ISBN978-4-8189-5000-9

Design Recommendations for Seismically Isolated Buildings

AIJ-2016

Architectural Institute of Japan

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Issued May 25, 2016
ISBN978-4-8189-5000-9　C3052

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Edited and published by Architectural Institute of Japan

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Preface to the English Version

In Japan, it was in the early 1980s that laminated rubber bearings were first put to practical use and the research and development of seismically isolated structure became active. Although the first seismically isolated building, a house, was built in Yachiyo City, Chiba Prefecture in 1982, the spread of seismically isolated structures did not proceed.

Therefore, in 1986 the Subcommittee for Seismically Isolated Structures (Chair: Hideyuki Tada) was established by the Architectural Institute of Japan (AIJ) in order to clarify the problems of seismically isolated structures at that time and the underlying logical composition of the research development, as well as to present the appropriate scope of utilization of the seismically isolated structures. The subcommittee conducted its activities assertively and published the *Design Recommendations for Seismically Isolated Buildings* (first edition) in 1989. These design recommendations were based on following principles, which have retained in all subsequent revised versions:

"This book has been created with an emphasis on the development of objective judgment materials and criteria for supporting the decisions of structural designers. When exploring the possibility of new structural systems, it is important to recognize the essence of the design, and not to focus on the formal completeness of the design method. That is, where uncertain facts are involved, it is considered that the guidelines indicate only a decision and should avoid the convenience of the structural designer as much as possible. Because this kind of decision may apparently make the design easier, it would dampen the creativity of the designer and inhibit the progress of technology."

After publishing the first edition in 1989, the Subcommittee for Seismically Isolated Structures (Chair: Hiroshi Akiyama) has continuously striven to collect and develop seismically isolated structure-related technologies, and, based on these results, the revised second edition of *Design Recommendations for Seismically Isolated Buildings* was published in 1993. In this book, the subcommittee confirmed that the seismically isolated structure is an excellent choice among the various types of earthquake-resistant structures, capable of clearly achieving high performance. The subcommittee also revealed that seismically isolated structures should be subject to special restrictions as compared to normal buildings in terms of building scale, structural system, maintenance management system, and so on.

After the 1995 Kobe earthquake, the continued use and functional maintenance of many buildings became very difficult, and various problems such as repair huge costs emerged. Since the Kobe earthquake, seismically isolated structures have come to be employed in a large number of constructions, and significant progress has been observed in the design of seismic isolation systems and the development of seismic isolation devices. To reflect these developments, the Subcommittee for Seismically Isolated Structures (Chair: Akira Wada) published the revised third edition of *Design Recommendations for Seismically Isolated Buildings* in 2001.

Since then, the application area of seismic isolation technology has expanded such as that it is now used in high-rise buildings. In addition, issues such as the response evaluation by long-period ground motion have arisen. Therefore, in 2013 the Subcommittee for Seismically Isolated Structures (Chair: Mineo Takayama) collected the latest findings and published the revised 4th edition of *Design Recommendations for Seismically Isolated Buildings*, which summarized the latest findings to support the design of seismically isolated structures.

The seismically isolated structure is a relatively new technology, and there are some building owners and structural designers who have a sense of distrust for the new technology. The reason why the seismically isolated structure has been able to develop in such circumstances includes a range of factors, including the AIJ's efforts in disseminating information about the new technology to society by publishing the *Design Recommendations*; the Japan Society of Seismic Isolation (JSSI), founded in 1993, developing various efforts for the healthy spread of seismic isolation technology; and the seismically isolated structure having proved its performance by demonstrating it in the 1995 Kobe Earthquake and the Tohoku Earthquake of 2011.

This English version is a translated version of the first and second parts of the *Design Recommendations for Seismically Isolated Buildings* (4th edition). In the third and fourth parts of the Japanese version of *Design Recommendations*, descriptions of the design examples and design documents are included, respectively, but these have been omitted from this translation.

We hope that this book will help to spread the use of seismic isolation technology in foreign countries. We will be happy if the environmental improvement that have been made enable many structural designers to tackle the seismic isolation design on a daily basis, leading to protect the citizens and cities of the world from the threat of earthquakes.

In preparing this book, we have had cooperation from many private companies and JSSI, and engineers both in the translation and financially, with a total budget of about 3.5 million yen, including 0.5 million yen from the International Activity Fund of the AIJ. In particular, we would like to express deep gratitude to Mr. Masanori Tasaka (Nikken Sekkei Ltd.), Mr. Akitsugu Muramatsu (Taisei Corporation), Mr. Ryotaro Kurosawa (Kurosawa Construction), Mr. Shigenobu Suzuki (Bridgestone Corporation), Mr. Yasushi Ichikawa (Nippon Steel & Sumikin Engineering Co., Ltd.), Mr. Yasuo Tsuyuki (Kayaba System Machinery Co., Ltd), Mr. Toru Takeuchi (Tokyo Institute of Technology), Mr. Nagahide Kani (JSSI), and Mr. Mineo Takayama (Fukuoka University). For any inquiries about the contents of this document, please contact Mineo Takayama (mineot@fukuoka-u.ac.jp).

April, 2016

Architectural Institute of Japan

Preface

This is a revised version of the third edition of *Design Recommendations for Seismically Isolated Buildings* published in 2001.

