APPLICATION OF SEISMIC BASE ISOLATION TECHNOLOGY IN IRAN

Senior Researcher in Earthquake Engineering, Imensazeh Company, Tehran, Iran
Ahmad Naderzadeh

ABSTRACT

Application of base isolation techniques in Iran goes back to hundreds of years ago and even to ancient times. Installing pieces of wood between the foundation and the walls of buildings is among the earthquake resistant construction techniques that have been applied in some areas of Iran in the past. However, contrary to other technologies which are generally adapted soon after their development, modern seismic base isolation technology took almost a quarter of a century to be adapted and utilized in Iran. This paper presents the historical as wells as the modern application of seismic base isolation technology in Iran.

1 INTRODUCTION

Iran is located in an active seismic area and we frequently observe heavy casualties and damages due to destructive earthquakes. Therefore, people have tried to cope with this natural hazard using different techniques throughout the history. Application of base isolation concept is one of the techniques that have been used in some areas of the country in the past. However, modern base isolation technology was not used in Iran until very recently. One important reason for the long delay can be referred to the fact that it is difficult to change the mentality of the builders from their current way of construction to a newly developed technology. However, this can be acceptable to some extend, as it is human nature to resist against change, and life would certainly be easier if engineering practices and building construction remained unchanged. We should note that advances in earthquake engineering and the construction practice that follow are as dynamic as the world we live in. In order to use the latest technology and ensure highest level of safety in the built environment, it is imperative that the design and construction communities utilize the most current technologies available.

2 BASE ISOLATION TECHNOLOGY IN IRAN

2.1 Historical Structures

Study of historical structures in Iran show that some base isolation techniques had been utilized to reduce seismic impacts on some types of structures throughout the history. For instance, construction of multi-layer stones, pouring sand between the ground and the bearing walls, and installing pieces of woods (timbers) between the ground and the bearing walls of some traditional structures were among the techniques that use to be applied in earthquake resistant construction.

2.1.1 Multi-Layer Stones

The first application of the base isolation concept in Iran goes back to ancient times when some structures were built on multi-layer stones with flat and smoothed surfaces. The smooth surface of the stones would contribute to an easier slide of the structure with respect to the foundation during earthquakes. Therefore, it can be concluded that application of multi-layer stones which uses a base isolation concept, could overcome to the earthquake effects.

2.1.2 Pouring Sand between the Ground and Walls

There are evidences of pouring sand between the ground and the bearing walls of some historical structures in Iran. This would create a sliding mechanism for the structure during earthquakes.

2.1.3 Using Timber under Bearing Walls

Study of historical areas in the northern part of Iran also shows a good practice of earthquake resistant construction. One example is the town of Masooleh which is famous because of its 4,000 years history. Its architecture is based on the need for protection against environmental conditions as well as earthquake resistance. In this town, architectural elements, local materials, and construction techniques have created a unique homogenous environment, a combined texture of houses and buildings with nature and culture. The natural sloping condition of Masooleh affected the building forms and methods of construction. Buildings in the town are generally of two or three stories and most of them are more than 100 years old and constructed with adobe and mud. Because of the sloping site of the town, the roof of every building forms the front surrounding of the house behind or is a path-way or bazaar. The roofs are heavy and constructed with strong wooden beams. Wooden beams, columns and ring ties are combined with thick adobe walls. Roofs are heavy and are comprised of strong wooden beams located close to each other. What are notable are the tie beams and tie columns which are used in most of the buildings in both horizontal and vertical directions (Figure 1), [2].

