Seismic Risk Prevention in Costa Rica: A Successful 39 Year Experience

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SUMMARY:
Successful seismic risk prevention in a particular country or region is the result of a multitask social and economic endeavor with coordinated participation of engineers from academia, consulting and construction sectors, as well as other professional groups, together with law enforcers and administrators from both private and public sectors. This paper summarizes the author's experience during 39 years of continuous participation as a founding member of the Costa Rican Permanent Seismic Code Committee, the country's professional group legally responsible for the drafting and dissemination of its Seismic Code, which also advices in technical decisions related with matters of public policy regarding earthquake damage prevention. The paper reviews the most important activities of the Committee along 39 years, that have materialized in four Codes, published in 1974, 1986, 2002 and 2010, as well as the related professional, technical, educational and legal changes that the country has been able to implement.

Keywords: Seismic Codes, Social Organization

1. INTRODUCTION

With 51100 km^2 and 4.3 million inhabitants, Costa Rica is a small developing country located in Central America, flanked by the Caribbean Sea and the Pacific Ocean and having borders with Panama and Nicaragua. The Central American Region is located in the boundaries of the Cocos, Caribbean, Nazca and North American Plates, and consequently presents conditions of high superficial and intermediate seismicity, with numerous destructive earthquakes of intermediate and large magnitudes ($5.5 \leq M_W \leq 8.0$) associated to both interplate and intraplate sources (Benito and Torres, 2009). For instance, in 1991, a M_W 7.7 earthquake struck the Limon Province of Costa Rica, causing damages in an area of about 8000 km^2, mostly in lifelines (roads, bridges, railroads, ports and aqueducts). That particular quake was the highest magnitude quake for the entire planet in that particular year.

The seismicity of the Central American Region is predominantly severe in Guatemala, El Salvador, Nicaragua and Costa Rica (Fig. 1). However, it is interesting to note that, having similar patterns of seismicity, the earthquake losses of Costa Rica, measured in terms of human lives or economic disruption, has been strikingly lower than in the other three countries; this was the case in historic times and particularly during the past century. This is partly due to decisions made by wise political leaders of the time: For instance, in 1841, a very strong earthquake destroyed 2500 houses; in less than two months, President Braulio Carrillo issued, as a legal decree, a technical document with very sound mandatory technical rules for the reconstruction of all damaged and collapsed buildings. Furthermore, in 1910, another severe earthquake practically destroyed the city of Cartago, capital of the country during colonial times, killing more than 700 people. Within five months, President Ricardo Jiménez issued a legal decree with technical requirements for the repair and reconstruction of buildings, including the ban of highly vulnerable adobe, the prevalent construction material of the time. As a result, timber became the predominant building material and a beautiful timber vernacular architecture emerged all over the country. This visionary decision greatly contributed to the very few earthquake fatalities in the country during the 20th century.

Figure 1. Seismic Risk in Central America in PGA for RP=500 years (Benito and Torres, 2009)

During the second half of the 20th century, the country underwent very important social and political transformations that propitiated a very rapid economic expansion. As a result, new and more sophisticated civil infrastructure was built and the old practical rules for safe construction turned inadequate. For some time, meticulous structural engineers resorted to foreign seismic codes, but there were no mandatory regulations. The situation changed in 1973, with the draft of the first national seismic code. This paper tells the story of how seismic prevention in the country has been dealt since, a 39 year successful experience.

2. BIRTH: THE FIRST COSTA RICAN SEISMIC CODE

2.1. The beginnings

Two events may be considered the triggers of the first Costa Rican Seismic Code. First, the December 22, 1972, Managua earthquake (M_W = 6.3) that struck the capital of Nicaragua, killing 10,000 people, out of a city population of 400,000, with considerable destruction and damage in the downtown area, including many modern engineered buildings. Being Managua just 130 km from the Costa Rican border, this tragic event produced great concern in the general public as well as in professional groups of engineers and architects, which traveled to Managua and became direct witnesses of the tremendous damage and chaos that earthquakes can produce to an unprepared country.

