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Seismic Design Implications of Revisions to the National Building Code of Canada

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ABSTRACT: This paper begins with a brief introduction to Canadian seismicity and the history of seismic code development in Canada; a summary of major changes planned for the 2005 edition of the National Building Code of Canada follows. Areas of major change include seismic hazard, site effects, irregularities, force reduction factors and methods of analysis (dynamic analysis now being preferred). The implications of the proposed changes are presented in terms of impact on seismic design force for several structural systems located in regions of high, moderate and low seismicity; implications for seismic level of protection and the seismic design process are also discussed. The paper concludes with a discussion of ongoing seismic code development issues.

1 INTRODUCTION

1.1 Canadian Seismicity and Code Development History

The seismicity of the large Canadian landmass varies considerably and comprises the following main features:

- A relatively high seismicity region near the plate boundary along the western coast of British Columbia; hazard is influenced both by relatively shallow crustal earthquakes and by the Cascadia subduction zone; the cities of Vancouver and Victoria are located in this region.

- A large region of low to moderate seismicity in southeastern Canada and the eastern Arctic in which hazard is influenced largely by intraplate earthquakes; the cities of Toronto (low seismicity) and Montreal (moderate seismicity) are in this region. High seismicity in a very small area in the lower St.Lawrence valley arises from a zone of crustal weakness thought to be due to the impact of a meteor; this is a rural area with no sizeable cities.

- A large stable region in central Canada which is for all practical purposes aseismic; this region includes most of the land area of the provinces of Alberta, Saskatchewan and Manitoba as well as a substantial portion of northwestern Ontario and the western Arctic.

Adams and Atkinson (2003) describe how this seismicity is modelled for the purpose of calculating seismic hazard.

The first edition of the National Building Code of Canada (NBCC) in 1941 contained seismic provisions in an appendix; specific seismic provisions in the code proper did not appear until the 1953 edition. There have been nine editions since 1953 up to and including the edition which is currently in use, i.e. NBCC 1995 (Associate Committee on the National Building Code 1995). As has been the case with the evolution of most other building codes, there have been major changes in seismic provisions during that period. Since 1965, the overall responsibility for developing these seismic provisions has been the responsibility of the Canadian National Committee on Earthquake Engineering (CANCEE), which operates under the direction of the Associate Committee on the National Building Code, National Research Council of Canada (NRCC).

The next edition of the NBCC is to be published in 2005; at the time of writing this paper, the seismic provisions for that edition have been completed and are about to be made available for public review and comment. An overview of those provisions is given by Heidebrecht (2003). The changes to these provisions are substantial and will have a major impact on seismic design of buildings in Canada.

1.2 **Objectives**

The primary objectives of this paper are to outline the major changes being proposed for the 2005 NBCC seismic provisions and to discuss the impact of these changes on seismic design and the seismic protection of building structures. Discussion of the implications of these changes for designers and the design process is also included as well as a brief presentation of issues applicable to seismic codes and design in general, whether in Canada or any other country. The views expressed in this paper are those of the author and are not to be construed as official positions of CANCEE or of the Associate Committee on the National Building Code, NRCC.