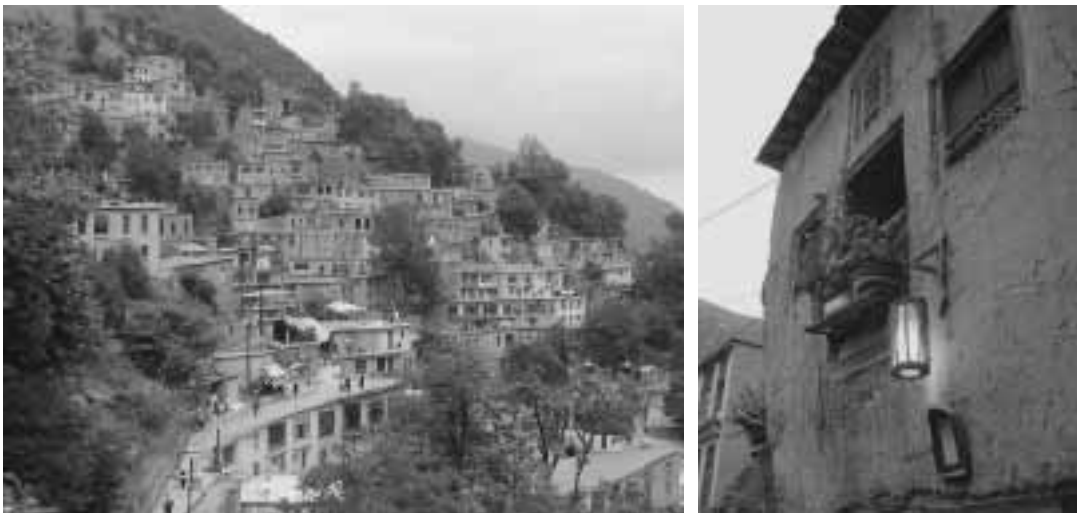

Figure 1. Masooleh historical town in north of Iran; construction in this town has been based on the need for protection against environmental conditions as well as earthquakes.

Investigation on the good behavior of the traditional buildings in Masooleh, following the 1990 Manjil earthquake (Mw 7.3), showed that two main concepts of earthquake resistance have been applied in construction of these buildings. One considered the dissipation of energy due to earthquake and the other considered the whole building as a single unit.

For the first technique, many traditional buildings are constructed on base isolated foundations. They have been designed and constructed in a way that allows the ground to move with the rolling movement of the building on the foundation. The foundation is constructed on layers of timber which can roll on each other and dissipate the earthquake induced energy (Figure 2).

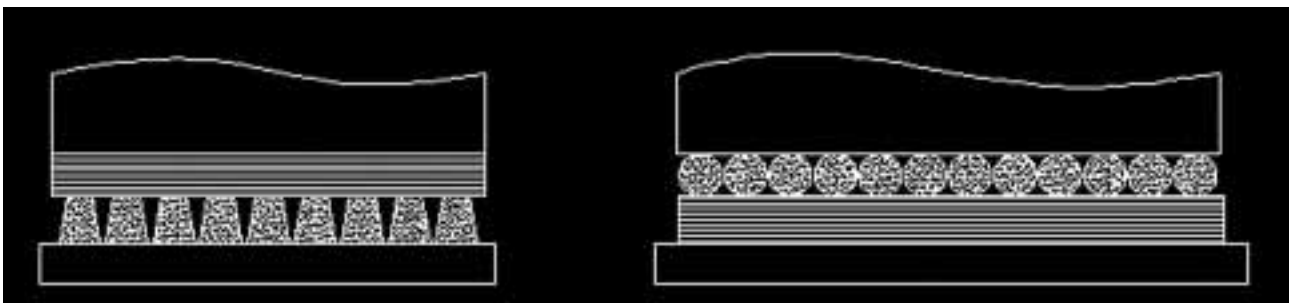

Figure 2. Two sides of a foundation constructed on layers of timber in many traditional buildings shown in Figure 1 (Masooleh, north of Iran).

The other technique is to construct buildings that can behave as a single unit during earthquakes. Other than applying base isolators, traditional buildings in Masooleh are braced in both vertical and horizontal directions, and the wooden columns used in the walls are anchored at the roof and at the foundation. The buildings are also braced at the corners with both vertical and horizontal wooden members (Figure 3). These are not timber frame buildings but could act as monolithic structures during earthquakes.