A few months later, in April 14, 1973, a very similar superficial quake (M_W = 6.5) struck Tilarán, fortunately a rural area of Costa Rica. It killed 23 people, destroyed 84 dwellings and damaged another 500. These two events lead to a wise initiative by the School of Civil Engineering of the University of Costa Rica (UCR): the creation, in May 1973, of a Committee to draft a seismic code for the country. Four structural engineers integrated the Committee, three consulting engineers and a construction engineer; all were university professors at UCR with an extensive professional experience.

At that time the author of this paper was a young professor at UCR about to complete a Master Program in Structures and Earthquake Engineering at the University of California, Berkeley (UC Berkeley) and planning to spend the summer in Costa Rica before continuing his Ph.D. studies in the fall. He received a letter inviting him to join the Committee. That was an offer he could not refuse: in those years, the top earthquake engineers in USA, from academia and professional practice, were deeply engaged in drafting a set of provisions for the development of seismic regulations for buildings, meant to represent a qualitative and quantitative giant leap forward from the earthquake design practice of the time; that document came to be known as ATC-3 (ATC, 1978). All the advanced concepts eventually incorporated in ATC-3 were already the substance of graduate courses and research programs at UCBerkeley and other top leading universities in USA. Hence, having spent two years in a graduate program at UC Berkeley, the opportunity to incorporate the most advanced concepts in earthquake engineering in a code of practice for his country was very appealing and challenging, and the answer to the Committee was an enthusiastic yes.

2.2. The drafting and approval of the document

Once in Costa Rica, a procedure for the drafting of the Code was defined: the author would dedicate full time to the drafting of the Code and would present his writings weekly to the Committee, who would discuss them and present their observations and suggestions. This agreement produced excellent results as the author was able to incorporated quite advanced concepts and techniques, even for leading countries, but adjusted to the reality of the professional practice of the country that the other Committee members knew so well.

The world list of seismic codes, published by the International Association of Earthquake Engineering (IAEE, 1973), were very helpful for the basic scheme of the document, not necessarily for its contents. After three months of very intensive and rewarding work, a final draft was approved by the Committee. The author returned to UC Berkeley and the Committee continued their work, establishing a relationship with the College of Engineers and Architects (CFIA for its Spanish acronym), the institution in charge of regulating the professional practice of engineers and architects in the country. They enthusiastically endorsed and formally approved the Code and published it in January 1974 as the Costa Rican Seismic Code-1974, CSCR-74 for its Spanish acronym (CFIA, 1974).

2.3. Main features of the CSCR-74

For reasons already explained, the first seismic code of Costa Rica was conceptually more advanced than most contemporary official seismic codes. The more relevant innovations will be mentioned now; more detailed comments have been presented elsewhere (Gutiérrez, 1980).

2.3.1. Strength design

In those days, “working stress design” was still the usual design method in most codes, even for seismic design; in contrast, the CSCR-74 prescribed “ultimate strength design” as the design method even for gravitational loads and recognized the earthquake effects on the structure as an extreme condition, therefore the load combinations that included earthquake effects were $U=0.75(1.4D+1.7L)+E$ and $U=0.9D+E$.

2.3.2. Constant ductility design spectra

Perhaps the more daring and farsighted innovation of the CSCR-74 was the use of constant ductility spectra for the computation of the seismic coefficients C. The values of C were presented in two figures, corresponding to non-alluvial (rock or firm soil) and alluvial (soft soil) sites. In each figure, values for C for the structural period T are given for five structural types corresponding to: ductile frames (type 1), dual wall-frames (types 2 and 3, according to their assigned ductility capacity), walls (type 4) and cantilevers (type 5). The values of C are in fact constant ductility acceleration spectra derived for estimated values of global ductility capacities of 6, 3, 2, 1 and 1, respectively assigned to each structural type; however, those are implicit values, as they were not explicitly mentioned in the Code. The use of constant ductility design spectra for the determination of the seismic coefficient C has been a characteristic of all versions of the Code (1974, 1986, 2002 and 2010).

