construcción histórica sino que se trabaja en las bases sin la necesidad de retirar o alterar otras partes de la edificación. De este modo también se preserva el legado histórico.

Cabe indicar que Armenia es uno de los países con mayor cantidad de edificios con aislamiento sísmico en el mundo. Las disposiciones del Código Sísmico de Armenia para estructuras sísmicamente aisladas son mucho más progresistas a la de otros países como Estados Unidos.

¡CELEBRAMOS 16 AÑOS CONTIGO AREQUIPA! noticias

MUCHAS GRACIAS A NUESTROS LECTORES

Reportaje publicado en la página 11 del diario Noticias, el 4 de noviembre de 2016.


Aisladores sísmicos son la solución en edificaciones

Mikayel Melkumyan, presidente de la Asociación de Ingeniería Sismoresistente de Armenia, quien es además el creador de la técnica de aislamiento sísmico de base y de piso superior, estuvo de visita en Arequipa y realizó una serie de sugerencias.

Explicó que su creación consiste en separar el edificio del suelo colocando en medio de ambos elementos flexibles como amortiguadores o cojinetes, llamados aisladores sísmicos, de tal modo que cuando se produce un movimiento sísmico, la estructura no se afecta.

"No hay que esperar que ocurra una catástrofe para aplicar el aislamiento sísmico en las edificaciones tanto nuevas como en las ya existentes en Arequipa", explicó el especialista y además dijo que es un sistema económico.

Mikayel Melkumyan, presidente de la Asociación de Ingeniería Sismorresistente de Armenia y especialista en sistemas de construcción, estuvo visitando desde hace algunos días la ciudad de Arequipa y pudo confirmar que las construcciones, no solo las que están ubicadas en el Centro Histórico, sino aquellas que ostentan algún grado de modernidad, no reúnen requisitos mínimos de seguridad como para soportar un sismo de grandes proporciones.

Nota publicada en la página 06 del diario Correo, el 4 de noviembre de 2016.

Rueda de Prensa con el Dr. Melkumyan.

andina 35 años DEL PERÚ PARA EL MUNDO **Impulsan proyecto de aislamiento sísmico en universidad arequipeña**

Protege estructura de impacto sísmico. ***Publicado: 9/11/2016.***

Dr. Sc. Mikayel Melkumyan, uno de los principales exponentes del aislamiento sísmico en el mundo

Arequipa, nov. 9. Un proyecto de aislamiento sísmico que busca proteger una estructura de un impacto sísmico desarrollan docentes y estudiantes de una universidad de Arequipa con apoyo de especialistas extranjeros, se informó. El proyecto es desarrollado por el grupo de investigación en Ingeniería Sismo Resistente y Mecánica Estructural de la Escuela Profesional de Ingeniería Civil de la Universidad Católica San Pablo (UCSP) de Arequipa.

Se informó que el proyecto recoge lo último en tecnología de aislamiento sísmico que evitará pérdidas humanas y materiales en caso de sismos en el Perú.

Dr. Sc. Mikayel Melkumyan, uno de los principales exponentes del aislamiento sísmico en el mundo, presidente de la Asociación de Ingeniería Sismo Resistente de Armenia, llegó a Perú para colaborar en las investigaciones.

Según la universidad, se trata de la herramienta más potente de la ingeniería sísmica, capaz de proteger a una estructura del efecto devastador del impacto sísmico a través de un diseño inicial apropiado o de su modificación posterior, sin necesidad de que el edificio sea deshabitado durante los trabajos.

"Esta tecnología consiste en separar del suelo la infraestructura de un edificio, para que el movimiento del suelo debido al sismo no llegue a las estructuras de la edificación y, por ende, no se dañe. Se logra mediante la instalación de elementos muy flexibles en sentido horizontal por encima de la cimentación, llamados aisladores sísmicos que permiten soportar el peso de la estructura", declaró Mikayel Melkumyan.

Agregó que en la actualidad, utilizando esta tecnología, el número de edificios ya construidos y modernizados en Armenia ha llegado a 45, mientras que siete están en construcción. Por lo tanto, el número de edificios con aislamiento sísmico per cápita en Armenia es uno de los más altos del mundo, debido a que el país es fabricador de aisladores sísmicos de caucho.