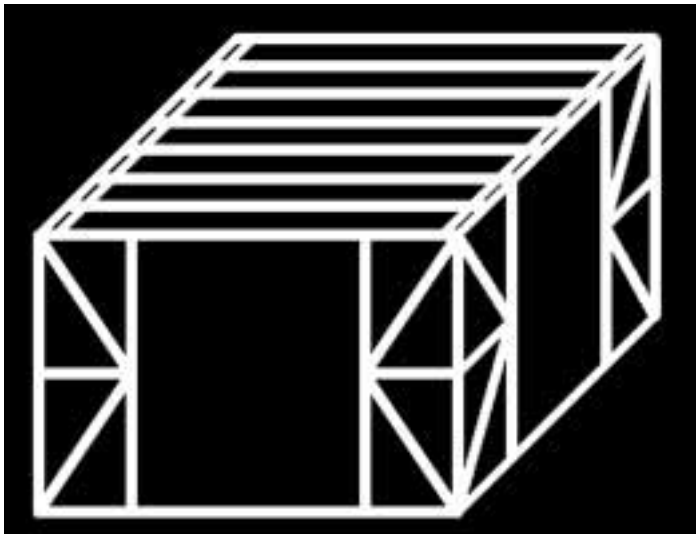

Figure 3. Structural system of traditional buildings in Masooleh. Wooden tie beams and tie columns plus vertical and horizontal bracings at the corners provide an integrated structure.

Figure 4 shows an example of a traditional house constructed in Lahijan, another city in north of Iran using pieces of woods under the walls with a different configuration shown in Figure 2. There are evidences that application of this technique goes back to several hundred years ago. Although this technique had several advantages (e.g., prevention of moisture to enter to the house, creation of gallery effects which cause the air ventilation under the structure, and using the space between the ground and the floor as a storage), it was an effective measure for earthquake resistance as well. Detailed field survey from very old people residing in those houses and further studies showed that those pieces of woods were intentionally installed horizontally in different layers in order to have a better performance against earthquakes; otherwise, if it were only for the purpose of moisture prevention, they could simply use some vertical members rather than laying the wood pieces as shown in the figure. Anyhow, these buildings also performed well during the 1990 Manjil earthquake in north of Iran. Some of these buildings had a permanent displacement of 15-20cm almost without any damage. This was mainly due to the fact that they basically rely only on the friction and they do not have any restoring force (like Friction Pendulum System) to bring them back to their original position.

Figure 4. Use of pieces of wood between the ground and the bearing walls of traditional houses in Lahijan, north of Iran. This demonstrates a base isolation technique that was applied long before the introduction of modern base isolation technology.

Above examples and many other evidences indicate that earthquake engineering concepts have been applied in Iran since ancient times. Using base isolators and other means of seismic resistance concepts clearly show that our ancestors were aware of the earthquake hazard and had learned how to cope with it. Their constructions have been experiencing earthquakes throughout the history but most of them are still remaining without significant damages. Perhaps we should realize that the engineering practice in the past was better than today. As a matter of fact, our ancestors had learned better than us how to live in harmony with earthquakes and other natural hazards.

2.2 Modern Structures

In modern age, the first attempt to utilize a seismic vibration reduction system in Iran goes back to early 1970's when the 15 (13 above ground) storey telecommunication building was constructed in the central part of Tehran (Figure 5). Two Teflon plates with rubber in between were installed between the basement ceiling and the ground floor columns of the building. However, there are no accessible details and drawings available on those plates to find out or to further investigate their expected function during earthquakes.

Figure 5. Telecommunication building in the central part of Tehran built in early 1970's. Two Teflon plates with rubber in between are installed between the basement and the ground floor columns of the building.

To the best of the author's knowledge, the first public introduction of modern seismic base isolation system in Iran took place by him after his return from Japan and observation of several buildings constructed on base isolators in 1989. He presented a lecture on base isolation technology and its application at Sharif University of Technology in that year. Since then, he has made so much effort and has worked hard to create a culture of safety through application of base isolation technology and other means of seismic control in Iran. There have been several other experts, especially in recent years, who have tried to promote the use of base isolation system in Iran. Major activities carried out so far can be summarized as follow:

At least one book and several research papers are already published on base isolation system in Iran. Many graduate students have worked on this subject as their theses. The subject is also presented in numerous lectures, seminars, conferences, etc. Some technical journals and periodicals have published articles on the advantages of base isolators. However, it should be noted that all these activities were generally done by and for technical people, not the main builders of buildings who could use these devices in their real practice. In addition, a few attempts have been made to produce base isolators in Iran; and a couple of samples have also been made but have not reached to mass production yet. At present, there are at least two companies who represent two foreign producers of base isolators in Iran. One of these companies has even obtained permission to produce a well known base isolator brand in the country, but it is not

started yet.

