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Introduction to Shock-Resistant Design of Buildings

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PREFACE TO ENGLISH EDITION

This book is the abridged English translation of the guideline: “Introduction to Shock-Resistant Design of Buildings” published by the Architectural Institute of Japan (AIJ) in 2015, which is thought of as a pioneering work for structural design against shock-load-induced building behaviors in the architectural engineering field in Japan. Readers may benefit from this book, which presents fundamental concepts for performing shock-resistant design for building structures by quantitatively considering the accidental shock loads that accompany impacts and explosions. An automobile impact, derailed train impact, small aircraft impact, helicopter impact, and forklift impact are all considered as collision scenarios for buildings. For buildings with a gas supply, internal explosions are considered, and the leakage of city gas or liquefied petroleum gas and the ingress of underground methane gas are assumed to be possible explosive sources. Where hazardous facilities, such as petrochemical plants, fireworks factories, or hydrogen stations, are located in the neighborhood of a target building, external explosions are considered.

This guideline contains respect to objective and scope, design loads, member design, design criteria, nonstructural element, progressive collapse and design examples for the shock-resistant design of buildings. The standard framework of performance-based design consists of the combination of load intensities and permissible damage states induced by accidental actions. The design loads are presented in the form of dynamic time-histories, and these are proposed to evaluate dynamic phenomena during accidental events. Buildings subjected to the identified accidental actions are primarily designed by performing dynamic analyses using equivalent models of individual members.

After the terrorist attack on the World Trade Center (WTC) buildings in New York in 2001, accidental actions that depend on human error or accidents not attributable to natural hazards have become significant concerns to the protection of buildings in Japan. The AIJ has focused on this problem. In 2005, the AIJ “Sub-committee on Impulsive Performance Evaluation” commenced surveys and research on structural analyses and building design against accidental actions, which is meant to provide building structures sufficient safety and functionality under the artificial shock loads resulting from impacts and explosions. Since 2009, the “Working Group on Practical Application of Building Design Method against Impulsive Loads” has worked on editing a guideline for the shock-resistant design of buildings, and the first guideline of the AIJ for shock-resistant design was published six years later.

When considering scenarios where shock loads act on buildings, it should be noted that these events are extremely rare and must occur accidentally. Whatever the causative factor of these is, the event probability or damage scale is difficult to predict and reasonably explain. However, building designs that provide shock-resistant performance must maintain a high degree of structural and functional capacity and minimize human injury. In order to reasonably respond to these required design conditions, we need to focus on the improvement of shock-resistant design. Moreover, the environments around

buildings, accident scenarios, and types of shock loads are always changing. Further investigation will also be required to determine a method for re-estimating building performance against accidental actions. Recently, international motivation to standardize the evaluation of design loads caused by impulsive actions has increased. In the near future, more importance will be placed on the determination of reasonable shock-resistant design strategies to protect modern society, which has grown more sophisticated and complicated.

The “Sub-committee on Prevention and Mitigation of Impulsive Loads”, which took over the former committee, started its mission in 2016 and is working to propose a new approach for reasonable shock-resistant design. This new committee has also been working on publishing the English translation of “Introduction to Shock-Resistant Design of Buildings”. We hope that this English edition of the guideline will be useful for performing and applying shock-resistant building design both inside and outside of Japan. We will be pleased if the enhancement and improvement of shock-resistant building design strategies becomes globally motivated and if structural designers will challenge current shock-resistant design strategies on a daily basis, leading to the increased protection of the people and societies of the world from the threat of accidental actions.

December 2021

Architectural Institute of Japan

PREFACE

Shock loads have been recognized as a new threat to building structures in this century. This was seen in the tragedy of the building collapses caused by airplane collisions to the World Trade Center (WTC) buildings in New York City and the Pentagon, which is the headquarter building for the National Defense Agency of the USA, as a result of a terrorist attack on September 11, 2001. Hydrogen explosions in the Fukushima Daiichi nuclear power plant caused serious and wide-spread nuclear contamination, which resulted from the 2011 off the Pacific coast of Tohoku Earthquake on March 11, 2011. Accidental actions accompanying shock loads can happen under uncertain and limited conditions, with low probability, and are usually extremely short period actions. However, once an accidental action with a shock load occurs, serious damage and influence are often observed. Such experiences have become common with the ability to broadcast news worldwide; thus, the significance of considering shock loads is widely and strongly recognized by many people in society.

On the other hand, building design strategies for shock loads have not been given enough technical discussion because there have been fewer opportunities to consider shock loads directly in the building engineering field in Japan. The following description can be seen in Article 83 of the Building Standards Law in Japan:

Article 83: Kind of loads and external forces:
1. Dead loads
2. Live loads
3. Snow loads
4. Wind Forces
5. Seismic Forces

Other than loads and forces in foregoing Paragraph 2 of Article 83, soil pressure, water pressure, external forces induced by vibration and shock have to be estimated depending on the building situation.

There are individual notes to explain dead loads in Article 84, live loads in Article 85, snow loads in Article 86, wind forces in Article 87, and seismic forces in Article 88 in addition to Article 83. However, shock loads can be found only in the last part of Article 83.

Based on this limited background, the AIJ has recommended that the consideration of shock loads be included with one of the design loads for building structures and accompany a revision of the AIJ's "Recommendations for Loads on Buildings (2015) ". Shock loads caused by impacts or explosions have recently received increased attention in the building design field in architectural engineering. On the other hand, there are few reference documents available for practical structural design and analyses, even though building owners are requesting effective measures against shock loads.

This guideline was written with the purpose of satisfying these technical points-of-view regarding

shock loads and impulsive actions. We are hopeful that the “Introduction to Shock-Resistant Design of Buildings” will prove itself valuable for engineers and researchers designing buildings against shock loads and will contribute to the response to social demand for safer building structures.

January 2015

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