La implantación de esta tecnología en el Perú significaría un paso importante en la prevención ante sismos y también permitiría el ahorro en costos de construcción, pues su aplicación en Armenia redujo el uso del concreto y el refuerzo en estructuras portantes (columnas y vigas), lo que representó un ahorro entre 30 a 35 por ciento en una construcción nueva; mientras que en una ya existente el costo que se estimó fue de 3 a 5 veces menor que los sistemas de reforzamiento tradicionales.

Por último, Melkumyan sostuvo que para iniciar con la aplicación del aislamiento sísmico en el Perú se necesita del financiamiento de empresas y personas de poder adquisitivo y pensamiento preventivo, como ya se muestran en países de Latinoamérica como es el caso de Chile, que como el Perú, está ubicado en una zona altamente sísmica.

El Pueblo el Día PATRIMONIO CULTURAL DE AREQUIPA

Un terremoto como el de Italia destruiría Arequipa en un 90%
06 de Noviembre de 2016. Por: Roxana Ortiz A.

Fuerte terremoto se trajo abajo las principals viviendas de Italia.

"Lo que se ha visto con el reciente sismo de Italia es lo que podría estar pasando en Arequipa, porque las construcciones tienen características similares. Yo creo que por ahora solo les queda rezar para que no tengan más víctimas que las que se tuvo allí", dijo el especialista.

Prefirió no mencionar casos específicos de lo que había observado, pero dijo que le llamó la atención que en las columnas que sustentan las construcciones, se utilicen materiales nada adecuados para soportar varios pisos. Dijo que las columnas que sostienen la edificación son demasiado delgadas y los fierros de la misma manera.

Ante decenas de estudiantes de Ingeniería Civil de la San Pablo, realizó una simulación sobre cómo quedaría un edificio al ser sometido a un sismo de más de 6 grados y con poca profundidad, comparándolo con otro debidamente reforzado, siendo las conclusiones evidentes.

Sin embargo, indicó que las cosas no están de alguna manera perdidas, ya que se pueden obtener soluciones utilizando métodos modernos para reforzar dichas construcciones y sobre todo, evitar que los sismos que son muy comunes en esta zona del país, no causen mayores daños.

AISLAMIENTO SÍSMICO

Luego del terremoto de Armenia, que dejó más de mil muertos en el año 1988, comenzó a investigar cómo se podía lograr la resistencia de los edificios ante los movimientos de la tierra.

Llegó a la conclusión que se podía utilizar aisladores para disminuir los efectos de los sismos en los edificios, tal y como se viene utilizando en países como Japón o Chile, metodología que ha demostrado a nivel mundial, que son capaces de aminorar notoriamente los daños que producen los terremotos en las estructuras de edificios.

La idea está basada en aislar una estructura del suelo mediante elementos que reducen el efecto de los sismos sobre la construcción. Estos elementos se denominan aisladores sísmicos y son dispositivos que absorben mediante deformaciones elevadas, la energía que un terremoto transmite a la edificación, una especie de grandes resortes que se colocan entre el piso y la base del edificio.

Estos dispositivos pueden ser de diferentes tipos y formas, los más conocidos son los hechos en goma de alto amortiguamiento, goma con núcleo de plomo, neoprénicos o friccionales.
Al utilizar estos elementos, la estructura sufre un cambio en la forma cómo se mueve durante un sismo y la reducción importante de las fuerzas que actúan sobre ella en esos momentos.
El aislamiento sísmico surge en Armenia a partir de 1994 en donde se ha desarrollado a través de los proyectos financiados por instituciones internacionales (Banco Mundial, la ONUDI, Huntsman Corporation, Caritas Suiza). Las ventajas de aislamiento sísmico eran tan evidentes que en los años siguientes hubo un gran interés en la aplicación de esta tecnología demostrada por las empresas privadas y el gobierno de ese país.
Desde allí se produjo un mayor desarrollo de la aislación sísmica, la que continuó a través de proyectos financiados por las instituciones gubernamentales, no solo en edificios privados, sino en escuelas, colegios, universidades, hospitales y otros, que albergan a gran cantidad de personas.
Los aisladores sísmicos de goma que patentó Mikayel Melkumyan permite el ahorro significativo en los costos de construcción, y al mismo tiempo aumentan la fiabilidad de los edificios de nueva construcción o los reacondicionados.
Hay varias razones por las cuales aplicando esta tecnología se puede ahorrar mucho dinero en la construcción, si es que por ejemplo, se adquiere los aisladores de goma hechos en Armenia, los que cuestan significativamente más barato que los aisladores fabricados en otras partes del mundo. Esto está condicionado por el menor costo laboral, disponibilidad de componentes de caucho en el país, así como la existencia de varias fábricas dedicadas a su elaboración.
A ello se suman las disposiciones del Código Sísmico de Armenia para estructuras que son más progresistas en comparación con, por ejemplo, el Código de Estados Unidos en términos de análisis y diseño de superestructuras de edificios con aislamiento sísmico de base.

