Submitted on: 12.07.2019

Preparing for Mega-Quakes: Disaster Mitigation at the National Diet Library, Japan

Yoriko Sato
Acquisitions and Bibliography Department, National Diet Library, Tokyo, Japan.
satoyori@ndl.go.jp

Abstract:

In Japan, efforts to improve earthquake resistance of buildings are continuing based on past experience and the assumption that another large-scale earthquake will occur in the near future.

The National Diet Library has implemented countermeasures for each of its five buildings depending on their age, location, functionality, and other conditions. The Brick Building of the International Library of Children's Literature was the first library in Japan to be retrofitted with seismic isolation technology. This technique effectively lessens the shaking experienced by a building while preserving the building's original architecture. On the other hand, conventional seismic reinforcement was implemented at the Main Building of the Tokyo Main Library, and there are three other buildings that have underground stacks, which is also an effective protection against earthquake damage. All three types of buildings survived the Great East Japan Earthquake in 2011 without any structural damage, but there were significant differences in the impact on the collections in the buildings. Aseismic isolation and underground stacks have provided better protection for collections.
The NDL will continue its efforts to give proper consideration to both the risks we face and the constraints we work under in implementing measures to reduce damage and to effect prompt recovery from earthquakes.

Keywords: Earthquake-resistant building, seismic isolation retrofit, seismic reinforcement, underground stacks, National Diet Library

Introduction

In Japan, disaster prevention measures have developed along with the history of earthquake damage. Learning from major earthquakes such as the Great Kanto Earthquake of 1923, the Great Hanshin-Awaji Earthquake of 1995, and the Great East Japan Earthquake of 2011, laws were revised to prepare for the next earthquake, countermeasures were strengthened, and disaster prevention awareness has improved. In addition, the disaster-affected areas became the stage of the international conferences that created the Sendai Framework for Disaster Risk Reduction 2015-2030[1] and, prior to that, the Hyogo Framework for Action 2005-2015,[2] and have led international consultation and decision-making on disaster reduction.

Moreover, the Headquarters for Earthquake Research Promotion at the Ministry of Education, Culture, Sports, Science and Technology reports that there is a 70% probability of a magnitude-7 earthquake occurring within the next 30 years in the Tokyo metropolitan area. And it is also predicted that an earthquake of about magnitude 8 to 9 will occur with a probability of 70 to 80% within the next 30 years in the Nankai Trough which extends south of Tokai to Shikoku.[3]
Based on the assumption that large-scale earthquakes will occur, efforts to reduce the damage as much as possible are becoming increasingly important in Japan.

In this paper, after introducing the country-level risk governance with regard to earthquakes, that is, the development of laws and standards and measures to promote their implementation, I will report on how the National Diet Library (NDL) takes measures to mitigate damage to its buildings, as an example of investment in disaster risk reduction.

Earthquake-resistant measures in Japan

(1) Seismic strengthening of buildings
Large earthquakes often cause complex disasters such as tsunamis, fires, and liquefaction of the ground, so the countermeasures to be taken are not simple. However, it is clear from the past experience that the most direct and effective countermeasure is to strengthen the earthquake resistance of building structures.
For example, the magnitude-7.3 Great Hanshin-Awaji Earthquake that occurred in January 1995 caused 6,434 deaths. And out of the approximately 5,500 people directly killed by the earthquake, most people died immediately under collapsed houses or furniture.[4] Prior to this, the Building Standards Act had been revised in 1981, significantly strengthening earthquake resistance standards. Specifically, it stated that all newly built structures must be capable of resisting damage during medium-sized earthquakes (intensity 5 upper in the JMA Seismic Intensity Scale[5]) and not collapse during large-scale earthquakes (intensity 6 upper to 7). Many of the victims of the Great Hanshin-Awaji Earthquake were people who lived in wooden houses built under the old building standards, and there were far fewer causalities in buildings built according to the 1981 standards.
This major disaster proved that the 1981 earthquake resistance standards were effective, and efforts to promote earthquake resistance were strengthened after that.