The first edition was published in 1989, followed by the second one in 1993. The publication of the series corresponded to the burgeoning of seismic isolation technology at the time. The series is the first attempt to describe device properties used for seismically isolated building structures from the ultimate state performance to the durability. The Hyogo-ken-Nambu Earthquake in 1995 increased public awareness of the high performance of seismic isolation. Since then, the number of application projects had been on an exponential curve until the third edition was published in 2001. At that time, this technology had already been applied to high-rise buildings of more than 100 meters. On the occasion of earthquake events such as Tokachi Oki Earthquake 2003, Niigata-ken Chuetsu Earthquake 2004, and Fukuoka-ken Seiho Oki Earthquake 2005 to name a few, a huge amount of data were acquired and agreed well with the analytical expectations conducted in advance, which further accelerated expansion of the application projects. A task committee was formed under the Steering Committee for Structural Dynamics in 2009 to revise and elaborate the third edition and to reflect the latest findings and innovations.

In the dawn of the technology’s history, pioneering engineers developed the devices, designed the structures, and decided the safety margin. As time passed, computer software for dynamic analysis has matured and useful technical manuals for devices have been prepared. Seismic isolation is now regarded as a mature technology rather than a cutting edge one. In fact, it has been applied to a wide variety of structures, from residential houses to super high-rise buildings. In spite of the maturity of seismic isolation technology, the intensity level of the ground motion for structural design has become the main issue from the seismological point of view. This trend has been accelerated by the latest event, the Tohoku Earthquake in 2011. The practical issue faced by engineers who would like to design seismically isolated buildings is now how to select an appropriate device according to the increasing intensity level of an earthquake.

The task committee hopes that the fourth edition will help structural engineers to expand the seismic isolation technology to create a safer and better society by natural disaster mitigation.

October, 2013

Architectural Institute of Japan

Introduction

These Recommendations relate to seismically isolated structures. Such structures contain a seismic isolation level that includes isolators, which mainly support the building and can deform flexibly in the horizontal direction during an earthquake, and dampers, which reduce the displacements and absorb the seismic input energy. Above this level is the normal building (superstructure).

The major supplements for seismically isolated structures after publication of the third edition to the present are the revision of the Building Standards Law (amended 1998, enforced in 2000), and the Great East Japan Earthquake (2011).

In the revision of the Building Standards Law, notifications and recommendations for seismically isolated structures were established, and Ministerial approval was required for seismic isolation devices. In the notifications, the term “seismic isolation material” is used. However, in these current Recommendations, the term “seismic isolation device” is used, because it is considered that isolators and dampers, which are the most important constituents of seismically isolated structures, should be dealt with in the same way as ordinary structural members. Various types of seismic isolation devices are currently on the market, and their performance has improved. The development of various types of seismic isolation devices contributes to expanding the range of application of seismically isolated buildings. On the other hand, matters of concern are the ensured margin in the energy absorption capacity of seismic isolation devices due to long-period, long-duration seismic motions, and in the large response deformations due to pulse waves near faults. It is necessary for seismic isolation devices to be used only after their ultimate performance has been sufficiently confirmed.

In addition to time history response analyses discussed in the first edition, the Recommendations described response prediction methods based on the energy method as seismic response prediction methods for seismically isolated buildings. In this revised edition, a response prediction method by equivalent linearization is introduced, in addition to the energy method. Although many seismically isolated buildings exhibited a sufficient effectiveness of seismic isolation in the Great East Japan Earthquake, problems were reported in some seismic isolation expansion joints and hysteretic dampers. Furthermore, the damage caused by the tsunami in that disaster was enormous. The design of seismically isolated structures against tsunamis is a task for future investigation.

Seismically isolated structures exhibit sufficient effectiveness of seismic isolation with respect to the predicted seismic motions. Seismically isolated structures are simple structural systems, and the effect of the properties of seismic motions on the response of such structures is large. The seismic forces acting on seismically isolated structures are uncertain, so in the design of seismically isolated structures it is essential to provide an appropriate margin. It is desirable that the response of a superstructure does not become excessive; that is, the response to the seismic motions does not exceed those predicted. On the other hand, for small seismic motion input and strong winds, it is desirable that the oscillations of seismically isolated buildings are within an allowable range.

Seismic design starts by setting the input seismic motions, but at present it is almost impossible to accurately predict the seismic motions at a site where a building is to be constructed. However, structural engineers have carried out designs under these uncertain conditions. This edition was produced with an emphasis on providing objective decision-making material to support the decisions of structural engineers. The main points that have been strengthened in comparison with the previous editions are as follows:

- Introduction of the most recent knowledge regarding the properties of seismic isolation devices
- Introduction of new knowledge regarding input seismic motions, such as long-period, long-duration seismic motions.
- Evaluation of the response of super high-rise buildings to strong winds
- Seismic isolation effects based on the seismic observation records from the Great East Japan Earthquake (not contained in the English edition)
- Upgrades of examples of seismically isolated buildings (not contained in the English edition)

In this edition, incorporating new knowledge as much as possible was prioritized, so in some cases duplication of the contents of the previous edition was eliminated. This edition should be considered to be a supplement to the previous edition.

This edition consists of Part I “Design Recommendations” and Part II “Commentaries.” The Design Recommendations describes the properties of seismically isolated structures, the basic requirements of design, and the basic concepts of design. The Commentaries include explanations and material to deepen understanding of the Recommendations. No single approach can achieve all design targets, so various options are available. The independent actions of the structural engineer must be to comprehensively assess the options and to produce a single design.

From this point of view, the Design Recommendations are as objective as possible, and the methods of realizing a specific design are contained in the Commentaries, so that it is possible to appropriately add or modify the contents in accordance with the developments of future technology. Chapters 1 and 3 of the Commentaries section have been written so that they can be easily read by designers other than structural design specialists.

October 2013

Architectural Institute of Japan

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