Aislamiento sísmico para reducir la vulnerabilidad de las edificaciones ante terremotos

25 noviembre, 2016

El **Dr. Mikayel Melkumyan, presidente de la Asociación de Ingeniería Sismorresistente de Armenia**, llegó a Arequipa a fin de presentar una **innovadora técnica de aislamiento sísmico** en las construcciones la cual puede ser aplicada tanto en edificaciones nuevas como en edificios ya construidos. Utilizando esta técnica en las construcciones se reduciría la **vulnerabilidad de las ciudades ante los terremotos** porque se evitaría el colapso de las estructuras.
El especialista llegó a Arequipa gracias a la invitación de la **Escuela de Ingeniería Civil de la Universidad Católica San Pablo (UCSP)**, a fin de dar una serie de charlas por la **semana de aniversario de la Facultad de Ingeniería y Computación**. Él es uno de los mayores expertos en técnicas de aislamiento sísmico a nivel internacional.
La técnica utilizada por el Dr. Melkumyan consiste en separar la edificación del suelo colocando en entre uno y otro, elementos muy flexibles en dirección horizontal llamados **aisladores sísmicos.** De este modo al ocurrir un movimiento sísmico, la estructura no se ve afectada. Es más, las personas pueden permanecer dentro pues es totalmente seguro.
Los **aisladores** colocados en la base se da en el caso de los edificios nuevos. Para los que ya están construidos se interviene en sus bases de modo paulatino a fin de ir colocando los aisladores por etapas sin afectar la **estabilidad de la estructura**.
El especialista precisó que esta técnica es más económica que las tradicionales. El **ahorro** en caso de una construcción nueva puede ser de 30 a 35%. En los edificios ya construidos el costo es 3 a 5 veces menor que los sistemas de reforzamiento tradicionales.
Otra de las ventajas es que **no se necesita desocupar el edificio** para realizar los trabajos y se hace en un **tiempo menor**, de 3 a 5 meses. Por lo general, trabajos similares tardan entre año y medio a 2 años.

El caso de Arequipa y Perú

Aunque esta es la primera visita del **Dr. Melkumyan** a nuestro país dijo que es evidente que la **calidad de las edificaciones** es deficiente porque no tienen un buen diseño, ni una buena construcción y no se aplica la tecnología. Ante esta situación exhortó a los profesionales y a las autoridades tener en cuenta **nuevas técnicas** como la que ha presentado ya que así se puede proteger a la población.
"**No se debe esperar a que pase una catástrofe sino que se tiene que actuar antes**. En Perú se debe aplicar el aislamiento sísmico principalmente en edificaciones públicas como hospitales y colegios, porque tiene una gran afluencia de personas. Al inicio va a ser costoso e incluso va a haber oposición, pero al ver los resultados se darán cuenta que es importante y necesario aplicar estos nuevos métodos. Eso es lo que pasó en Armenia", comentó.

Uno de los mayores expertos en técnicas de aislamiento sísmico a nivel internacional llegó a Arequipa

La **técnica de reforzamiento con aislamiento sísmico** del Dr. Melkumyan también es propicia para Arequipa pues puede ser aplicada en **monumentos históricos** tal como ya lo ha hecho en países de Europa y en el suyo propio. La ventaja es que al aplicarla no se altera en nada la construcción histórica sino que se trabaja en las bases sin la necesidad de retirar o alterar otras partes de la edificación. De este modo también se preserva el legado histórico.

Cabe indicar que **Armenia** es uno de los países con mayor cantidad de edificios con aislamiento sísmico per cápita en el mundo. Las disposiciones del **Código Sísmico de Armenia** para estructuras sísmicamente aisladas son mucho más progresistas a la de otros países como Estados Unidos. Con la técnica del Dr. Melkumyan se ha mejorado 45 edificios ya construidos en Armenia y se están levantando otros 42 aplicando el aislamiento sísmico de base.