In the Code, effective peak ground accelerations of 0.15 and 0.17 for non-alluvial and alluvial soil sites, were prescribed for the entire country, the reason being that in 1973, when the Code was drafted, there were no seismic hazard studies for the entire country. Those figures were estimates of the effective peak ground accelerations, for both sites, for the Central Valley of Costa Rica, where up to 70% of the population lives and where the most important civil infrastructure was to be found at that time. This lack of information lasted only a few years, as it will be described latter.

2.3.3. Dynamic modal analysis

With the exception of buildings regular in plant and elevation with 30 m or less in height and up to 7 stories, the Code prescribed that seismic effects should be calculated with the modal analysis response spectrum method. This was not the usual practice at the time and, even in recent codes, all kind of approximate methods are usually presented to estimate the seismic response of buildings. The fact is that modal analysis gives much better estimates and, even in 1974, reliable computational algorithms were available to perform these calculations. Obviously, this requirement forced all consulting structural engineers to get acquainted with the basic concepts of dynamics of structures and to introduce computers in their design offices.

2.3.4. Non linear displacements

Another important Code innovation was the evaluation of nonlinear lateral displacements and interstory drifts, which were assumed as the corresponding values resulting from elastic analysis multiplied by the global ductility capacity assigned to each structural type. Admittedly, it was a rough simple estimation for a very complex problem, but it provided the designer with more realistic values to check for interstory drifts or separation of non structural walls. Inelastic story drift limits of 1% and 0.5% were prescribed for normal and essential buildings, respectively.

2.3.5. Capacity design and ductility considerations in structural materials

There were specific chapters dedicated to the design of prevalent structural materials: reinforced concrete, reinforced masonry and steel. The chapters included requirements to provide sufficient local ductilities at the element level, a basic requirement for adequate structural global ductilities. In addition the, at that time, new concepts of capacity design, were incorporated in the Code: strong column-weak beam requirements, maximum possible shear in columns and beams as a function of their flexural capacity and effective length, to name the more noticeable.

2.3.6. Simplified design of one and two story dwellings

Recognizing the fact that one and two story single family dwellings were prevalent and usually do not require qualified structural engineering for their design, the Code included a specific chapter with simple design and construction regulations and structural details that have demonstrated their effectiveness during strong earthquakes.

3. YOUTH: THE EARLY YEARS OF THE CODE COMMITTEE AND THE 1986 CODE

Once the CSCR-74 was approved by the CFIA, they decided, with remarkable wisdom, to give continuity to the work of the original drafting Committee, creating the "Permanent Committee for Study and Review of the Costa Rican Seismic Code" (CPCSCR for its Spanish acronym), ascribed to the CFIA. For that purpose, they appointed the five members of the original drafting Committee and added four renowned structural engineers, selected from the consulting practice and the construction industry. This group was responsible for the consolidation of the Committee and developed important and innovative activities. In this section, the main actions and more remarkable accomplishments achieved during the first 12 years will be described; this period culminated with the official approval and publication of the second Code, twelve years later.

Although most members have changed, the Permanent Committee has remained active, meeting every month for the last 38 years without receiving any economic compensation; an outstanding commitment with their profession and their society. Their fruits have been plentiful and have had a deep impact in the reduction of the seismic vulnerability of the country.

3.1. Spreading the concepts

Once the Code was published and the Permanent Committee became active, a period of intense dissemination of the concepts and the general knowledge contained in the Code followed. Motivated students did choose earthquake engineering as their field of interest and were able to obtain scholarships or financial support to pursue graduate studies abroad, mostly at top American universities. Concurrently, technology transfer courses about the Code and its underlying concepts were offered to the professional community and seminars, with the presence of distinguished professors from well known foreign universities, were held with some regularity, attracting scores of professionals and students. Lectures presenting the most frequent types of structural damage caused by strong earthquakes were organized by the Committee, whenever a destructive event struck anywhere around the world.

In synthesis, the publication of the CSCR-74 and the creation of the CPCSCR generated in few years a thriving interest in the field of earthquake engineering in Costa Rica that eventually permeated not only the engineering profession but the society as well. In few years, enough critical mass had been created and, in 1981, the first National Seminar on Structures and Earthquake Engineering was held. These Seminars became a tradition in the country[1] and nowadays they are organized, every other year, by the Costa Rican Society of Structural and Earthquake Engineering, created in 1985 as another offspring of the momentum created by the Code.