(2) Efforts to promote earthquake resistance
In response to the lessons of the Great Hanshin-Awaji Earthquake, the Act for Promotion of Renovation for Earthquake-Resistant Structures of Buildings was enacted in 1995. Currently, the government makes it a goal to increase the earthquake resistance rate of dwelling houses[6] and the earthquake resistance rate of buildings used by many people such as schools and hospitals to 95% or more by 2020, respectively. Support system by the national and local governments for expenses for seismic diagnosis and seismic retrofitting is established. (As of 2013, the rates are about 82% of houses, and about 85% of buildings used by many people)[7]
In addition, government offices are required to maintain a safer building, based on Comprehensive Standards for Earthquake Resistance and Tsunami Planning of Government Offices (March 2013) and Comprehensive Standards for Seismic Diagnosis and Repair of

Government Offices (October 1996). According to these standards, the NDL, as a public facility used by a large number of people, is aiming to secure the earthquake safety of 1.25 times the level of a building that meets the Building Standard Act.

Outline of the NDL buildings and their earthquake resistance

The NDL has the mission to preserve Japanese publications and to pass them onto future generations as a sole deposit library in Japan. It also plays a role in supporting the activities of the National Diet by utilizing its collection. Currently, five buildings are built at three sites, but different earthquake countermeasures are taken depending on the construction time and feature of each building. Table 1 summarizes what kind of earthquake countermeasures are taken in each building.

(Table 1) NDL buildings and earthquake countermeasures

Building	Completion year	Storage capacity	Countermeasures for buildings	Advantages and disadvantages
Tokyo Main Library, Main Building	1968	4.5 million volumes	Seismic reinforcement	・The least expensive. ・As shaking is not reduced, large earthquakes may cause major damage to the collection.
Tokyo Main Library, Annex	1986	7.5 million volumes	(In addition to the seismic building) Underground stacks	・As shaking is reduced compared to the ground floor, mitigation effect is high. ・Several other advantages than earthquake resistance; the temperature and humidity can be easily maintained, etc. ・The construction cost is higher than that of the above-ground stacks.
Kansai-kan	2002	6 million volumes		
International Library of Children's Literature, Arch Building	2016	650,000		
International Library of Children's Literature, Brick Building	Construction in 1906 Expansion in 1929 Large-scale renovation in 2002	400,000	Seismic isolation retrofit	・Shaking is greatly reduced and disaster mitigation effect is high. ・Earthquake-proof building can be achieved without changing the interior and exterior of the building. ・Construction cost is large.

Renovation of the Brick Building of the International Library of Children's Literature with seismic isolation retrofitting

The Brick Building of the International Library of Children's Literature (ILCL) was renovated using seismic isolation retrofitting. With current technology, seismic isolation is the most effective way of suppressing the shaking of buildings caused by an earthquake, but there are few examples of seismic isolation retrofit used in libraries. So I will introduce this case in more detail than other measures.