El especialista espera volver a **Arequipa** próximamente ya sea para aportar en la difusión de estas técnicas, o colaborar con profesionales como el **Dr. Enrique Simbort y el M.Sc. Galvarino Pinto**, quienes lideran el **Grupo de Investigación en Ingeniería Sismorresistente y Mecánica Estructural,** en donde actualmente se vienen realizando investigaciones sobre la aplicación del aislamiento sísmico de estructuras en Arequipa.

II. Design of the 7-Story "Chullo" Residential Building in the City of Arequipa (Peru)

It should be noted that in Peru there is practically no regulatory framework for the design and construction of buildings with seismic isolation systems. There is also no in-house research and development in this area. However, among young specialists there is a certain knowledge base and a great desire to create and implement seismic isolation systems in their country. But the most important and surprising thing that was noted with satisfaction by the author of this article is the genuine desire of some architects and people engaged in the construction business to introduce seismic isolation technologies in their buildings. It was this aspiration of young scientists, engineers, architects and businessmen that formed the basis for uniting their efforts and inviting the author to cooperate with the involvement in the development of seismic isolation systems in relation to structural solutions common in Peru. In addition, the aim was to develop regulations and requirements for the implementation of seismic isolation systems in the country.

Thanks to the author's efforts, seismic isolation systems were developed for three buildings (two residential and one hotel and restaurant complex). At the same time, the buildings have already been designed in traditional versions with conventional foundations. However, this article provides, as an example, a design solution for a seismic isolation system for one of them. It is a residential building (Fig. 4) with six above-ground floors and one semi-basement floor, which also serves as a parking lot. The load-bearing structure of the building is a reinforced concrete frame where columns have a cross section of 200×200 mm and filled with weakly reinforced masonry made of hollow artificial blocks. There are practically no beams at the level of the intermediate floors, and the monolithic slabs themselves have a thickness of 200 mm. The building is designed for seismic impact with a maximum ground acceleration of 0.35 g.

From the above, it follows that the building is not reliable, having very weak load-bearing elements and an unsuccessful design solution. The trouble is that such houses are widely used in Arequipa and are quite popular among architects, who, unfortunately, set the tone in the local construction industry. The opinion of the structural (design) engineers, as the author was told, is of little interest to anyone here. Even the earthquakes that take place here are not very strong, although they cause damage to buildings, but do not change the mentality of Peruvian designers. Apparently, only strong vibrations of the earth's crust will force them to change their ideas about the reliability of structures, as it was in Armenia immediately after the Spitak earthquake of December 7, 1988. In this regard, it can be said that the desire of a new generation of scientists and engineers to change the current situation and move to the introduction of innovative seismic isolation technologies in Peru is very encouraging.