2 MAJOR CHANGES IN NATIONAL BUILDING CODE OF CANADA, 1995 TO 2005

2.1 **Seismic Hazard**

As noted in Table 1, which summarizes major changes being proposed for NBCC 2005, both the seismic hazard format and probability of exceedance are being changed; seismic hazard has been recomputed using a so-called fourth generation hazard model (Adams and Atkinson 2003) which incorporates new knowledge from recent earthquakes, new strong ground motion relations, measures of uncertainty and a more systematic approach to reference site conditions. Because the spectral acceleration ordinates $S_a(T)$ (calculated on a uniform hazard basis) are being specified directly for each geographical location, design forces for the same structure will vary continuously rather than being the same within a seismic zone or changing abruptly over zonal boundaries, as is currently the case. Similarly, the shape of the spectrum, i.e. its variation with period, varies from location to location. The spectral values tend to fall off more rapidly with increasing period than the equivalent spectrum (i.e. amplified peak ground motions) in NBCC 1995. For example, the ratio $S_a(0.2)/S_a(1.0)$ ranges from approximately 2 to 3.5 in the southwestern plate boundary region and 3 to 6 in the eastern intraplate region; the corresponding ranges of this ratio for the NBCC 1995 equivalent spectrum are 1.4 to 2 and 2 to 2.8 respectively. This feature has the impact of significantly increasing the design loads of short period structures relative to long period structures; this increase is somewhat ameliorated for structures of limited ductility or better by applying a 2/3 factor to short period loads.

The change in probability level is being introduced to provide a geographically more uniform margin of safety against collapse; the proposed 2% in 50 year probability level is somewhat nearer to the expected probability of structural collapse or failure of structures designed and constructed in accordance with code provisions. The reason for making this change is that the slopes of the hazard curves (defined as the relationship between spectral acceleration and probability of exceedance) vary considerably between interplate and intraplate regions. For example the ratios of $S_a(1.0)$ at 2% in 50 year to 10% in 50 year probabilities are in approximately 2 in Vancouver and 2.8 in Montreal.

2.2 **Site Effects**

It has long been recognized that the amplification of seismic motions from rock to soil sites can be significant, especially for sites with soft soil conditions. The site factor approach being proposed for NBCC 2005 is an adaptation of that used in NEHRP 2000 (Building Seismic Safety Council 2001) which is based largely on research done by Borcherdt (1994). The substantive impacts of this change are to include: a) short period amplification, b) non-linearity of site amplification, i.e. amplification decreasing with increasing levels of rock motion, and c) de-amplification of seismic motions at rock or hard rock sites, i.e. those having shear wave velocities higher than that of the reference site condition, which is described as “very dense soil and soft rock”. Short period amplification occurs primarily on soft soils in regions of low seismicity and can increase ground motions by as much as a factor of 2;

NBCC has no short-period amplification on soft soils because of a cap on short period force levels. Non-linearity has the effect of eliminating short period amplification on soft soil sites in regions of high seismicity and reducing medium to long period amplification by 20 to 40%. De-amplification for hard rock sites (shear wave velocities of 1500 m/s or more) can range from 20 to 50% depending upon period and the intensity of rock motion.

Table 1 Summary of Major Changes in Seismic Provisions, NBCC 1995 to 2005

Topic	NBCC 1995	NBCC 2005
Seismic hazard format	Zonal peak ground velocity and acceleration	Location specific uniform hazard spectral acceleration values at 0.2, 0.5, 1.0 and 2.0s, with linear interpolation
Seismic hazard probability	10% in 50 years	2% in 50 years
Site effects	Single foundation factor F ranging from 1.0 to 2.0 for four foundation categories; short period force cap equiv to F of 1.0 for all sites	Site factors F_a and F_v with values dependant upon spectral accelerations at 0.2s and 1.0s respectively (direct adaptation of approach used by NEHRP*)
Vertical irregularities	No specific requirements	Six types defined with restrictions on method of analysis and design for each type
Torsion	Static torsional moments include amplified natural eccentricity and accidental eccentricity 0.1 x plan dimension; same accidental eccentricity added to 3D dynamic analysis	Torsional sensitivity defined on basis of ratio of max edge displ to ave displ; dynamic analysis required for torsionally sensitive structures; static method may be used for non-sensitive structures, with no amplification of natural eccentricity
Structural system force modification factors	Single factor R; values range from 1.0 (e.g. unreinforced masonry) to 4.0 (e.g. steel or RC moment-resisting frame)	Ductility related factor R_d (range 1.0 to 5.0) and system overstrength factor R_o (range 1.0 to 1.7); product R_dR_o ranges from 1.0 to 8.5
Analysis	Equivalent static load prescribed; dynamic analysis permitted	Dynamic analysis prescribed (normally linear modal response or numerical integration); equivalent static load permitted as exception (e.g. low seismicity, most regular structures and short period irregular structures)
Calibration	Level of protection factor U = 0.6 applied in determination of seismic load	No calibration but maximum seismic load limited to 2/3 of short period maximum for structures with R_d of 1.5 or higher, i.e. limited ductility or better