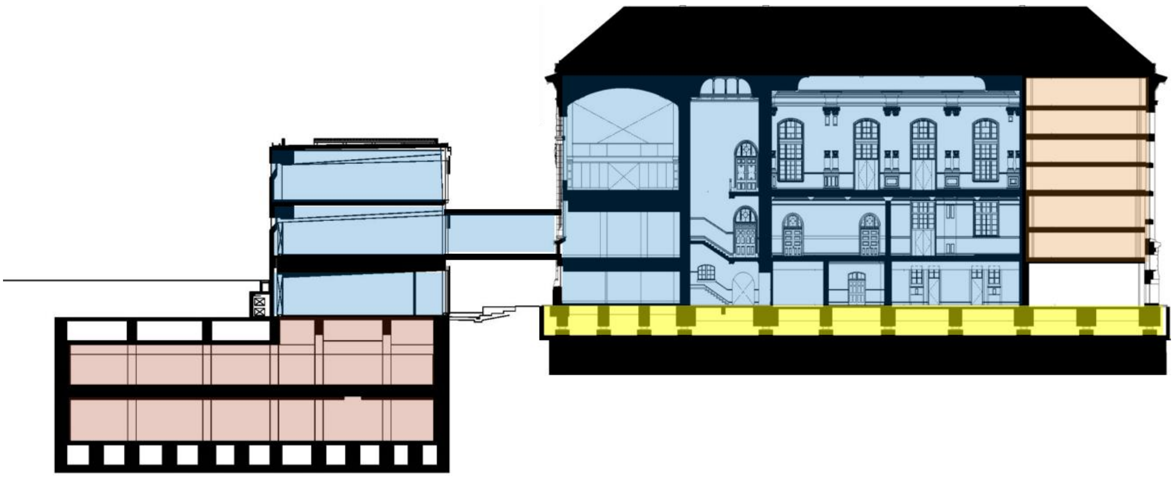
(Fig. 1) International Library of Children's Literature, Brick Building

This building was built in 1906 as the Imperial Library of Japan, expanded in 1929, and after the World War II, it had been used as the Ueno Library, a branch of the NDL. It has been designated as a metropolitan historic building by the Tokyo Metropolitan Government as a representative Renaissance-style architecture of the Meiji-era. In order to reopen the building as the International Library of Children's Literature in 2000, a large-scale repair work was carried out to conform to the disaster prevention and fire code while preserving the design and structure of the interior and exterior of this precious architectural heritage. The renovation work took about four years from 1998.

(1) Seismic isolation retrofit

The biggest challenge in the renovation work was the earthquake resistance of the building. As a result of the survey carried out before the renovation, it became clear that the building did not meet the 1981 earthquake-resistance standard and the comprehensive standards for earthquake-resistance plan of the government facilities at that time. We discussed with the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the design company in charge of design and construction, and finally, decided to adopt seismic isolation retrofit method. In Japan, as a general rule, the budget request to construct a government or other public office facility is made by each ministry or agency, but the expenditure of the allocated budget is delegated to the MLIT and the MLIT takes the initiative in the construction project.[8] This renovation, which was entirely covered by the national budget, was also implemented by the MLIT.

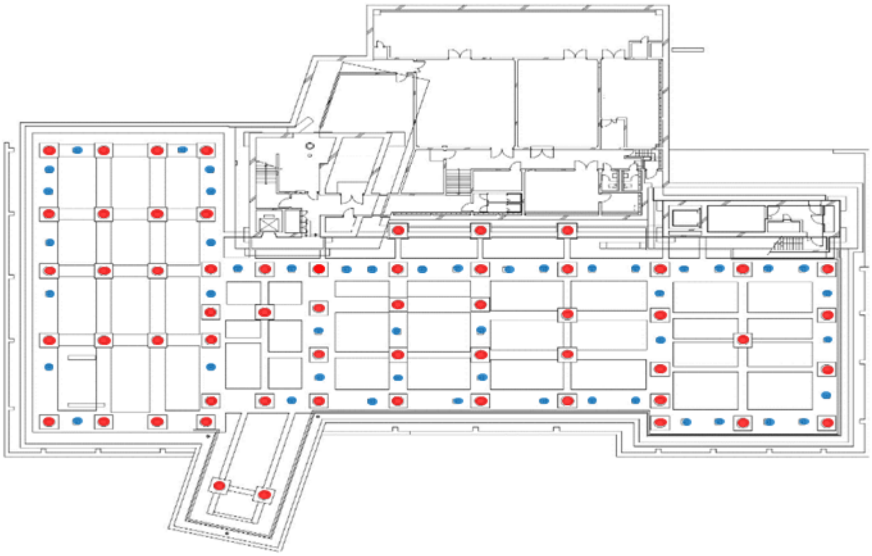
Seismic isolation is a method to concentrate and absorb ground shaking caused by seismic energy at the junction between a building and a base by installing rubber and other seismic isolation devices at this junction. The shaking can be reduced from one-third to one-fifth. In the ILCL, 69 laminated rubber isolators to support the weight of the building and to insulate it from the ground, and 52 lead dampers (Figs. 3-5) to absorb vibration energy were installed on the first basement floor to make the existing aboveground floors seismically isolated.[9]



(Fig. 2) Sectional plan of the ILCL buildings
(The seismic isolation devices are installed in the yellow part.)