3.2. Seismic hazards studies

As mentioned, lack of seismic data when the first Code was drafted, lead to the dubious statement of a seismically uniform country. To overcome this serious deficiency, the Committee acted as a promoter for a study on seismic hazard for the country, contacting Prof. Haresh Shah from Stanford University, whose group had been involved in Central America after the Managua earthquake. With financial support from the National Insurance Institute (INS), the state insurance agency that had the monopoly of all insurance activities in the nation, the first study of seismic risk for Costa Rica was presented in 1977 (Mortgat et al, 1977).

Among other results, the study provided iso-acceleration curves for peak ground accelerations in rock, corresponding to return periods of 50, 100, 500 and 1000 years. The main weakness of this study was associated with the uncertainties inherent to the seismic data used as input, as most of the earthquake parameters, mainly magnitude and location, had been gathered from seismological stations located abroad. This was indeed a serious drawback; however, for the first time, the country had information that provided a description of its seismicity. Furthermore, those results would be significantly improved as more reliable information from the country's seismological and strong motion networks was being gathered, as would soon be the case, as commented in 3.4.

3.3. Providing legal support

A stronger Code enforcement, not only within the engineering profession but by the society at large, is essential to its effectiveness. Turning the Code into as a law approved by the National Congress, was the obvious alternative, but it represented a very serious drawback as changes in the law would then be required every time that the Code had to be modified for technical reasons. For this intricate conundrum, the Committee found a very practical solution: a law was indeed necessary but it should be very simple, just a few articles stating that it was the duty of the Executive to issue a legal Decree to regulate the seismic design of buildings and other structures. The law should indicate that, to issue such a decree, the Executive must consult the CFIA, as the professional organization of engineers; needless to say, the CFIA will then deliver the new Code as their answer to the Executive.

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[1] And in Latin America as well, where similar events, but at a regional level, were initiated by Venezuela in 1979 and subsequently held in different Latin American countries, with some periodicity, for several decades. Costa Rica hosted two of them, the 4th in 1986 and the 10th in 1998.

With lobbying from the Committee and the CFIA, such law was easily approved by the National Congress in November 1977; it indeed consists of one page with six short articles but it is a national law; hence, to comply with the Code is a legal mandate for professionals and society. A new Executive Decree must be issued every time a new Code is approved, but that is a relatively easier task.

3.4. Measuring the country's seismicity

On April 3 1983, a M_W 7.3 earthquake struck the southern Pacific coast of Costa Rica causing severe damage around the epicenter. It was followed three months latter by a M_W 6.2, caused by a nearby local fault. These events, in a time when Central America was in deep political turmoil, with guerrilla warfare in Nicaragua, El Salvador and Guatemala, led to a generous grant by the USA government, that resulted in a modern network that currently has 70 accelerographs installed in selected buildings and sites all over the country and is operated by UCR. The grant also provided modern seismological equipment. As a result, a well instrumented country started to collect systematic information about its seismicity, its strong quakes and their effects in engineering structures. This modern and extensive instrumentation would play a crucial role in the 1990-1991 biennia, characterized by intense seismicity, including the M_W 7.7 Limon Earthquake of April 23 1991, commented in the Introduction.

3.5. The 1986 Seismic Code

A decade of continuous activity by the Permanent Committee, lead to the important results already commented plus a significant number of research projects done at UCR that produced valuable information for the Code. The time was appropriate for a new Code, to incorporate all the accumulated new knowledge and experience. For that purpose, a strategy similar to 1973 was defined, with the author drafting the new document and presenting his writings to the other members of the Committee for their observations and suggestions. However, this time there were not stiff datelines; hence, the author was involved only part time but during a longer period of time. In addition, the drafting of the sensitive subject of one and two story dwellings was assigned to another professional who worked with a Housing Subcommittee in a similar fashion, expanding the subject to 8 chapters. The final document was approved by the CFIA in 1986 and published one year later (CFIA, 1987).