*National Earthquake Hazards Reduction Program (Building Seismic Safety Council 2001)

2.3 Irregularities

As noted in Table 1, NBCC 1995 has no specific requirements for vertical irregularities, although it does require that building design take into account the effect of setbacks; the commentary provides a few paragraphs describing setbacks and their effects. The significant effect of such irregularities on the performance of structures during earthquakes is being recognized in NBCC 2005 by defining six types (stiffness, mass, geometric, discontinuities (in-plane and out-of-plane) and weak storey) and specifying restrictions applicable to the different types. The kinds of restrictions include: analysis (i.e. requiring dynamic rather than static analysis), design (e.g. specific requirements associated with diaphragms, openings and discontinuities) and use (e.g. restrictions related to type and level of seismicity). One of the major use restrictions is the proposal to prohibit weak storeys in regions of moderate to high seismicity.

The consideration of torsional effects for all structures continues to be a requirement but it is being proposed that dynamic analysis be required for structures which are torsionally flexible, based on studies (e.g. Humar et al 2003) which show that a static approach cannot consistently represent torsional effects for such structures. Rather than requiring designers to compute the ratio of torsional to lateral period, a torsional sensitivity parameter B is to being introduced. This parameter is defined as the maximum value, in both orthogonal directions, of the ratio of edge displacement to average displacement in each storey when the static seismic load is applied at distances of ± 0.1 x plan dimension from the centres of mass at each floor. A structure is deemed to be torsionally sensitive when $B > 1.7$ in which case dynamic analysis is required; otherwise torsional effects can be determined statically by applying torsional moments based on the natural eccentricity plus an accidental eccentricity of 0.1 x plan dimension. Accidental eccentricity must also be included when dynamic analysis is used.

2.4 **Structural Systems**

NBCC 1995 specifies a force modification factor R, which is equivalent to the maximum system ductility capacity, for a number of types of lateral-force-resisting systems for which the design and detailing requirements are specified in the steel, reinforced concrete, timber and masonry materials standards published by the Canadian Standards Association (CSA). The linkage to updated editions of these materials standards continues to be important in the proposed NBCC 2005 requirements because of the significance of these design and detailing requirements in assuring that these systems have the properties associated with the specified force modification factors. As noted in Table 1, it is being proposed that both a ductility related factor R_d and an overstrength related factor R_o be specified for each structural system; the product R_dR_o appears as a composite reduction factor in the denominator of the expression for calculating the seismic design force V. The introduction of R_o is intended to recognize the dependable portion of the reserve strength in the various structural systems; this is consistent with the use of seismic hazard at a lower probability of exceedance, as discussed previously. Mitchell et al. (2003) describe the components used to determine R_o and show the detailed calculations for the various values assigned to the different structural systems.

It is also being proposed that NBCC 2005 include height limits for structural systems having limited ductility when these are to be built in regions of high seismicity. The most common limit is 60 m although limits as low as 15 m are specified for so-called “conventional construction” in steel and concrete, i.e. buildings designed with no specific attention to ductility capacity. Also, it is being proposed that very brittle structures such as unreinforced masonry be prohibited in regions of moderate and high seismicity.

