Creative Construction Conference 2012
June 30 – July 3, 2012, Budapest, Hungary

INTEGRATED SEISMIC RISK MANAGEMENT – THE DIFFERENCE BETWEEN THE CODES AND THE REAL LIFE PRACTICE

Zvonko Sigmund
Faculty of Civil Engineering, University of Zagreb, Zagreb, Croatia, zsigmund@grad.hr

Mladen Radujković
Faculty of Civil Engineering, University of Zagreb, Zagreb, Croatia

Damir Lazarević
Faculty of Civil Engineering, University of Zagreb, Zagreb, Croatia

Abstract
Earthquake Engineering emerged during the time from 1910 to 1930's, resulting with first building codes which included earthquake activities as loads. Seismic engineering need was triggered by devastating earthquakes in Northern California, and Messina – Italy. Since then, and especially during the last decades, earthquake engineering has increasingly advanced ever changing the norms and building codes. By now the preventive measures of earthquake risk mitigation have drastically evolved suggesting protection not only for new buildings, but also for the existing ones which make the majority of our surrounding built world.

The article is the introduction into a larger research program seeking to close the huge gap between the newest advances in preventive earthquake engineering measures for existing buildings and a successful implementation of earthquake hazard mitigation policies. This article is a short overview of the latest international preventive earthquake norms and regulations for existing buildings, focusing on the positive examples of implementation and application of the same managing complex challenges by balancing technology, organization, design and economy.

Successfully implemented earthquake mitigation practices for existing buildings developed after larger earthquakes are presented and compared focusing on the implementation type and execution plan.

Keywords: Earthquake hazard mitigation, existing buildings, seismic regulations implementation, comparison.

1. INTRODUCTION

Earthquake engineering has increasingly advanced ever changing the norms and building codes. By now the preventive measures of earthquake risk mitigation have drastically evolved suggesting protection not only for new buildings, but also for the existing ones which make the majority of our surrounding built world. There is a growing global momentum to address the seismic (earthquake) resistance of older existing buildings that may not meet the stricter requirements of current building codes for seismic loading and design of new buildings (Sundararaj, Foo et al. 2004). However earthquake mitigation measures for existing buildings are rarely implemented into earthquake mitigation policies (Alesch and Petak 2002). This paper is presenting and comparing successfully implemented earthquake mitigation policies of Switzerland, USA and Canada. For the simplicity of the organizational structures of the policies regulating earthquake mitigation measures only earthquake mitigation policies for nationally owned buildings is presented.

2. EARTHQUAKE MITIGATION POLICIES

2.1. Switzerland and SIA 2018

Swiss Society of Engineers and Architects have developed a 3 stage federal building evaluation process. This process as a result has a list of prioritized federally owned buildings that are sorted by the descending order of priorities for increasing the earthquake resilience.

The standard was designed for evaluation of federally owned buildings of the building class 2 and 3 in seismic zones 2 and 3. The building classes 2 and 3 include buildings that are characterized by: large public gatherings, goods of particular value, important or vital infrastructure functions, limited and/or considerable environmental risk. (SIA 2003)

2.1.1. The beginning

The earthquake resistant design was introduced to Switzerland quite late, since the earthquake risk was estimated as low. The SIA 160 norm dating from 1970 was the first Swiss building norm which introduced the rules for earthquake capable building design introducing horizontal loads as replacement for the real earthquake forces. (SIA 1970) The norms introduced in 1989, the SIA 160 Norm – "Actions on Structures", introduced a more stringent earthquake design. These are now used for design of new buildings. (SIA 1989)

90% of the existing buildings were built by the time new SIA 160 norms were introduced. These buildings weren't designed to cope with the earthquake forces, and therefore the earthquake of such buildings is unknown. It might be that the bearing capacity of these buildings is not satisfactory.

2.1.2. The mission

During the year 2000 the Federal Office for Environment of Switzerland has received a task to make an inventory of the federally owned buildings by the year 2004. The buildings of construction class 2 and 3 in seismic areas 2 and 3 were supposed to be categorized, and their earthquake vulnerability should have been checked. The Federal Office for Environment decided to develop a 3 staged concept of the building vulnerability estimation and building mitigation prioritization process.