However, these activities and some other efforts did not come to reality to construct even a single building on modern base isolators in Iran. This was the case until very recently that we suddenly observe construction of many buildings on base isolators in a new town near the capital city of Tehran.

3 MODERN BASE ISOLATION APPLICATION

A contract was made between the Ministry of Housing and Urban Development of Iran and the government of Malaysia in 2006. According to the contract, a Malaysian developer would invest in Iran to construct tens of blocks of residential buildings in two new towns of Parand and Hashtgerd near Tehran as part of the New Town Development Program. According to the contract, all buildings shall be constructed on base isolators.

The project will be carried out in two Phases. In Phase 1A, in total 24 blocks of residential buildings are going to be constructed in the Parand New Town. This Phase consists of 8 blocks of Type A, which is a 12 storey high building with 73 units of apartments and 16 blocks of Type B, which is an 8 storey high building with 96 units of apartments.

Currently, 5 blocks of 12-storey buildings are under construction. Upon completion of all 24 blocks of buildings in Phase 1A, they will proceed to Phase 1B which consists of 10 blocks of type A and 23 blocks of type B. Details of both types of buildings are shown in Table 1.

Table 1. Base isolated buildings under construction near Tehran, Iran

Buildings	Structural material	No. of storey	No. of isolators	Type of isolators
Type A	RC*	12	66	HDRB**
Type B	RC	8	88	HDRB

* RC= Reinforced Concrete ** HDRB=High Damping Rubber Bearing

Overall perspective views of a part of the Parand New Town where typical base isolated buildings are under construction are shown in Figure 6. Typical plan and elevation views of 12 story buildings (Type A) are demonstrated in Figure 7. Typical elevation view of 8 story buildings (Type B) is presented in Figure 8. Figure 9 shows typical 12 story buildings under construction.

Figure 6. Overall perspective view of a part of the Parand New Town near Tehran.
All buildings on this site are going to be constructed on base isolators.