2.5 **Analysis**

As indicated in Table 1, it is being proposed that dynamic analysis be the “default” method of analysis, with static analysis permitted as an exception. Linear methods of dynamic analysis (either modal response or numerical integration time history) are specified although nonlinear dynamic analysis is permitted provided that a special study is performed. The input for the linear methods must conform to the site specific spectral acceleration values, i.e. either using these as response spectrum ordinates or using accelerograms having spectra which are compatible with such a spectrum. The dynamically determined base shear must be at least 80% of that determined using the static method for regular structures and 100% of the static value for irregular structures; these restrictions are intended to provide a safeguard against the use of structural models which are inadvertently much more flexible than actual structures. Of course, it is intended that the designer use the actual dynamic base shear if it is larger than the static value, which is likely to be the case for structures in which the higher modes dominate the dynamic response, e.g. tall long period structures.

The NBCC 2005 static method uses the spectral acceleration at the fundamental period of the structure to compute the elastic base shear coefficient. However, since spectral acceleration represents the maximum force in a single-degree-of-freedom system, a higher mode factor M_v is applied for structures with fundamental periods in excess of 1.0 s. That factor varies with period and with the type of lateral load resisting system; it can be as high as 2.5 for long period wall and wall-frame systems.

2.6 Level of Design Load

In this context, the value of the seismic design load is considered a proxy for the level of protection although there are several other factors which contribute significantly to the actual level of protection, e.g. maximum interstorey drift. NBCC 1995 deliberately calibrated the "average" seismic design load to that in the previous code by incorporating the multiplier U = 0.6 in the expression for determining that load.

As the provisions for NBCC 2005 were being developed, the consensus among the members of CANCEE was that it would be preferable, if possible, for the calculation of the seismic design load to be done rationally without resorting to a calibration factor. However, as studies were done to compare seismic design forces using the proposed code provisions with those determined in accordance with the NBCC 1995 provisions it became clear that the resulting increases in design forces for short period structures would be unacceptably large; in many situations such forces would be nearly doubled. There are several major reasons for such changes: a) the spectral shape, i.e. higher ratios of short to long period values and b) short period site amplification in regions of low to moderate seismicity, both of which have been discussed previously in this paper.

While dramatic increases in short period design forces could be explained, these go counter to experience during earthquakes which shows that it is very unusual for well designed short period structures to collapse, especially if they have even a limited amount of ductility capacity. As a consequence, it is being proposed that NBCC 2005 limit the design force to 2/3 of the short period maximum value for systems having $R_d \geq 1.5$, i.e. in all but the least ductile structures.

Other codes also reduce seismic loads on the basis of experience. NEHRP 2000 (Building Seismic Safety Council 2001), which also uses hazard computed at a 2% in 50 year probability of exceedance, applies a factor of 2/3 for all structures at all periods on the basis of an experience-based estimated lower bound margin against collapse of approximately 1.5 inherent in structures designed in accordance with those provisions. The 1992 New Zealand Code of Practice (Standards New Zealand 1992) includes a structural performance factor $S_p = 0.67$ in the static base shear expression; one of the arguments for this factor is that experience in past earthquakes indicates that, on average, buildings sustain less damage than would be predicted from simplified calculations.

3 IMPLICATIONS OF PROPOSED CHANGES IN SEISMIC PROVISIONS

3.1 Seismic Design Forces

Figures 1-6 present a comparison of NBCC 1995 and 2005 seismic base shear coefficients for two different structural systems (conventional construction steel moment frame and ductile reinforced concrete coupled wall) located in Toronto, Montreal and Vancouver, i.e. low, medium and high seismicity locations respectively. Figures 1-2 are for sites on the reference ground condition (very dense soil and soft rock); Figures 3-4 are for soft soil sites (shear wave velocity < 180 m/s) and Figures 5-6 are for hard rock sites. In each case, bold lines are used to show the NBCC 2005 values.

The force modification factors are $R_d = 1.5$ & 4.0 and $R_o = 1.3$ & 1.7 for the steel moment frame and the RC coupled wall respectively. Accordingly, the multiplier of 2/3 of the maximum short period value has been included in the preparation of these figures. Without that multiplier, the maximum short period values would be 50% larger than shown.