2.1.3. The execution

The building safety evaluation according to SIA 2018 standards is divided into 3 steps with the main goal of time and funds preservation. Therefore is the 1st step of the evaluation process designed to consume the least time and expert knowledge. The whole evaluation process is described by steps below:

1) Step 1: For this step a check-list was created which is designed to conclude the risk evaluation with a “risk value”. The check-list can be completed just after studying the architectural plans and after building walkthrough while checking the most important building constructive elements. (Time consumption: up to 4 hours)

2) Step 2: In this step just the buildings with a high risk are rechecked. The recheck is conducted based on civil engineering design and by checking critical structural points aided with a questionnaire and simple engineering equations. The questionnaire is structured to cover the common structure types. The process is relatively simple and therefore the results are not as accurate as in the step 3. (Time consumption: up to 4 hours)

3) Step 3: The step 3 should result with a definitive statement about the earthquake safety of the building based on dynamic simulations. The strengthening recommendations are designed in this step, if necessary. The norm SIA 2018 (2004) serves as the basis for the evaluation stage 3. Based on the compliance factor α_{eff} and the efficiency criteria of the strengthening measures the norm suggests whether the building can be strengthened or can the existing condition be accepted. (see Fig.1)

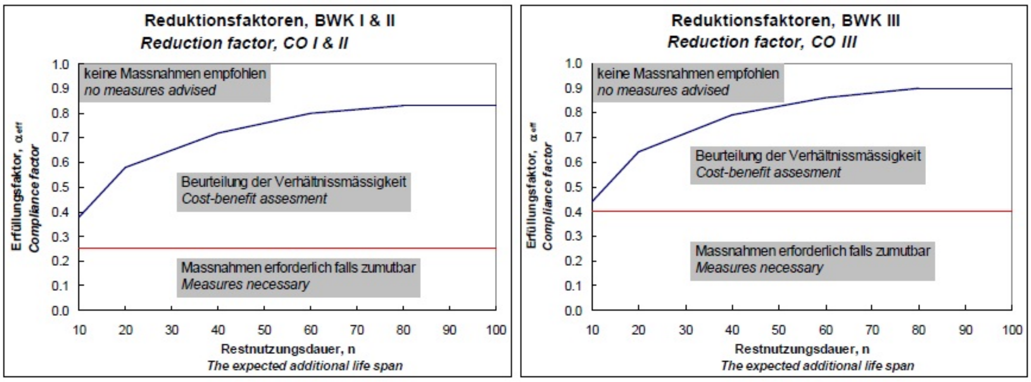

Figure 1: The compliance factors (red – minimum; blue advised) in respect to the expected life span

The evaluation has two main decision making standpoints. One is considering the safety of the people inhabiting the building as unacceptable, and the other one is opposite.

If the earthquake security of the building is not acceptable strengthening is advised. The costs of the strengthening measures are limited to approximate cost of saving action in case of an earthquake which is 100 mil. CHF per person. If the strengthening cost is within the estimated cost of a human life, the strengthening is to be conducted. If these measures are not possible for a reasonable price, the building safety as is can be accepted.

2.2. Canada and the Policy on Seismic Resistance of Existing Buildings

The National Building Code of Canada does not apply retroactively to older buildings, and therefore there is a clear need for a duly diligent approach for Canadian building owners. It was with this in mind that PWGSC, as knowledgeable owner and manager of a significant amount of federal building infrastructure, created a Guideline in 1998 to allow for a more consistent approach to dealing with existing buildings. This was subsequently adopted as a Policy on Seismic Resistance of Existing Buildings in 2001, (Sundararaj, Balazic et al. 2001) . Key elements include incorporating seismic considerations in major renovations of PWGSC crown-owned buildings in moderate to high seismic zones, and gathering basic information about each building through seismic screenings.