As in the first Code, implicit constant ductility spectra were included for the calculation of the seismic coefficient C. However, as the Code provided isoacceleration curves with peak ground accelerations at the site, the Code presented normalized dynamic amplification factors derived using the methodology proposed by Riddell and Newmark (1979) for implicit ductilities of 6, 4, 2, 1.2 and 1 for structural types 1 to 5 respectively, and for three types of soil sites: rock, firm soil and soft soil.

As it had become customarily, after the publication of the new Code a series of seminars and continuous education courses were offered to students and practicing engineering. This time, however, the effort required by the professionals was not as intense, as the 1986 Code was in fact an evolution of the 1974 version, without major changes in concepts or in the analytical and design procedures.

4. ADULTHOOD: THE LAST 25 YEARS AND THE 2002 AND 2010 CODES

Once the new version of the Code was published, a few members of the Permanent Committee presented their resignation. New members were then incorporated, young and motivated structural engineers selected from academia and from the design and construction practices, with graduated degrees obtained from excellent overseas universities, another positive consequence of the momentum created by the publication of the first Code twelve years ago; the total number of members had been eventually increased to thirteen. During the following sixteen years, many positive developments and significant seismic events, both at home and abroad, strengthened the practice of earthquake engineering in the country, leading to a new and more advanced version of the Code in 2002.

4.1. Graduated studies and research

The engineering knowledge required for an adequate design of earthquake resistant structures have become very sophisticated and it is not taught in the civil engineering undergraduate programs of most universities. In 1991 the University of Costa Rica initiated a graduate program in civil engineering which offers, among other degrees, a two year M.Sc. program comprising 8 graduate courses, mostly related to earthquake engineering, and a dissertation. This is the only graduated program in structural engineering in the country and all the professors are members of the Seismic Code Committee. Needless to say, this program has significantly contributed to raise the level of earthquake resistant design in the country and many of the dissertations have made very valuable contributions to diverse subjects addressed by the Code.

4.2. Getting to know materials and structures

Advanced experimental facilities to study the structural materials and building components of a particular country or region are of paramount importance for the correct practice of design and construction and for the elaboration of effective seismic codes. In 1994, the School of Civil Engineering , UCR, inaugurated the National Laboratory for Materials and Structural Models (LANAMME for its Spanish acronym) a well equipped experimental facility in structural, geotechnical and transportation engineering. It has testing facilities for construction materials and a strong floor-reaction wall for large scale testing of structural components and even structures. Professors and students, both at undergraduate and graduate levels, benefit from these facilities for their research projects and dissertations and many results derived from experimental and analytical research programs and dissertations carried out at LANAMME have resulted in valuable inputs for the Code and for the earthquake engineering practice at large.

4.3. Learning from earthquakes

Strong earthquakes in populated areas of the world, especially in those with a large variety of engineered buildings, represent huge and very valuable large scale tests. The decade 1985-1995 was particularly intense in these events (i.e. Chile and Mexico City, 1985; Loma Prieta, 1989; Northridge, 1994; Kobe, 1995); all these events were, and still are, the subject of exhaustive studies and their results have had a very significant impact in the earthquake engineering conceptualization and practice all over the world. Costa Rica also had a series of medium to strong earthquakes in the biennia 1990-1991, which provided valuable material for new seismic hazard studies (Laporte et al, 1994) and other types of research that eventually turned into regulations for a new Code.

4.4. The drafting of a new Code: the CSCR-2002

In 1998, after another twelve year period since the last Code, the circumstances already commented lead to the need of a new updated version. At that time, the main problem was not lack of new knowledge and information, but the excess of it, not only at a national level but, most important, worldwide. In effect, the strong earthquakes of California and Japan had shown serious drawbacks in certain structural details prescribed in the codes. Furthermore, those quakes had persuaded the leading earthquake engineers of the world that a new design philosophy was needed to be able to achieve specific building performances under particular levels of ground shaking. Under these circumstances, the Code Committee decided to go ahead with the drafting of a new Code.