Consider first the results shown in Figures 1-2, i.e. when these structures are located on the reference site condition of very dense soil and soft rock. NBCC 2005 short period forces in the ductile RC coupled wall structure at all three locations are similar to those determined using NBCC 1995. Forces at a fundamental period of 1.0s are also similar but NBCC 2005 forces tend to be lower at long periods. For the conventional construction steel moment frame, NBCC 2005 short period forces are considerably larger in both Vancouver and Montreal, but also tend to fall below NBCC 2005 at long periods.

Figures 3-4 show clearly the effect of soft soil amplification at short periods, which is particularly pronounced in the low and moderate seismicity locations, i.e. Toronto and Montreal, even though the maximum forces have been reduced by the 2/3 multiplier. Long period amplifications are somewhat similar and show a similar trend as for structures on the reference site condition, i.e. NBCC 2005 values below the NBCC 1995 values.

Deamplification on hard rock sites can be seen in Figures 5-6, reducing the NBCC 2005 short period forces below the comparable NBCC 1995 forces for the ductile reinforced concrete coupled wall structure at all three locations. This site condition is quite common in Toronto and Montreal but not in Vancouver.

While these figures are for only two types of structural systems at three different locations, similar data for other systems and other geographical locations show that there are no general trends, i.e. design force levels changes vary with little or no apparent pattern. This variability arises largely because the geographical distribution of seismic hazard has changed markedly; however, spectral shape and site amplification or de-amplification also contribute significantly to changes in seismic design force levels.

3.2 **Seismic Level of Protection**

In this context, seismic level of protection is defined as being the protection against serious damage or collapse provided to building structures when they are designed, detailed and constructed in accordance with the seismic provisions of a code, in this case the provisions of the proposed NBCC 2005. Clearly the adequacy of the design load is a significant component of the level of protection; however, other measures such as maximum interstorey drift and the inelastic deformation capability of the structural system are also important. While all of these dimensions are important, this discussion is based primarily on the impact of the proposed changes on the seismic design load.

Changes in how seismic hazard information is presented and used are expected to have one of the most significant impacts on seismic level of protection for building structures throughout the country. The adoption of a spectral approach with calculations of uniform hazard spectral ordinates using updated seismicity and strong ground motion relations results in a geographical pattern of hazard which provides for more consistent protection throughout the country. The move to a lower probability of exceedance improves protection in eastern Canada in particular by using spectral values which consistently provide more realistic representations of ground motion levels at which severe structural distress would be expected. The use of location specific hazard values rather than zonal values with significant discontinuities at zone boundaries also improves the consistency of protection, particular in areas near former zone boundaries.

Period and intensity dependent site factors are used to modify reference spectral values to obtain design spectral values. These site modified design values are also used as input for dynamic analysis, either to form the response spectrum for modal analysis or as the target spectrum for the development of spectrum compatible time histories for the numerical integration approach. Defining site categories by using quantitative definitions (shear wave velocity, standard penetration resistance or undrained shear strength) rather than qualitative descriptions will help designers to use the appropriate site category. This overall approach to site effects serves to improve the consistency of seismic protection between sites of different characteristics.

The changes in requirements for irregular structures will also have a major impact on the seismic protection of those kinds of structures. The requirement for dynamic analysis is expected to improve the distribution of internal forces which are used to proportion and detail members. The imposition of additional design requirements, e.g. at discontinuities, is expected to ensure that the structural system will perform as expected, e.g. that systems designed to be ductile will in fact have the capability to deform inelastically to the expected ductility capacity or greater. The proposed prohibition of weak storey irregularities in all but the lowest seismicity regions should have a major impact in reducing catastrophic failures of building structures with that weakness.

The explicit recognition of dependable (i.e. minimum) overstrength in the form of an additional reduction factor enables more realistic distinctions among structural systems based on characteristics arising from design and detailing in accordance with the applicable materials standards. The increase in the overall range of force reduction (maximum to minimum) from 4.0 to 8.5 provides for a greater distinction between systems with different overall performance capabilities. In a relative sense, the design forces in more ductile systems are being reduced, recognizing that inelastic deformation capability under reversing loads is the basis for performance rather than strength alone.