2.2.1. The beginning

Creation of this Policy was a process that begun in 1997/1998 with internal discussions within the National Structures Discipline meetings of Architectural and Engineering Services, bringing together the varied inputs of Regional engineers. A key concern was the lack of a consistent approach to dealing with seismic deficiencies in building infrastructure. A draft Policy was prepared and released as a Guideline to begin with in late 1998, the reservation being the cost implications for the PWGSC program. This was followed by a legal review of a duly diligent approach to be taken by the owner, which finally resulted in bringing all stakeholders to the table to finalize a formal policy.

2.2.2. The mission

The Policy’s scope applies to crown-owned buildings currently in or to be added to the custody of PWGSC, in zones of moderate to high seismicity. “Moderate to high” is defined as an effective Seismic Zone between 2 to 6 as defined in the NRC Guidelines „Guidelines for the Seismic Evaluation of Existing Buildings“.

When Significant Projects are being planned for existing buildings located in zones of moderate to high seismicity, a detailed seismic assessment is mandated to be conducted in the project planning stage. A project is considered significant under any of the following conditions: I) when the interior finishes are planned to be stripped for substantial wings or floors; II) there will be a change of intended use of the facility as per the NBCC, such as from office to warehouse, etc.; III) there will be significant weight added to the existing building such as the addition of one or multiple floors; IV) key seismic resistance elements such as walls, braces or sections of the building, will be removed or modified; V) the project costs are at or above 50% of replacement costs for the building.

The policy requires federal building projects to be in full seismic compliance with current local by-laws and provincial/territorial building codes in addition to the NBCC, where such requirements exist.

Where the detailed seismic assessment finds the building’s seismic resistance does not meet 60% of the seismic load requirement for new building construction as specified by the current NBCC, seismic upgrading of the main structure is required. Upgrade options and approaches are to be investigated, so as to upgrade the seismic resistance of the main structure to the 60% or higher level. Consideration shall be given to upgrade the building to full current NBCC requirements or higher. Incorporation of practical aspects of the building alteration is to be carefully considered. New and emerging technologies are also to be carefully considered. Upgrade options for non-structural items are also to be investigated. Options, cost estimates and recommended seismic upgrading approaches are to be documented.

2.2.3. The execution

Whether major renovations are planned or not, basic Seismic Screenings shall be conducted on all buildings in zones of moderate to high seismicity per available manuals, NRC Manual for Screening of Buildings for Seismic Investigation (NRC and IRC 1993). For buildings in PWGSC's custody, screening results are to be included in each building's long-term Asset Management Plan. Results are to be used in the investment analysis planning process on a building-specific and portfolio-wide basis. For buildings that have not been subject to an earlier seismic screening, such a screening will be completed as part of the input to the completion of the next Asset Management Plan for the building. These screenings are part of the operation and maintenance activity and are to be funded out of the building's existing annual budget using the Building Condition Report and Building Management Plan process. Seismic screening of buildings in zones of moderate to high seismicity that are not yet within the custody of PWGSC shall be completed prior to a final agreement to acquire the facility. For a building with a confirmed Structural Priority Index SPI through this procedure of greater than 30, a detailed seismic assessment is mandatory and must be completed within a reasonable period and not later than the subsequent fiscal year after confirmation of the SPI. A seismic database for the PWGSC building inventory is to be maintained, including such information as base building information; screening and/or detailed evaluation information; scope/cost of seismic improvements where done; and mission-criticality information.

2.3 USA and Standards of Seismic Safety for Federally Owned and Leased Buildings (ICSSC – RP6)

The intent of the Standards of Seismic Safety for Federally Owned and Leased Buildings (NIST 2002) is to provide Federal agencies with common minimum and higher standards for the evaluation and mitigation of seismic risks in their owned or leased buildings, and privately owned buildings on Federal land to ensure that all agencies have a balanced, agency-conceived and controlled seismic safety program. The Standards allow for two levels of seismic performance: a minimum Life-Safety level intended to provide a low risk of earthquake induced life safety endangerment and a higher Immediate Occupancy level, intended to minimize the risk of earthquake-induced impairment of mission, recommended for critical facilities. The Standards build upon previous efforts by the Interagency Committee on Seismic Safety in Construction (ICSSC) in support of the National Earthquake Hazards Reduction Program (NEHRP). This document supersedes the Interagency Committee on Seismic Safety in Construction's Standards of Seismic Safety for Existing Federally Owned or Leased Buildings and Commentary (RP 4).