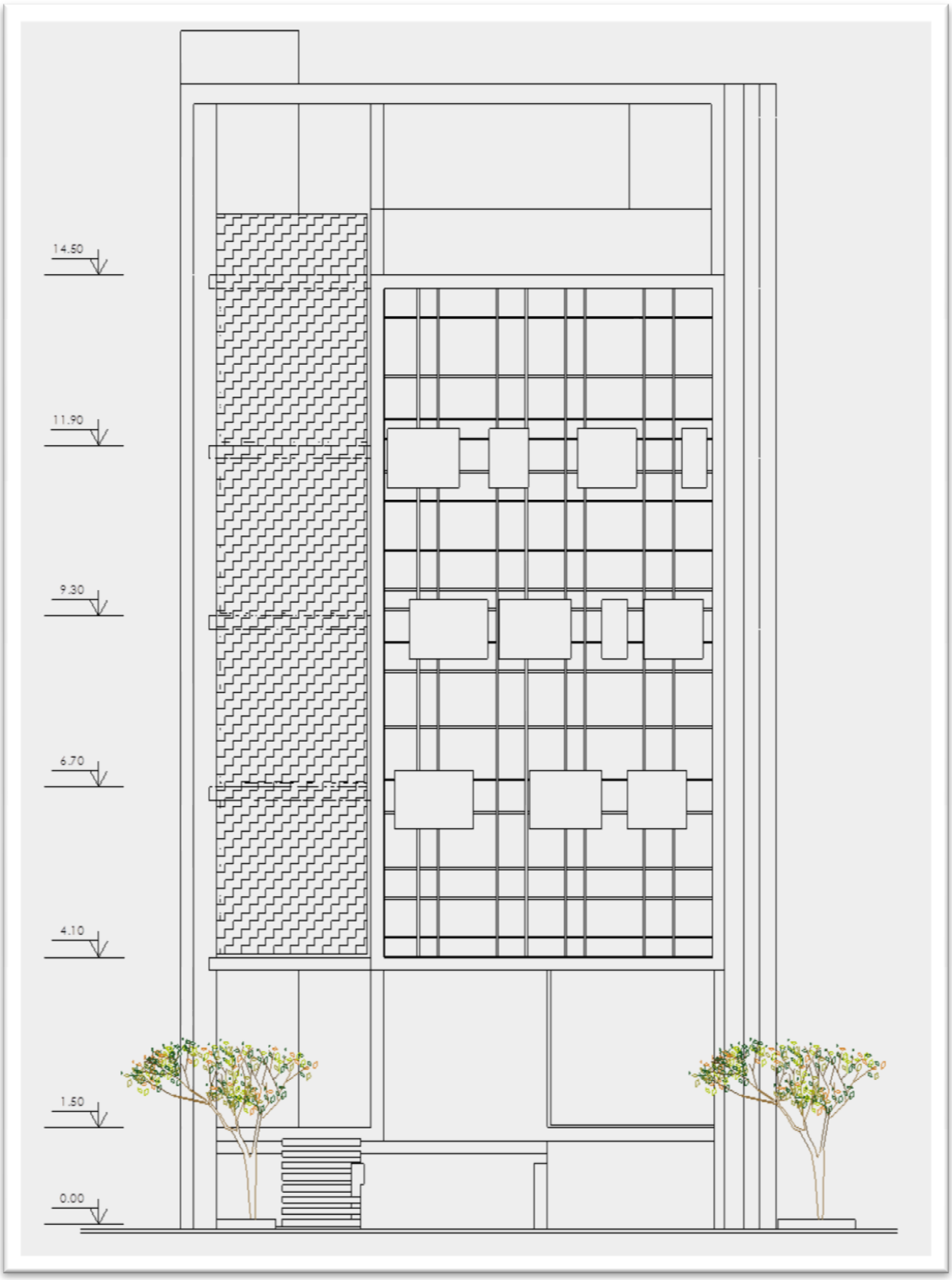

Figure 4. The main façade of the designed residential building on Chullo street in Arequipa (Peru)

Based on his own experience gained in Armenia, the author, in order to train Peruvian engineers and provide technical assistance to local developers, has developed a new version of the design for the above-mentioned residential building, but with the use of a seismic isolation system in the semi-basement floor. The plan of the load-bearing structures of this floor, designed for location of the seismic isolation system is shown in Figure 5.