(Fig. 3) Laminated rubber isolator

(Fig. 4) Lead damper



(Fig. 5) Layouts of the seismic isolation devices   Isolator   Damper

(2) The reasons the seismic isolation retrofit was adopted
The seismic isolation retrofitting costs more than normal seismic reinforcement, that is reinforcing walls and columns with steel frames or other materials, and there were few precedent cases at the time. Why was it adopted? Several factors came together to make it happen.

First, as mentioned above, the building was selected as a historical building of Tokyo in 1990 as one of the few Western-style Meiji-era buildings that exist, and it is located in a district where cultural institutions with historical buildings are gathered. So, it was premised to make improvements while preserving its appearance and design as much as possible.
In addition, there were expectations and support from the political circles and publishing industry regarding the establishment of a national library specialised in children's books. Request from outside stakeholders for making this building an international children's library greatly boosted the budgetary allocation for the renovation work.

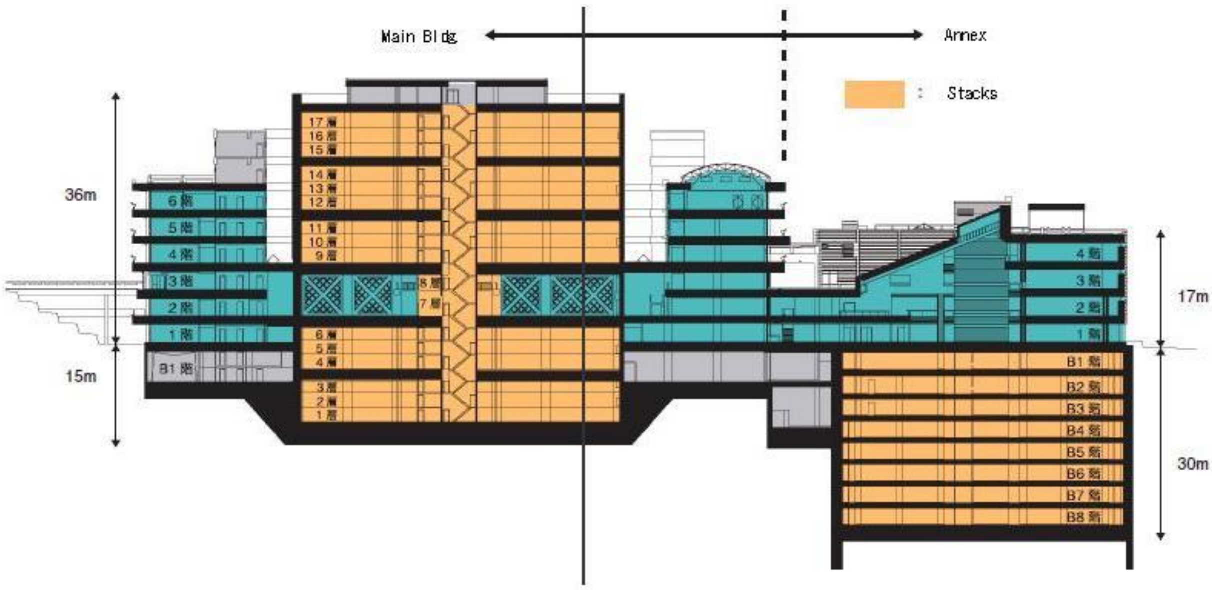
On top of that, this method was adopted because of the advantages of the seismic isolation retrofit.

