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SEISMIC RISK REDUCTION OF OPERATIONAL AND FUNCTIONAL COMPONENTS OF BUILDINGS: RESEARCH PERSPECTIVE

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SUMMARY

Past earthquakes have demonstrated the severe consequences of the failure of non-structural building components upon life, property and economic losses. These non-structural components, including architectural, mechanical, electrical and building elements, are essentially the operational and functional components (OFCs) of the building simply. It is these components that keep a building operating and functioning. Quite often, a building's structural components survived an earthquake with little or no damage, but the facility was rendered unusable due to the extensive damage to these OFCs. While building codes provide guidance for the safety of buildings, the provisions for the design of buildings are primarily intended for the structural components of buildings. Provisions given for the architectural, mechanical and electrical components of a building are rather empirical in nature due to general lack of sufficient data and information on the performance and requirements of OFCs during earthquakes. Seismic design, evaluation and retrofitting of OFCs have not been as well established as for the structural components of buildings. Research is needed to enhance our understanding of the performance and requirements of OFCs. The purposes of the Special Theme Session on Operational and Functional Components of Buildings are to facilitate discussions and exchange of information, and to identify common research needs in the practice of seismic risk reduction of OFCs.

INTRODUCTION

There are two main categories of building components: structural components and operation and functional components (OFCs) which are commonly referred to as non-structural components. Structural components are designed and constructed specifically to carry and transfer loads applied to the building. OFCs include all other components that are required to provide the operational and functional requirements of a building. It is preferable to use the term "OFCs" rather than "non-structural components" as seismic design, evaluation and retrofitting of these components and their safeguards do require the attention of "structural" engineers.

Failure of OFCs of a building posts at least three severe consequences during and after an earthquake:
(1) Casualties due to falling objects and debris

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(2) Property and economic losses as a result of the building being rendered non-operational and non-functional
(3) Delay of search and rescue mission due to accessibility problems within a building, leading to further increase in casualties.

From emergency management point of view, it is imperative that buildings' OFCs be properly protected against the effects of earthquakes such that:
(1) Immediate and continued operation of vital facilities (emergency command and response centers, hospitals, communications and water supply facilities etc.) can be maintained, and
(2) Search and rescue operations can be carried out promptly and safely.

Much progress has been made in the past 20 years in the design, evaluation and retrofitting of buildings' structural components. In comparison, advances in our understanding of the performance and requirements of OFCs against seismic hazards have not been kept in pace. The paper presents a research perspective for seismic risk reduction of OFCs.

RESEARCH IN SEISMIC RISK REDUCTION OF OFCS

Several state-of-the-art reviews on the seismic performance of OFCs have been report over the years. Villaverde [1] in 1997 provided an interesting perspective of the OFCs as secondary structures and a very comprehensive state-of-the-art overview of the seismic risk reduction of OFCs. Later in 2000, Villaverde [2] proposed a simplified method for seismic nonlinear analysis of OFCs, which accounts for nonlinear characteristics of components as well as the structure to which the components are attached. Required input included geometric characteristics, weights and ductility factors of the OFC and its supporting structure, and the elastic design spectra of the structure. Examples were given on the application of the proposed simplified method.

The 12th World Conference on Earthquake Engineering in Auckland, New Zealand in 2000 included several interesting articles on seismic performance assessment of air handling unit, fire sprinkler distribution network, a pump with pipe work suspended from the floor ceiling, suspended ceilings and other building contents. The 13th World Conference on Earthquake Engineering in Vancouver, Canada in 2004 will have a special theme session on seismic risk reduction of OFCs of buildings. Articles included in this special session are:

(1) "Performance of OFCs in earthquakes and in shake table tests" by Ventura and Kharrazi [3]: This paper presents a summary of the shake table tests and a comparison of the test results with design requirements on OFCs such as bookshelves, file cabinets, photocopier, office work stations, communication racks, LAN rack, motor control centre, equipment seismic isolation and restraining systems and other office equipment.