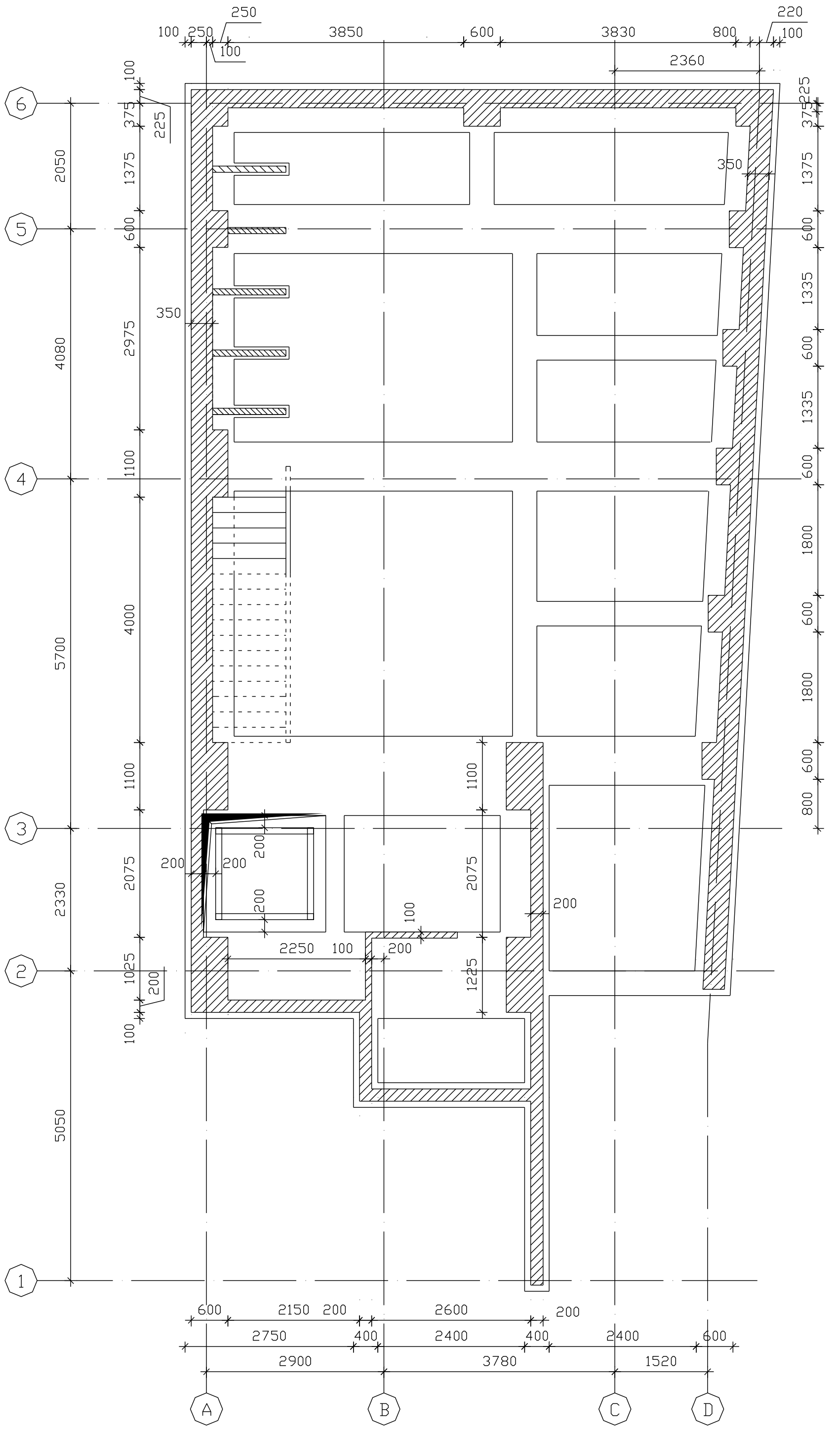

Figure 5. Plan of the load-bearing structures of the semi-basement floor, where the seismic isolation system is located (in this plan the foundation strips are also shown)

Plan of the location of SILRSBs in the semi-basement floor and plan of the upper beams and a slab above the seismic isolation system of this residential building are shown in Figure 6. Different vertical elevations of the building are shown in Figure 7, where the gaps of the seismic isolation system and of stairs are clearly seen. Special attention needs to be paid to the stairs leading to the semi-basement and stairs at the entrance of the building. There are the gaps envisaged in the design for these structural elements. The main purpose of these gaps, as well as the 200 mm gap of isolation system is to ensure unhindered movement of the superstructure (the part of the building above the seismic isolation interface), as well as effective action of the seismic isolation system and accommodation of its horizontal displacement during any seismic impact.