2.3.1. The beginning

In 1994, the President signed Executive Order 12941, Seismic Safety of Existing Federally Ownedor Leased Buildings (FEMA 1995). The order adopted minimum technical standards for all future seismic safety evaluation and rehabilitation projects for Federally owned and leased buildings. In addition, the order called for all agencies and departments owning or leasing buildings to develop a seismic inventory of their owned and leased buildings, and to estimate the costs of mitigating unacceptable seismic risks in that inventory. The order directs the Interagency Committee on Seismic Safety in Construction (ICSSC) to issue guidance on how to develop the inventory and cost estimate.

2.3.2. The mission

The primary objective of the Standards is to reduce the life-safety risk to occupants of Federal buildings and to the public. Life-Safety is the minimum performance level appropriate for Federal buildings. In addition, this Standards provide for a higher level of performance, commonly referred to as Immediate Occupancy, when needed to meet agency mission requirements (NIST 2002).

2.3.3. The execution

By this Standard all owned buildings are to be listed in the inventory database and screened into "exempt" and "non-exempt" categories, and to develop estimates of the cost of mitigating unacceptable risks.

Exempt Buildings are those which meet the criteria for exemption. The seismic risk in these buildings is expected to be very low, such that seismic rehabilitation would not be necessary. Additionally, buildings may be exempted if they will no longer be used by any branch of the Federal government in five years, because they are scheduled to be abandoned, demolished, sold, or otherwise removed from government service.

Non-Exempt Buildings are those which do not meet the criteria for exemption. The level of seismic risk in these buildings is not immediately apparent; the fact that they are not eligible for exemption means that they cannot be readily identified as presenting very low risk.

The Standards allow for two levels of seismic performance: a minimum Life-Safety level and a higher Immediate Occupancy level:

Life-Safety Level: Building performance that includes significant damage to both structural and nonstructural components during the design earthquake, though at least some margin against either partial or total structural collapse remains. Injuries may occur, but the level of risk for life-threatening injury and entrapment is low. People will likely be unable to reoccupy the building for continuous use until structural repairs are completed.

Immediate Occupancy Level: Building performance that includes very limited damage to both structural and nonstructural components during the design earthquake. The basic vertical and lateral-force-resisting systems retain nearly all of their pre-earthquake strength and stiffness. The level of risk for life-threatening injury as a result of damage is very low. Although some minor repairs may be necessary, the building can be fully occupied after a design earthquake, and the needed repairs may be completed while the building is occupied.

Seismic risk mitigation program consists of "active" and "passive" components. Active components of a seismic risk mitigation program specifically require some action to be taken, such as inventory, evaluation, planning for rehabilitation and the rehabilitation itself.

The focus of passive components is on changes to the building which increase its life of value or will increase the risk level of the building, such as a change in occupancy. The philosophy of the use of triggers is to achieve safety similar to a new building when renovating an old building, resulting with gradual overall seismic risk reduction. Exception to the passive triggers to the building renovation process is when a building is evaluated with "exceptionally high risk" level. In that case the earthquake risk mitigation process is being planned immediately.

3. COMPARISON

In the table 1 (below) the three policies mentioned in this paper are compared.

