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SEISMIC PROTECTION OF OFCs IN NEW AND EXISTING BUILDINGS

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ABSTRACT

Seismic protection provisions for OFCs (otherwise known as non-structural) have been in the Canadian National Building Code since 1953. Application of these provisions has largely been ignored until recent years when studies revealed that the bulk of the damage costs of an earthquake in a developed urban area are due to failures of OFCs. In the 2005 edition of the National Building Code of Canada, the section on earthquake design for non-structural components has greatly expanded from previous editions. US building codes have also expanded their section on earthquake design for non-structural components. This paper will look at the current practice of seismic protection of OFCs in British Columbia (BC) for new and existing buildings.

For OFCs in new buildings, this paper will look at the regulatory requirements regarding design and construction. The roles and responsibilities of the specialty engineer will be looked at together with the various standards and guidelines used in the industry. Our own experience in this field will be presented together with suggestions to improve the system that can be used as a model to serve as standard practice.

Seismic protection of OFCs in existing buildings can be divided into two groups. The first group consists of new OFCs in an upgrade/renovation project. The challenges involves working in existing buildings will be discussed. The second group consists of protection of existing OFCs in existing buildings. This paper will show how CSA S832 seismic risk assessment procedures can be used as a valuable tool in identifying and prioritizing the OFCs in the seismic risk mitigation project.

Introduction

Seismic protection of operational and functional components (OFCs) may have been in building codes for many years; however, practice was limited to those where operational continuity was critical. In the early 1990, the City of Vancouver introduced the use of Letters of Assurance. This requirement was added for those working under the British Columbia Building Code immediately thereafter. Seismic protection of OFCs became an integral part of the building permit and occupancy process. The new regulatory requirements, together with unwillingness by the main stream building designers to tackle seismic protection of OFCs, resulted in the adoption of a variety of approaches to deal with the issues. It also spawned the growth of a new group of specialty engineers.

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OFCs in New Buildings

For OFCs in new construction, the need to obtain a building permit and an occupancy permit, made it necessary to include seismic protection of OFCs as part of the project. It is no longer possible to conclude a new project without involving some professionals signing off on OFC seismic protection. It is, however, interesting to note that the regulatory requirements did not specify the discipline of the professional providing the assurance. A professional seal to identity the person responsible is all that is required.

Most traditional professionals practicing in their respective disciplines are not familiar with OFC seismic protection. They are not willing to take on this responsibility. The result is the creation of various approaches to download the responsibility to someone else. Occasionally, on small projects where the potential extra cost may be a concern, these professionals are tempted to assist in reducing the costs for the project by assuming responsibility normally out of their range of expertise.

Current Practice in British Columbia

Letter of Assurance was first introduced by the City of Vancouver in 1990 and followed by the Province of British Columbia in 1992. The letters are legal documents required before the granting of a building permit at the start of a project and the granting of an occupancy permit at the completion of a project. By completing these Letters, the signing professional is giving assurance that the project has been designed professionally and that professional field reviews have been provided to ensure compliance with the designs submitted in support of the building permit application and compliance with building codes.

In British Columbia, regulatory diligence in the enforcement of the aspect of OFC seismic protection included in the letter of assurance varies significantly from cities to rural communities. Cities and municipalities in and near the Lower Mainland areas are much more stringent with respect to the requirements for Letters of Assurance. This means all projects requiring a building permit are to be accompanied with Letters of Assurance where OFC seismic protection is required.

Enforcement of the same building code requirements regarding OFC seismic protection is much more varied for cities and municipalities further away from the lower mainland areas. In some municipalities, the OFC seismic protection portion of the Code is largely ignored, while enforcement in some other municipalities is stricter than the City of Vancouver.

The most commonly used approach is to write clauses in the project specifications, making the contractor responsible for engaging the services of a professional who will provide the necessary paper work to obtain building occupancy at the end of the project. As most projects are designed today, selection of OFCs for many building services are not finalized until well after the building contractor is awarded. This approach makes the matter easy for the prime consultants and it eliminates the need for seismic risk mitigation planning and any potential added designs necessary to deal with unforeseen site conditions identified after tender.

The obvious drawback of this approach is the potential conflict of interest for the professional engaged by the contractor to provide OFC seismic protect services. The lack of specific standards in this field opened the door to selective interpretation of industry standard practice. Some people have elected to use their good judgment to guide their design, instead of seeking out standards and practices adopted in other regions of the world where seismic protection is common.

For projects where OFC seismic protection is taken more seriously, the project manager/owner will specify the professional they want to provide seismic services to the contractors. An allowance is set up for the contractor to bill against. The professional in this situation will be responsible to the owner and services are paid from the allowance.

One variation of this is the use of cash allowance. The contractor will use the cash allowance to procure the services of a professional for the seismic protection of OFCs in the project. In this case, the contractors are left to select the specialty engineer of their choice who will be working for the contractor and paid for by the contractor using the cash allowance.