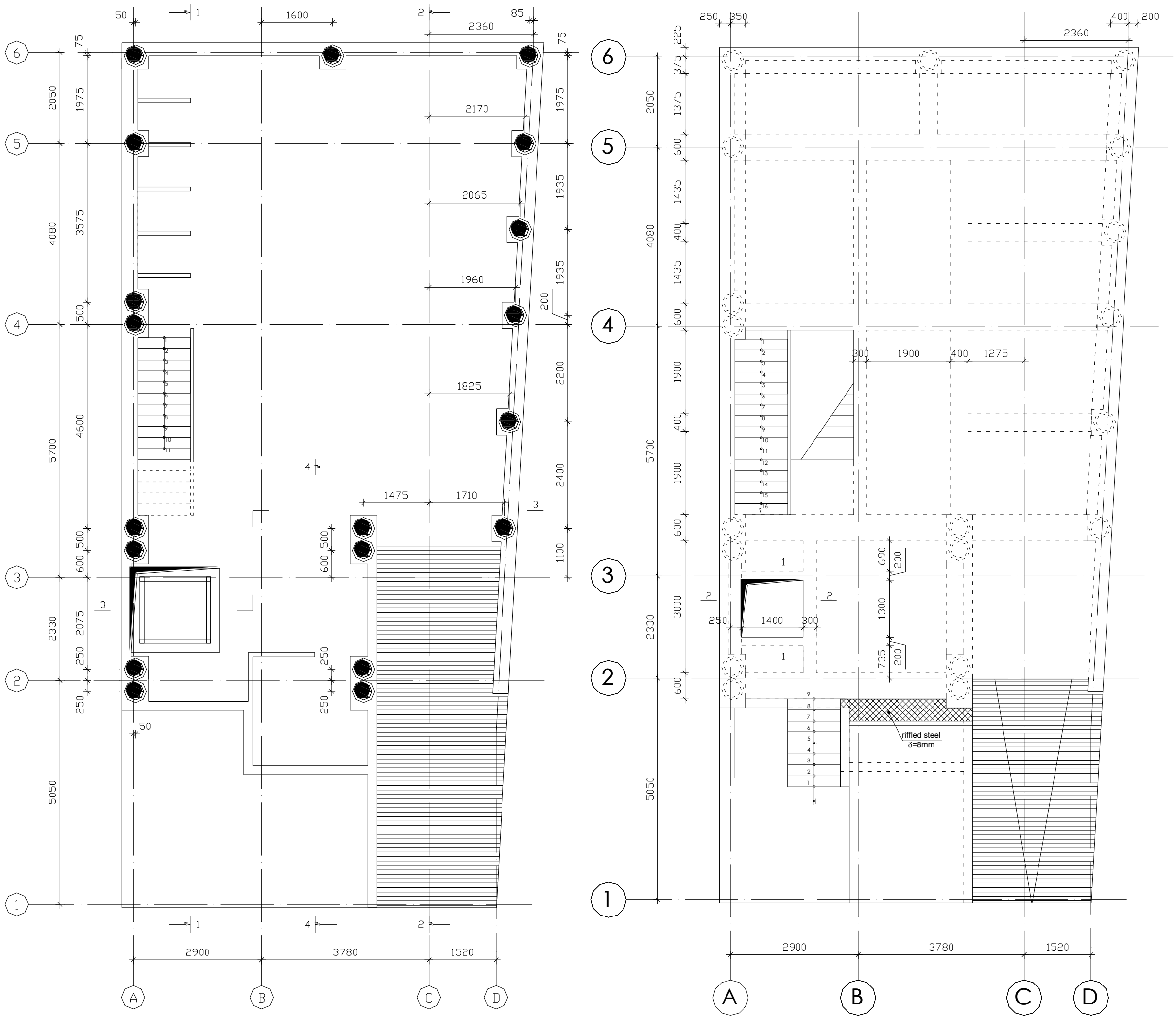

Figure 6. Plan of the location of SILRSBs in the semi-basement floor and plan of the upper beams and a slab above the seismic isolation system of the residential building on Chullo street in Arequipa (Peru)

From this it can be seen that the seismic isolation system, consisting of 19 SILRSBs, is located between the marks 0.70 and 1.50. Above the isolators it has reinforced concrete beams, in which the load-bearing structures of the superstructure are anchored. Thus, the interior space of the basement floor is free of intermediate columns. The SILRSBs are supported by columns with a cross-section of 600×600 mm and 600×1200 mm, which are connected by 350 mm thick shear walls along the outer contour of the semi-basement. The latter are calculated and designed in such a way that they reliably carry horizontal loads not only in their plane, but also out of the plane, since in this design solution there are no beams below SILRSBs (the mark 0.70) to connect all columns. Such design solutions were developed and implemented by the author in several base isolated buildings in Armenia. They are used either at the insistence of architects or when the height of the room where the seismic isolation system is located is insufficient. The latter case took place in the considered residential building, for which the calculated period of oscillations is equal to 1.95 sec.