Of the many other proposed changes in seismic provisions for NBCC 2005, it is not clear that any of them will, on their own, have a significant impact on the seismic level of protection, even though such changes would not have been proposed if thought not to be of significance. The move to dynamic analysis as the "default" method may, for regular structures, be of little significance in improving the level of protection, although the use of dynamic analysis for long period structures should significantly improve the distribution of internal forces. As indicated previously, the proposed 2/3 "experience factor" for short period structures with at least minimal ductility capacity is a result of broadly based considerations by members of CANCEE rather than arising from rigorous analysis. It is believed that this reduction in short period forces will not have a significant impact on the seismic level of protection. While these forces are lower than would otherwise have been computed in the static base shear formulation, in many instances they are still larger than the comparable forces determined from the NBCC 1995 formulation.

3.3 **Seismic Design Process**

The membership of CANCEE includes engineering practitioners as well as individuals in academia and government. In addition, groups of engineering designers in the more seismically active cities in the country, e.g. Vancouver and Montreal, regularly contribute to the code development process either by functioning as local subcommittees or by acting as more informal sounding boards for proposed code changes. The following comments and discussion are based on input obtained at several distinct stages during the development of these provisions as well as more recent discussions with several of the engineering practitioner members of CANCEE concerning the implications of the proposed seismic code changes on the seismic design process. The context of these comments is that, as a rule, designers do not like to see code changes, especially if they do not perceive them to be essential.

First, the proposed NBCC 2005 provisions will make the seismic design process more complex in several respects, even when the static analysis option is allowed. The location specific nature of seismic hazard means that a designer will need to determine the spectral acceleration values for each project rather than knowing the zone(s) which are applicable to the particular geographical area. The determination of the site factors F_a and F_v requires: a) testing and analysis to establish the site class and b) interpolation to determine factors associated with the location specific spectral acceleration values. The other complicating factor in the static seismic load expression is the determination of the higher mode factor, which is a function of the type of structural system, the period of the structure and the spectral shape (i.e. the ratio $S_a(0.2)/S_a(2.0)$)

There are of course both pros and cons to this additional complexity. Designers who have developed an appreciation for the nature of seismic response of structures will appreciate the reasons for using a spectral shape which is location specific and will understand the need for intensity-dependent site factors. Such knowledgeable designers will also appreciate the flexibility which goes with this additional complexity, e.g. the rewards and penalties associated with the choice of systems with different ductility capacities and the benefits of being able to compute fundamental structural periods using alternate methods. Such designers can also be expected to understand the dynamic nature of seismic response and appreciate the need for dynamic analysis in many circumstances; in many cases they will be as familiar with the nuances of dynamic analysis as with those of static analysis.

On the other hand, many designers perceive seismic design requirements as a design "hurdle", either because such requirements do not often govern actual design or because they simply do not recognize the need for seismic protection. Such designers may well find the additional complexity of the proposed NBCC 2005 provisions to be unduly onerous. However, even knowledgeable designers in the high seismicity regions have concerns about the growing complexity of code provisions. The following is a brief list of concerns arising from complexity, not necessarily in order of priority:

- The use of uniform hazard spectral ordinates does not provide the same "feel" for seismic hazard as is the case when seismic zones are used.
- The non-linear variation of site factors with spectral ordinates, including de-amplification on hard-rock sites, is puzzling in comparison with a foundation factor which is uniform for each site category and whose value increases as soil sites become softer.
- Complexity makes it difficult for a designer to detect errors since the final product, e.g. seismic design load, is dependent upon many more interrelated factors; designers may be prone to seeing the process as "number-crunching" rather than as one based on rational engineering.
- Dynamic analysis, which will be required for many more design situations, is not familiar to many designers; they may simply rely on the output of "canned" dynamic analysis options in structural analysis computer programmes without having the experience or judgment to recognize errors.