- The original exterior appearance can be maintained since there is no need to particularly strengthen the structure of the above-ground building.
- Because there is no need to install earthquake-proof walls, etc., the design inside the building can also be preserved and used as it is.
- Because the shaking of the building is greatly reduced, the safety of users including children can be secured even in large-scale earthquakes, and the stored library materials, electronic devices, etc. can be protected.
- In order to give contemporary design and function while maintaining the appearance of the old building, a glass-enclosed entrance and a cafeteria were added, and this design was also made possible because it was constructed on the seismic isolation structure.[10]

Other plus factors are; the effect of seismic isolation structures had already been demonstrated in the 1995 Hanshin-Awaji Earthquake, and the seismic isolation retrofitting had already been adopted for the renovation of the National Museum of Western Art, although there had been no case where it was adopted in a Japanese library. The Museum's building is one of the Le Corbusier's works, and was registered as a World Heritage Site in 2016.
In the Great East Japan Earthquake of March 11, 2011, the ILCL in Tokyo suffered an upper 5 quake. Although the people in the library felt a slow, horizontal shake that was characteristic of the seismic isolation structure, it was not at a level felt danger, and there was only a few falling of books. The library opened normally after the earthquake and continued to provide user services. (The Arch Building had not yet been built in 2011.)

Seismic reinforcement of the Tokyo Main Library

The Tokyo Main Library, located next to the National Diet Building in Tokyo, consists of two buildings, the Main building and the Annex (Figure 6). The stacks of the Main Building occupy the centre of this building and are divided into 17 decks, a square with a side of 45m. The stacks are surrounded by reading room and office area, which is also a square, six floors with a side of 90m.



(Fig. 6) Sectional plan of the Tokyo Main Library

Since the building was completed in 1968 before the application of the earthquake resistance standard in 1981, it was reinforced against earthquakes twice so far. Seismic retrofit of installation of seismic walls from 1986 to 1990, and expansion of seismic wall and installation of steel frame brace connecting office building and the stacks from 2010 to 2013, after the goal for seismic safety of governmental facilities was set in 1996.

In the Great East Japan Earthquake, the same 5 upper level shaking hit the Tokyo Main Library as at the ILCL. In the main building, the reinforcement work that started in 2010 had not yet been completed. Although there was almost no damage on people and facilities, about 1.8 million books fell from the shelves on the higher decks of the stacks due to the shaking (Fig. 7), of which about 500 volumes were damaged and repaired by the Preservation Division. The books that were not damaged were returned to the bookshelves by the library staff, but it took a lot of effort and 6 weeks before the materials of all decks became available for user service. However, we can say that it was possible to start the restoration work several days after the earthquake occurrence just because the building was not damaged. The reinforcement work was completed in 2013, and braces were installed on the four sides of the stacks as shown in Figure 9.

(Fig. 7) Stacks of the Main Building immediately after the Great East Japan Earthquake

(Fig. 8) Recovery work by the library staff

(Fig. 9) Steel braces connecting the stacks and the office building

(Fig. 10) Underground stacks in the Annex. This light well allows daylight to reach even the lowest level.

Underground stacks

The Annex building of the Tokyo Main Library has 4 floors above ground, 8 floors underground, and all the underground parts are the stacks (Fig. 6, 10). The Kansai-kan, another facility of the NDL, located in Kyoto Prefecture, 500 km away from Tokyo, and the Arch Building of the ILCL, which was completed in 2016, have also stacks in the basement.

There are several reasons why the NDL built the stacks underground.

- It is easy to maintain temperature and humidity throughout the year as it is less susceptible to external air compared to the ground floor.
- Being able to construct large-scale stacks even if the site area is limited and the height of the building needs to be reduced
- In the basement there is much less shaking of buildings due to earthquake, and therefore less damage, compared to the ground floor.