The least popular, but the most professional approach is to include OFC seismic protection right from the planning stages of the project. The professional in this case is a part of the building design team. The project will benefit from the experience and pre-emptive measures suggested to minimize seismic risk and mitigation costs from preliminary design phase. The big disadvantage with this approach is with timing and the amount of details required of the other disciplines. For the building owner, this approach provides the most complete package for tender and should theoretically result in the best tender price from the bidders.

Specialty Engineer in British Columbia

The inclusion of seismic protection of OFCs in the Letter of Assurance process spawned a group of professionals specialized in providing services to meet the Building Code requirements. This service is considered similar to other specialized services provided by specialty engineers. For this reason, professionals practicing in the field of OFC seismic protection are considered specialty engineers. The definition of the term “specialty engineer” is provided for in guidelines for each discipline published by the Association of Professional Engineers and Geoscientists of British Columbia.

The Association of Professional Engineers and Geoscientists of British Columbia are currently proposing the implementation of a Schedule S to address issues related to the services of a specialty engineer. This Schedule S will supplement the existing Letter of Assurance system.

OFC Seismic Protection Design

It is important to clarify the meaning of OFC seismic protection in this context. The design and construction of OFCs are generally not within the scope of work of the specialty engineer. This is particularly true when dealing with mechanical and electrical equipment. It is therefore unreasonable to expect a specialty engineer to take on the responsibility of providing assurance that the equipment construction and design will meet the level of seismic force defined in the codes. Seismic protection here is strictly for the attachment system design, anchoring or fastening of the equipment to the building structure.

For projects of significant importance, assurance regarding OFC structure should be requested with specific wording in the project specifications to avoid confusion with OFC seismic protection. This is normally furnished by the OFC manufacturer since they are the ones who design and manufacture the product. A number of documents and standards regarding procedures for seismic qualification are available and can serve as guides in the preparation of project specifications. They can also be used as reference documents in the review of the submitted OFC seismic qualification from the manufacturer.

The design seismic force calculation for OFCs is given in the National Building Code of Canada. A single static equivalent force equation is provided that governs the design of OFCs and their attachment to the building structure and incorporated with it are soils effect, building height effect, OFC dynamic amplification and OFC response modification factor. In the National Building Code of Canada, OFCs are grouped into categories with all the pertinent factors listed to assist the user of the code. Attachment design is simplified and reduced to basic structural analysis.

It should be noted that OFC sensitivity towards force, displacement or a combination of force and displacement can vary greatly. Knowledge of the characteristics exhibited by the OFC is essential in proper detailing of the attachment required.

Not all the OFC seismic protection designs are based entirely on structural analysis. OFCs such as suspended acoustical ceiling system, piping, air ducts, and electrical cable trays, rely on prescriptive methods for seismic protection. Based on past experience of the performance of these types of OFCs in earthquakes and simulation work in shake table labs, some practices have demonstrated better performance in providing seismic protection than others. The culmination of these practices have become industry standards, adopted in earthquake regions.

The following is a short list of some of these accepted industry standard practice prescriptive methods:

ASTM E580 Standard Practice of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Requiring Seismic Restraint
CISCA Guidelines for Seismic Restraint Direct Hung Suspended Ceiling Assemblies
SMACNA Seismic Restraint Manual Guidelines for Mechanical Systems
SMACNA Guidelines for Seismic Restraints of Kitchen Equipment
ECABC Seismic Restraint Standards Manual Guidelines for Electrical Systems

It should be noted that these standards and guidelines represent general concept of seismic protection procedure for the respective OFC. Sizing and design of the components used in the seismic restraint mechanism is still governed by the appropriate building code and the specific site conditions where the components are located.

Although the use of industry standards greatly simplifies the complexity of the design and implementation of some OFC seismic protection, misuse and misinterpretation is not uncommon. For example, SMACNA makes an exception for some pipes. When a pipe is suspended by individual hangers 12 inches or less in length – as measured from the top of the pipe to the bottom of the support where the hanger is attached – bracing is not necessary. The accompanying condition that the 12” hanger rod shall have top connection that cannot develop moments if braces are omitted is often ignored. Others interpretation of this exception includes applying it to mechanical equipment suspended within twelve inches to the ceiling structure, and no bracing for the pipe run when a few of the hangers are twelve inches long.

The adoption of these standards should be complete with no exception. The requirements and conditions forming a part of these types of prescriptive methods are essential for the method to perform as intended. Picking and choosing to use a part or some parts of these standards will invalidate the practice and rendered the installation vulnerable.

Engineering is a profession where innovations are generally encouraged. This is however a time when enthusiasm to innovate should be dampened. In situations where an individual has overwhelming evidence to support his/her actions, deviations from standard practice should still proceed with caution and third party review is recommended.