	Switzerland; SIA 2018	Canada	USA; ICSSC – RP6
Legal Basis	Euro code 8 (prEN 1998-3)	NEHRP Handbook for Seismic Evaluation of Existing Buildings (FEMA 1992-1)	*Standards of Seismic Safety for Existing Federally Owned or Leased Buildings and Commentary (ICSSC - RP* 4)
	FEMA 310: Handbook for Seismic evaluation of Buildings	Applied Technology Council of Redwood Canada: ATC-22 & ATC-21	*Handbookfor the Seismic Evaluation of Buildings -A Prestandard (FEMA 310)*
	Paulay T., Priestly M.J.N.: Seismic Design of Reinforced Concrete and Masonry Buildings	National Building Code of Canada (NBC, 1990)	*NEHRP Handbookfor the Seismic Evaluation of Existing Buildings (FEMA* 178)
	FOEN: Assessing the seismic safety of existing buildings and design guidelines, level 1 and 2	Uniform Code for Building Conservation, 1991	*Prestandard and Commentary for the Seismic Rehabilitation of Buildings (FEMA* 356)
	FOEN: Directive principles for the establishment and use of micro zonation studies in Switzerland		
Buildings of interest	Only federal buildings of specific building importance situated in specific regions	Buildings of federal interest owned by PWGSC, but can be used for private buildings as well	All federally owned or leased buildings

Who is responsible for the evaluation?	By government hired and/or educated personnel and companies	PWGSC	Federal agencies owning, or leasing the specific buildings
How is the evaluation conducted?	In 3 stages: 1-initial evaluation 2-additional more detailed evaluation 3-detailed evaluation +strengthening suggestion	In 2 stages: 1-initial evaluation 2-complete construction investigation + strengthening cost evaluation	1 stage: Complete construction investigation + strengthening cost evaluation
When is the strengthening conducted?	Within 5-10 years in accordance with the list of prioritized buildings	Immediately or gradually according to the PWGSC internal plan of priorities	Immediately or when other changes to the building are planned

Table 1: Comparison of the earthquake hazard mitigation policies from Switzerland, Canada and USA

3. CONCLUSIONS

Earthquake mitigation is becoming ever greater task of engineers all over the world in earthquake prone countries. Means exist to reduce the vulnerability of buildings, building contents, and infrastructure to losses from earthquakes. Often, however, these precautions have not been put in place, even in very dangerous areas. Indeed, individuals, organizations, and governments in dangerous places have been relatively slow to implement many risk reduction practices that have a high probability of reducing the vulnerability to earthquakes. Evidence continues to mount demonstrating that implementation lags sorely behind advances in scientific and engineering understanding. Getting policies and programs implemented is not a trivial matter.

This article is presentig three good examples of implemented earthquake mitigation policies. The policies are comared on the mitigation process approach level.

REFERENCES

Alesch, D. J. and W. J. Petak (2002). OVERCOMING OBSTACLES TO IMPLEMENTING EARTHQUAKE HAZARD MITIGATION POLICIES. Integrated Disaster Risk Management.

FEMA (1995). How-to Suggestions for Implementing Executive Order 12941 on Seismic Safety of Existing Federal Buildings. USA. **ICSSC TR-17**.

NIST (2002). Standards of Seisimc Safety for Federally Owned and Leased Buidlings. USA, U.S. Department of Commerce. **NISTIR 6762**

ICSSC RP 6: 27.

NRC and IRC (1993). MANUAL FOR SCREENING OF BUILDINGS FOR SEISMIC INVESTIGATION. Vancouver, Canada, National Research Council of Canada 1993. **NRCC 36943:** 106.

SIA (1970). Norm für die Belastungsannahme, die Inbetriebnahme und die Überwachung der Bauten. SIA 160. Zürich, Switzerland, SIA. **SIA 160**.

SIA (1989). Einwirkungen auf Tragwerke. SIA 160. Zürich, Switzerland, SIA. **SIA 160**.

SIA (2003). Actions on Structures. SIA 261. Zurich, Swiss Society of Engineers and Architects SIA. **SIA 261**.

Sundararaj, P. R., J. Balazic, et al. (2001). Seismic Resistance of PWGSC Buildings, Real Property Policy. Document No. PN 115e. Canada, Public Works and Government Services Canada.

Sundararaj, P. R., S. Foo, et al. (2004). "PWGSC POLICY ON SEISMIC RESISTANCE OF EXISTING BUILDINGS."