In particular, as a library stores a large amount of heavy books and journals, falls of bookshelves and books can damage other facilities in the building or block evacuation routes, causing serious damage to people, even if there is no damage to the building. So, lessening shaking is highly effective in mitigating damage. This is more apparent in the seismic isolation structure, but also applies to underground stacks.
In fact, even in the case of the Great East Japan Earthquake, the shaking was much smaller in the underground stacks of the Annex than in the Main Building, that results in some 20 books dropped.

Conclusion

Earthquake resistance standards for buildings are basically set to protect human lives, with lessons from past disaster experiences. Based on that, it will be left to each institution to decide what kind of measures to choose, taking into consideration various factors such as locations, facility functions / roles, characteristics of buildings, and costs.
The NDL is now constructing a new library building of the Kansai-kan, which will be an earthquake resistant building with the first basement floor and seven floors above the ground. Under severe financial conditions, construction of additional underground stacks was not permitted. However, it is designed to protect facilities and collections with an earthquake-resistant structure, compact shelves in the most parts of the stacks, and some fixed shelves equipped with automatic bars that prevents the books from falling when it senses an earthquake.

Lost lives cannot be recovered forever, and damage to buildings and materials, depending on the extent, may lead to long-term business and service outages, which incur significant recovery costs. Although we cannot prevent the occurrence of earthquakes, as an organization holding valuable cultural heritage, we must continue our efforts to reduce damage and enable early recovery as much as possible, by taking risks and constraints into consideration appropriately and taking necessary measures.

Acknowledgments

I would like to acknowledge the contributions to this paper made by my colleagues at the National Diet Library.

Notes and References

[1] Available at: <https://www.unisdr.org/we/coordinate/sendai-framework> (accessed May 23, 2019)

[2] Available at: < https://www.unisdr.org/we/coordinate/hfa > (accessed May 23, 2019)

[3] Ministry of Education, Culture, Sport, Science and Technology. The Headquarters for Earthquake Research Promotion, "Omona kaiko-gata jishin no hyoka kekka (jishin hassei kakuritsu)," February 2019. (in Japanese) https://www.jishin.go.jp/evaluation/evaluation_summary/#kaiko_prob (accessed May 23, 2019)

[4] Cabinet Office, "Hanshin-Awaji Daishinsai kyokun joho siryoshu, 02. Jinteki higai". (in Japanese). http://www.bousai.go.jp/kyoiku/kyokun/hanshin_awaji/data/detail/1-1-2.html (accessed May 23, 2019)

[5] For the explanation of Japanese seismic intensity scale, see "Summary of Tables explaining the JMA Seismic Intensity Scale" in the Japan Meteorological Agency website. https://www.jma.go.jp/jma/en/Activities/intsummary.pdf (accessed May 23, 2019)

[6] The earthquake resistance rate is calculated by dividing the number of residences that were retrofitted to conform or were built to conform to the 1981 earthquake resistance standard by the total number of all residences.

[7] Ministry of Land, Infrastructure, Transport and Tourism, "Jutaku, kenchikubutsu no taishinka ni tsuite" (in Japanese) http://www.mlit.go.jp/jutakukentiku/house/jutakukentiku_house_fr_000043.html (accessed May 23, 2019)

[8] Act concerning Construction etc. of Government and Other Public Office Facilities. http://www.mlit.go.jp/common/001057107.pdf (in Japanese) (accessed May 23, 2019)

[9] National Diet Library. International Library of Children's Literature. "Architecture of the International Library of Children's Literature: Preservation and Renovation of an Old Brick Building from the 1900's." https://www.kodomo.go.jp/english/about/building/history.html (accessed May 23, 2019)

[10] *Kokusai Kodomo Toshokan jigyo kirokushu : Meiji no renga kenchiku Kyu Teikoku Toshokan no hozon to saisei*. Ministry of Land, Infrastructure, Transport and Tourism. Kanto Regional Development Bureau, 2002.