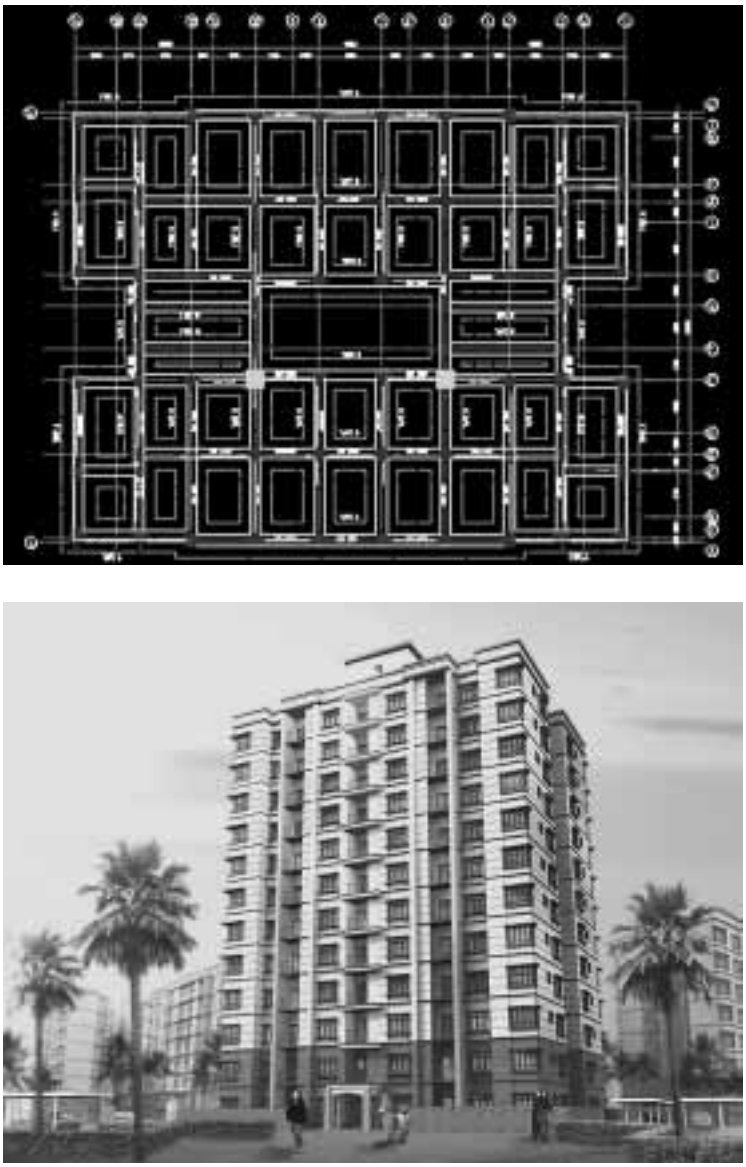

Figure 7. Typical plan and elevation views of 12 storey base isolated residential buildings under construction near Tehran

Figure 8. Typical view of 8 storey base isolated residential buildings to be constructed near Tehran

Figure 9. Typical 12 storey base isolated residential buildings under construction in Parand New Town near Tehran.

4 APPLICATION OF OTHER TYPES OF SEISMIC VIBRATION CONTROL

Besides base isolation, application of other types of seismic vibration control is already started in Iran. As an example, Figure 10 shows a (-2+26) storey hotel building in Tehran constructed in 1975. Hydraulic dampers are used as a part of the retrofitting plan for this tall building.

Figure 10. Application of hydraulic dampers as a part of the retrofitting plan for a tall hotel building in Tehran.

5 BASE ISOLATION AND THE SEISMIC CODE

Design of base isolated buildings is not yet included in the Iranian Building National Regulations including the 'Iranian Code of Practice for Seismic Resistant Design of Buildings' (Standard 2800). Therefore, base isolation design may require a special permission from the building code authorities of Iran, or alternatively, shall be done through application of a valid foreign code provided that the seismic loading fulfils the requirements of the Standard 2800. It is expected that the application of base isolators be included in the future revisions of the Iranian seismic code. This will certainly encourage many builders to utilize base isolators in new constructions in the near future.

However, application of base isolators is included in the Iranian 'Instruction for Seismic Rehabilitation of Existing Buildings'. This Instruction is basically adapted from Federal Emergency Management Agency and other relevant publications. Nevertheless, no building is retrofitted using base isolators in Iran yet. This is mainly due to the fact that this technology is just being introduced in the construction of new buildings and it may take some time till it can be applied for retrofitting of existing buildings.

6 CONCLUSIONS

Base isolation application was finally adapted in Iran following the efforts of the earthquake engineering community. However, production of these effective and useful devices is not started in Iran yet. As far as the raw materials and human resources and expertise are concerned, they are available in the country. It may only require providing a testing machine, if the prototype and production tests of isolators are going to be performed locally. Therefore, if a serious attempt is made, it will be possible to start producing them in Iran as well.

Similar past experiences have shown that once the builders and general public are convinced that the use of base isolators and other means of seismic control provide a much higher safety for their buildings against earthquakes, they will undoubtedly start using them in a large scale. Current construction of buildings on base isolators is a big starting step.

7 ACKNOWLEDGEMENT

The author is grateful to Amona Company for furnishing the information on their project in Tehran and providing the AutoCad files of the buildings drawings. Drs. A.A.Moinfar, H.Keypour, A.A.Shahkarami, M.Gh.Vetr and A.R.Rezaeian provided useful comments on the historical structures behavior as well as their photos. Their contribution is highly appreciated.

8 REFERENCES

1) Naderzadeh, A. and H. Keypour. (2007). Use of new technologies in construction of buildings and retrofitting of existing buildings against earthquakes - Introduction of base isolation systems. (In Persian).

2) Arbabian, H. (2002). Architectural issues in earthquake rehabilitation of the Iranian cultural heritage. In Hazard and Modern Heritage.