In general, the additional complexities are perceived to be justifiable for seismic design in regions of high seismicity but questionable for design in other parts of the country. Designers also have "credibility" concerns; these tend to be more common in regions of low seismicity:

- The use of the 2/3 short period factor appears to be arbitrary and not based on any recognizable rationale, even in comparison with the "calibration" factor U = 0.6 in NBCC 1995.
- Even with the above 2/3 factor in place, short period forces in regions of low seismicity are often significantly larger than in NBCC 1995; this result is often seen as not credible in areas which have never suffered a damaging earthquake, at least in the recorded history of less than 400 years.
- While the move from seismic zones to location specific values will remove the sharp changes of design load across zonal boundaries, designers tend to be sceptical of the validity of rather sharp changes in spectral acceleration values over short distances in some regions.
- The proposed severe restrictions on post-disaster buildings, e.g. prohibiting weak storey irregularity throughout the country, is perceived as "overkill" in regions of low seismicity; such a restriction would prohibit the construction of hospitals with large bottom storey openings in cities such as Winnipeg, which is located in the stable aseismic central region of the country.

While a detailed commentary is being prepared, in the author's view it is doubtful that the explanations and reasons given in such a commentary are not likely to be sufficient to overcome all of the complexity and credibility concerns. Nevertheless, it is important that every effort be made to help designers to understand why the proposed code changes are being introduced.

4 SEISMIC CODE DEVELOPMENT

The author's participation in the development of the NBCC seismic provisions since the late 1960s has stimulated thinking about the role of seismic codes and their current and future development. This part of the paper raises some of the issues which have arisen without attempting to suggest particular solutions or directions; these issue are applicable to seismic code development in other parts of the world as well.

Some information on the NBCC context may provide a useful introduction to these comments. Since it was first published in 1941 NBCC has been a model code which is maintained and developed by the NRCC. The authority for regulation rests at the provincial level, with some delegation of that responsibility to cities, towns and municipalities. The manner in which the NBCC is used as the regulatory framework varies considerable from province to province: some provinces adopt NBCC on a province-wide basis, in some provinces adoption is left to individual municipalities, some provinces adopt the NBCC with their own modifications and/or additions, and some provinces publish their own codes, which are based substantially on the NBCC.

NBCC 2005 will continue to be a model code but the format is being changed to that of an "objective-based" code. The fundamental objectives of the code (e.g. structural safety) will be stated up front followed by a number of more specific functional requirements (stated in qualitative terms) associated with each of the fundamental objectives. For example there will be functional requirements related to the reduction of the probability of structural failure and the anchorage of mechanical equipment associated with the structural safety objective. The proposed seismic requirements as discussed in this paper, which are referred to as the "seismic provisions", will remain in the code as one of the acceptable ways in which the objectives and functional requirements can be met.

4.1 **How Prescriptive?**

The seismic provisions of NBCC 1995 and previous editions have tended to be quite prescriptive with regard to aspects such as: calculation of the static seismic load, the distribution of that load with height and calculation of torsional moments. A few other aspects are handled more generally, e.g. stating that building design shall take into account the possible effects of setbacks without specifying how that should be done. The NBCC 2005 provisions, while somewhat more complex, continue that trend, including some additional prescriptive requirements, e.g. concerning the input for dynamic analysis. In NBCC 1995, the commentary includes a recommended approach for certain matters on which the code is non-prescriptive, e.g. for determining P-Delta effects. The NBCC 2005 commentary has not yet been completed but the plan is for it to concentrate on providing technical background (e.g. on seismic hazard and site amplification) and explaining reasons for the various code provisions rather than to be recommending specific technical solutions. It is not clear that the movement to an objective-based code has had or will have a particular steering direction. The steering is likely to come from regulatory bodies (e.g. those who approve building plans on behalf of a municipality are likely to prefer more prescriptive provisions because it is easier to check whether a design meets code requirements) and from design engineers (e.g. knowledgeable designers are likely to prefer less prescriptive provisions so that they have more flexibility in choosing how to meet stated performance requirements). In theory, the objective-based code approach should satisfy both ends of the spectrum by providing a more prescriptive alternative for those who prefer that route and by allowing other technical solutions which meet stated objectives and functional requirements.