(2) "Seismic evaluation of hospital piping systems" by Goodwin, Maragakis and Itani [4]: This paper presents findings from experimental research on cable-braced piping systems for hospitals. The full scale piping system was modeled after a piping system in the University of California, David Hospital and was tested on the shake table at the University of Nevada, Reno. The system was tested to the ICBO AC 156 criteria for non-structural components.

(3) Seismic considerations for telecommunication towers mounted on building rooftops" by McClure and Georgi [5]: Research was done on the lattice towers, which are used as antenna-supporting structures in telecommunication network systems. Correlation between the earthquake force and the maximum seismic

base shear and the base overturning moment of towers mounted on building rooftops were evaluated and compared using time history analyses, floor spectrum approach and simplified formulas proposed in building codes.

(4) “Elevator counter-weight derailment research in Taiwan” by Yao, Tseng and Shen [6]: This paper reports on a three-year research program in Taiwan on seismic performance of elevator counter-weight. Both experimental study with static and shake table testing of full-scale specimens and numerical analyses were carried out to study the mechanical behaviour, damage types and retrofit schemes of elevator counter-weight.

(5) “Seismic risk reduction of laboratory contents” by Comerio [7]: This paper presents a case study of the laboratory contents of a 200,000 square foot modern laboratory building. Each item was evaluated in terms of its life-safety hazard, value and importance to research. Shake table tests were conducted on various items. Based on the research findings, retrofit strategy and details were developed.

(6) “Seismic risk reduction of operational and functional components of buildings – Standard development” by Foo and Cheung [8]: After a brief discussion on various standards and guidelines, this paper gives an overview of the Canadian Standards Association’s “Guideline for seismic risk reduction of operational and functional components of building: S832” [9]. The seismic risk assessment methodology introduced in the CSA guideline was highlighted in the paper.

RESEARCH NEEDS IN SEISMIC RISK REDUCTION OF OFCS

Based on the literature review and on the proposed research program on seismic technology development by Public Works and Government Services Canada [10], the following common research needs are identified in the practice of seismic risk reduction of the vast variety of the OFCs:

(1) Development of series of synthetic time history records that can be used for testing of OFCs on shake table - Theses records, which are region specific to account for regional seismic zoning and building characteristics, can also be used in the analysis of building structures to determine the response spectra of different floor levels for various building structure types.

(2) Evaluation of performance, in terms of effectiveness and suitability for use as seismic restraint, of various seismic anchoring systems through experimental testing - Common anchoring systems are tested to assess their capacity in resisting the reversed and cyclic loads during an earthquake.

(3) Shake table testing of seismic restraint systems and techniques for OFCs using time history records developed in (1) above, especially for critical building systems and OFCs for hospitals, emergency response centers and post-disaster buildings.

(4) Correlation and parametric study of performance of OFCs and of interaction between OFCs and the building structure.

(5) Based on the above results, the development of a rational methodology for the evaluation and upgrading of OFCs for seismic risk reduction.

The objectives of the above research are (a) to better understand the performance characteristics of OFCs, and the interaction between OFCs and the building structure, and (b) to develop a rational methodology for the evaluation and upgrade of OFCs and of OFCs’ interface with the building structure.

SUMMARY

During the past few years, PWGSC has been rather active in conducting and supporting research and development on seismic retrofit technologies for both structural and operational/functional components (OFCs). In terms of OFCs, PWGSC has been collaborating with universities on shake table testing and with the Canadian Standards Association in the development of national guideline/standard on seismic risk reduction of OFCs. In order to continue to be able to providing the state-of-the-art guidance in safeguarding the operational and functional components of a building, PWGSC has been actively promoting an integrated research program for seismic technology development. The five main parts of the proposed research program on OFCs include the development of series of synthetic time history records as the test protocol for OFCs on shake table, experimental (static) testing of safeguard measures (including variations in types of restraint material and system), shake table testing of seismic restraint systems and techniques as per the testing protocol developed, computer simulation and parametric study of performance of OFCs with and without safeguards, and the development of a rational methodology for the evaluation and upgrading of OFCs, and of national standard/guideline on the seismic risk reduction of OFCs.

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