4.4.1. Reorganizing the Code Committee

This time, due to two main reasons, the organization was entirely different: first, the complexity of the task considerably increased in depth and diversity and second, the Code Committee had achieved a critical mass, with all members having particular strong backgrounds and preferences in diverse fields of earthquake engineering, propitiating team work. In consequence, the Committee organized itself accordingly, electing a Board of Directors (Chairman, Vice chairman, Treasurer and Secretary), appointing an Executive Secretary (with well defined administrative and technical duties and a small economic compensation, provided by CFIA) and creating 12 Technical Committees, conformed by its own members and some external qualified voluntaries, addressing the subjects of each specific chapter. Those Technical Committees met at least twice a month and coordinated their work in the monthly meetings of the Code Committee. Each member participated in at least two concurrent Technical Committees, resulting in a minimum of five monthly meetings, a formidable commitment. The fruits of this reorganization were plenty and resulted in a very complete updated Code that was approved in 2002 and published one year latter (CFIA, 2003).

4.4.2. Main features of the CSCR-2002

With 6 sections and 17 chapters, the CSCR-2002 was considerably expanded and included many important changes, most notable: a) it addresses only buildings, b) it explicitly accepts ductile damage and forbids fragile materials, c) for the definition of the seismic input, the return period is defined as 475 years instead of the 100 years in the previous Code, d) in addition, the isoacceleration curves are substituted by 3 seismic zones (Zones II, III and IV, with effective peak ground accelerations of 0.2g, 0.3g and 0.4g for rock sites) and 4 soil sites are defined (rock, firm, medium and soft), e) overstrength in the structure is explicitly acknowledged and accounted for, f) structural expected ductilities are explicitly recognized and defined as a function of 5 structural types (frames, dual, wall, cantilever and others), the regularity or irregularity in elevation and plant and the local ductility provided to structural elements and joints (either moderate or optimum), g) five chapters for the design of structural materials provide specifications to achieve either optimum or moderate local ductilities and h) seismic coefficients are then defined in terms of seismic zoning, soil site and assigned expected ductility.

A chapter on methods of analysis presents two elastic response methods: the Static Method, for regular buildings up to five stories high, which calculates seismic forces with a single linear mode and the Dynamic Method, which corresponds to a response spectrum analysis. The Code recognizes the weakness of these two methods to estimate the performance of buildings and, for that purpose, it provides another two methods that will be commented next.

4.4.3. Towards Performance Based Engineering

The two alternative methods of analysis appropriate for Performance Based Engineering (PBE) are the Time History Analysis Method and the Capacity Spectrum Method. The first one had already been included in the two earlier versions of the Code, mostly for the sake of completeness as, except for academic purposes, it has rarely been used in the country as it presents inherent difficulties, mainly associated with the availability of a set of ground motions compatible with the design spectra and of reliable computational algorithms required to accurately model the inelastic response of the structure.

The second method presented in the Code, the Capacity Spectrum Method (CSM), is conceptually more robust but at the same time much simpler than those methods that, with equal name, have been presented in the technical literature, mostly in the USA. The main conceptual advantage of the CSM included in the CSCR-2002 is a result of the use of explicit constant ductility design spectra to calculate the Seismic Coefficient C, and its simplicity comes from a graphic procedure that facilitates the calculation of the Performance Point of the structure. To illustrate with an example, in Fig. 2 the seismic coefficients C, which are in fact constant ductility inelastic design spectra, are represented in a Sa-Sd format (Sd inelastic). Concurrently, the capacity of the structure is represented in the same graph by a Capacity Spectrum curve, derived from a pushover analysis. The Performance Point is then determined as the point where the required global ductility μ_{GR}, as defined in the seismic demand curves of the Sa-Sd spectra, coincides with the one calculated from the Capacity Spectrum curve and the Equivalent Yield Point (in the example, the Performance Point corresponds to a required ductility μ_{GR} = 1.7). Next, the displacements, deformations and all desired variables of the structure, representing its seismic response, can be calculated and the performance of the complete building evaluated. A more detailed explanation of this conceptually robust but simple procedure can be found elsewhere (Gutiérrez, 2006). Needless to say, the method has been well accepted by the profession and is extensively applied for the evaluation of existing buildings and even for the design of new ones.