Suggested Changes to Improve the Current Practice

It is desirable to have one OFC seismic protection specialty engineer on a project responsible for all the OFCs, regardless of discipline within the project. The same engineer should be a part of the consulting team involved with the project right from the start. The experience brought to the table by the specialty engineer can benefit the project and at the same time reduce the cost of the OFC seismic project. This will also take away the conflict of interest that can be a potential problem for the project when the contractor engages the specialty engineer.

The specialty engineer will participate in spatial planning and preliminary designs. Consultants in other disciplines shall provide the specialty engineer with information on OFCs. Seismic protection design for OFCs will be based on the modeled OFCs. With the design available during tender, bidders are not faced with uncertainties and thus more competitive pricing is expected. Where the contractor is planning on providing different OFCs for the project to gain an advantage over their competition, they will just need to make allowances in their bid to take into account the possible differences in OFC seismic protection effort. The project specialty engineer’s responsibility will include the follow up design for all OFCs not represented in the tender package.

The concept of one specialty engineer per project is important for maintaining uniformity in the application of seismic protection for OFCs. The present system allows for multiple specialty OFC seismic protection engineers on the same protect. These engineers are only involved with the particular portion of the project they are aware of. Some may have provided designs to meet normal code requirements and are not informed of project specific requirements. Concerned specialty engineers are specific with the Letter of Assurance and will list all OFCs reviewed. Others will provide blanket coverage of all OFCs for the contractor without knowing the full extend of the work. With Building Code officials no longer doing site inspections, there is no way for them to know when all OFC seismic protection is in place, if there are multiple specialty engineers signing off on the seismic aspects of the project.

The proposed system will ensure Letters of Assurance provided do cover all aspects of the project and the OFC seismic protection designs are in conformance with the project specifications.

OFCs in Existing Buildings

OFC seismic protection in existing buildings can be substantially different from new construction. Where the work is a part of a renovation or change in occupancy requiring building permit, then it is the same as for new construction. Where a building permit is not required and the upgrade work is strictly voluntary, the approach to OFC seismic protection is simplified.

OFCs Seismic Protection in Existing Buildings Requiring Building Permit

This is very similar to OFCs in new buildings. All OFCs included in the building permit are required to have seismic protection. The main different with OFCs in new buildings is the fact that the OFCs are already existing and connected to other services. Relocation and removal are not acceptable alternatives. The lack of working space and heavy congestion around existing OFCs is a commonplace occurrence. Existing OFCs are usually older with no built-in provisions for the attachment of seismic protection. These are all challenges that must be resolved. Knowledge and familiarity with the workings of OFCs is essential to any effective seismic protection system for these components. Complete information of the areas surrounding the OFC installation is critical to a successful upgrade installation.

OFC Seismic Protection in Existing Buildings Not Requiring Building Permit

The number of OFCs in a typical building can number into the hundreds if not thousands. While the Building Code does not require that the seismic hazards be reduced in an existing building, the various applicable labour codes indicate that action is required. The WorkSafe BC regulations and the Canada Labour Code require that all health and safety workplace hazards be identified, that the workers be notified of the hazards and that the hazards be mitigated. Failure to comply involves significant penalties and prison sentences for those responsible for workplace safety. While seismic hazard mitigation has not been targeted by the regulatory agencies at this point, the following means of assessing those risks make it harder to ignore the situation in the future.

Any seismic risk mitigation program will be a daunting task without a reasonable and feasible approach. CSA Standard S832-06 “Seismic Risk Reduction of Operational and Functional Components (OFC) of Building” was published in 2006. It has a seismic risk assessment procedure for determining OFC seismic risk. The result of the assessment is a seismic risk index assigned to each OFC in the assessed building. The ranking of the seismic risk index forms a relative scale priority list for the OFCs.

The use of similar factors as in the National Building Code of Canada 2005 made it possible to compare results of the assessment for buildings across the country for different types of buildings on different types of soils. The CSA seismic risk assessment is a useful tool for risk mitigation planning. The parameters used in the program are ideally suited for use in a database computer program. Analysis of the data can produce reports of every kind from planning to tracking the risk mitigation progress of each OFC.

The CSA S832-06 standard for seismic risk assessment introduced a retrofit index to the assessed OFCs. The retrofit index is an indicator of the amount of retrofit work that can be done to a given OFC in order to reduce risk to the lowest possible value. It is a percentage value, where the smaller the value the less cost effective it is to upgrade. It is possible from the results of the assessment and retrofit index, that the upgrade of some OFCs are simply not feasible and alternate planning will be needed.

The actual work of seismic protection of OFCs is the same regardless of the presence of building permit.

Conclusions

With sixteen years of regulated seismic protection of building permits related OFCs in British Columbia; the practice is far from perfect. An improved system is needed to address concerns from specialty engineers and to better serve the public. For OFCs in existing buildings, the government is encouraged to take up a leadership role to adopt CSA S832-06 standard and determine OFC seismic risks in all their buildings. The data collected should be used to formulate an action plan for a general seismic risk mitigation program. Incentives should be provided to the private sector to encourage their participation in an overall plan to upgrade all buildings in areas subject to seismic activities.