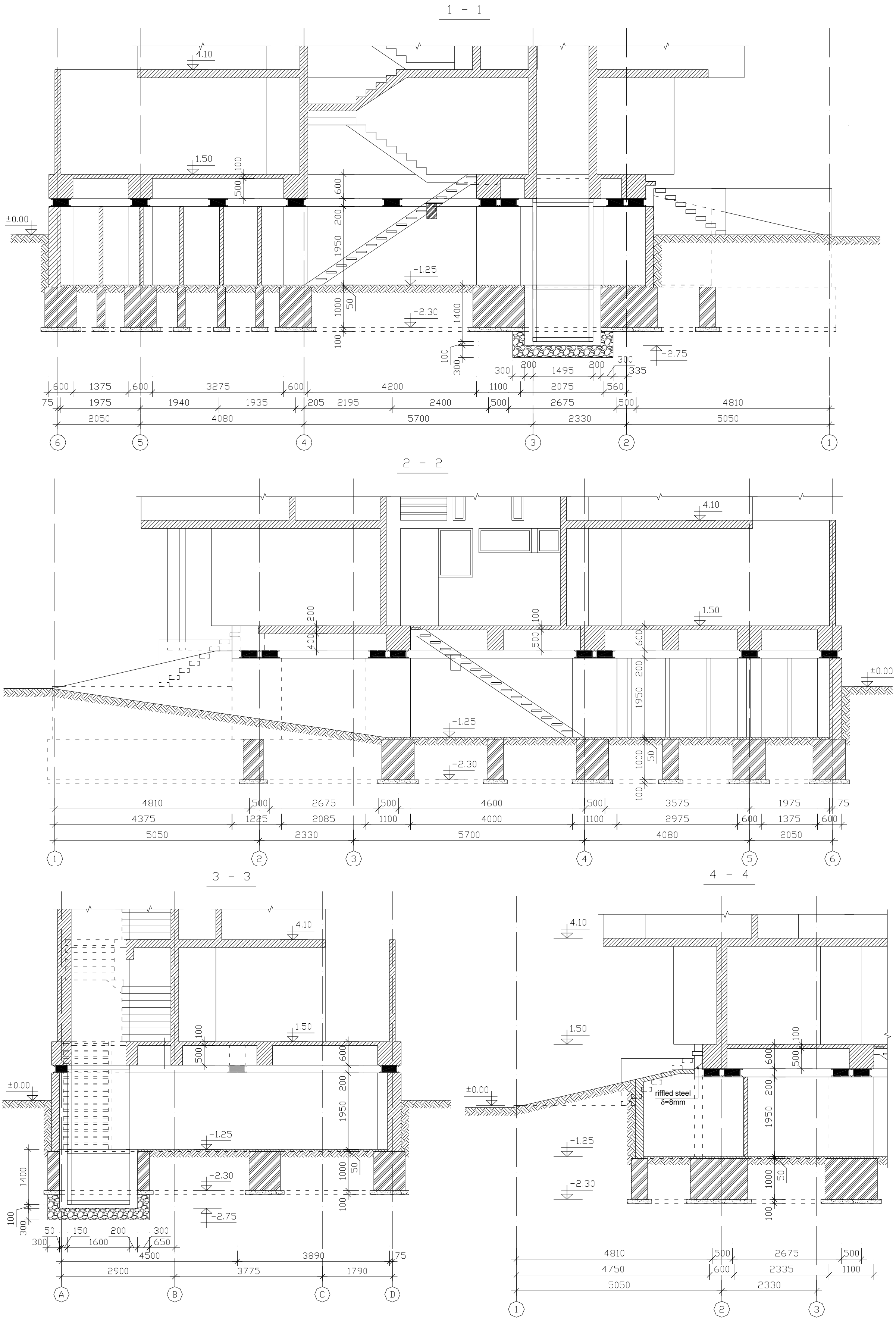

Figure 7. Different vertical elevations of the building on Chullo street in Arequipa (Peru)

III. Conclusions

Brief information about the newly constructed or retrofitted seismic (base and roof) isolated buildings in Armenia is given and the country's leading role in terms of the number of buildings and structures per capita, as well as of low-cost implementations of these systems, is stated.

Visit to Arequipa (Peru) was very fruitful and created a favorable basis for possible cooperation between Armenia and Peru in the development and design of seismic isolation systems for construction of new and retrofitting of existing buildings.

Export to Peru of various types of SILRSBs, which have different damping characteristics and dimensions, produced in Armenia was discussed.

Base isolation design of the 7-story "Chullo" residential building, with the calculated period of oscillations equal to 1.95 sec, for construction in the city of Arequipa was developed by the author. That will serve as a good start for further development of modern innovative seismic isolation technologies in Peru.

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