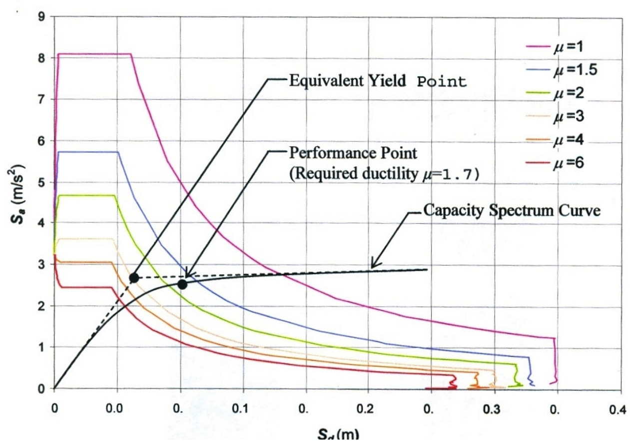

Figure 2. Graphic calculation of Performance Point and its corresponding required ductility (Gutiérrez, 2006)

4.4.4. Code dissemination and commentaries

As in the 1974 and 1986 versions of the Code, the official approval of CSCR-2002 by the CFIA was followed by a series of lectures and a complete program of continuous education courses for the profession, covering all the subjects addressed by the Code. As commented in 3.3, to be legally binding, the complete document was issued as an Executive Decree. Furthermore, a set of Commentaries to the Code were prepared, for the first time, by the Code Committee and published as a separate document (CFIA, 2007); a very valuable contribution to the understanding of its underlying concepts, contributing to a better application of the Code. In addition, the Committee has created a web site for Code users, where engineers and students can place comments and ask questions.

4.5. Updating the 2002 Code: the CSCR-2010

Sixteen years passed between the 1986 and the 2002 Codes, a significant time gap. After the publication of CSCR-2002, the Committee considered that these periods should be reduced, not necessarily with deep changes every time. In fact, after a few years of use, there were a good amount of comments and suggestions generated by the engineering community that required clarifications or even changes. Furthermore, to motivate research related to the Code, the Committee had created grants to provide financial support for dissertations, both at graduate and undergraduate levels, and some interesting results had been obtained from them. In addition, worldwide the regulations for some structural materials, mainly steel, were undergoing significant changes that demanded a thorough review in the corresponding chapter of the Code. Lastly, a complete review was necessary in the chapter of structural timber, as the demand and use of this material have been increasing in recent years. Using the proven successful organization and maintaining the same outline and chapters of 2002, after a thorough review of all chapters lasting several years, a new Code was drafted; it was approved in 2010 and published in 2011 (CFIA, 2011). The corresponding program of courses and the draft of comments are presently underway and expected to be completed in this current year.

5. A FEW IDEAS WORTH SHARING

After 39 years of experience as a member of the Code Committee, the author would like to share a few ideas that may be useful in seismic countries or regions of the world with similar conditions and circumstances:

a) Be proactive, not reactive. New codes should not be the result of recent destructive earthquakes in the country as, quite frequently, they are drafted in haste, overlooking some important issues, and becoming quite conservative, resulting in significant increments in construction costs and professional rejection. Code regulations should be drafted in times of seismic tranquility.

b) Organize and sustain a well balanced permanent organization. A permanent committee with simple but functional rules and a proper balance of members from academia, design and construction sectors is essential for the drafting of seismic codes that are well received and applied by the profession.

c) Generate high quality local knowledge. Always essential for reliable results, high quality local knowledge is usually produced at the country's research universities. Participation in a Code Committee of academics from those universities is the most effective way to generate useful results.

d) Do not be afraid of well supported deep changes. The engineering profession usually has a natural resistance for changes. However, earthquake engineering research and real earthquake experiences will eventually lead to the need of some radical changes. They must be pressed down by well respected professionals, preferably members of a code committee. Their implementation will always benefit the engineering profession and the society at large.

e) Obtain legal support but avoid legal tangles. In order to be effective, code compliance is essential and it is much easily achieved if they are legally binding; however, laws are stiff and difficult to change, and technical requirements need constant adjustments. The solution presented in this paper is, in the author's opinion, a very effective, practical and replicable solution.

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