4.2 **Performance Expectations**

Traditionally, performance expectations associated with use of NBCC seismic provisions have not been included in the code and are only stated in very general terms in the commentary. The expected performance of structural systems with different levels of ductility capacity when subjected to the design ground motions may be implicit for those involved in developing the code and a few very knowledgeable designers. One can understand the reluctance of codes to state performance expectations explicitly, given the possibility or even likelihood that these could in the future be the basis for litigation. Performance-based engineering approaches, e.g. such as developed by the Structural Engineers Association of California (Vision 2000 Committee 1995) have gained prominence in seismic design and it is likely that codes will need to reflect that trend, which includes more explicit performance objectives than is the case in the current and planned NBCC seismic provisions. The NBCC 2005 specification of seismic hazard at the 2% in 50 year probability level and the inclusion of an overstrength-related force reduction factor provides a fairly clear, albeit still somewhat implicit, understanding that these seismic provisions are associated with near-collapse performance.

4.3 **Serviceability**

The primary objective of the current and proposed NBCC seismic provisions is safety, i.e. the reduction of the loss of life through prevention of serious damage or collapse of building structures.

While serviceability is included in the broad objectives of building design, earthquakes are treated as rare events so the code provisions do not include serviceability limit state requirements for seismic loading. This is in marked contrast to other codes, e.g. the 1992 New Zealand Code (Standards New Zealand 1992) which include specific serviceability limit state design requirements.

While serviceability is not an explicit objective in the NBCC seismic provisions, it should be noted that it is recognized implicitly in several respects. First, the use of interstorey drift limits, while applied to deflections computed at the design load level, have a significant role in ensuring serviceability at lower loads, i.e. associated with ground motions at higher probabilities of exceedance. Second, for post-disaster buildings, the significantly lower drift limit (i.e. 1% of interstorey height) is intended to permit such buildings to remain functional during and after design level ground motions. Nevertheless, the need and desirability for more explicit serviceability requirements for all buildings is a matter of ongoing discussion.

5 CONCLUSIONS

The changes being proposed for the next edition of the NBCC are substantial and should, if used effectively, provide for an improved and more consistent seismic level of protection. However, these changes will make seismic design significantly more complex, which could have a negative effect because the less knowledgeable designers may not use its provisions appropriately; designers in regions of low to moderate seismicity are likely to view this additional complexity as unwarranted. The development of the NBCC 2005 provisions has raised certain issues, e.g. complexity, prescriptiveness, and performance objectives, which are of ongoing concern in the development of seismic codes, whether in Canada or elsewhere in the world.

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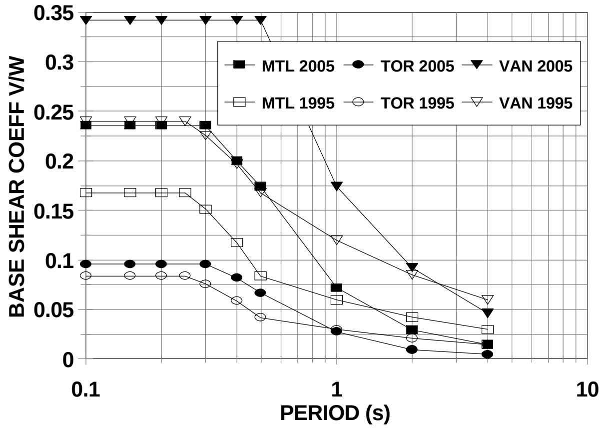

Figure 1 Conventional Construction Steel Moment Frame on Very Dense Soil and Soft Rock

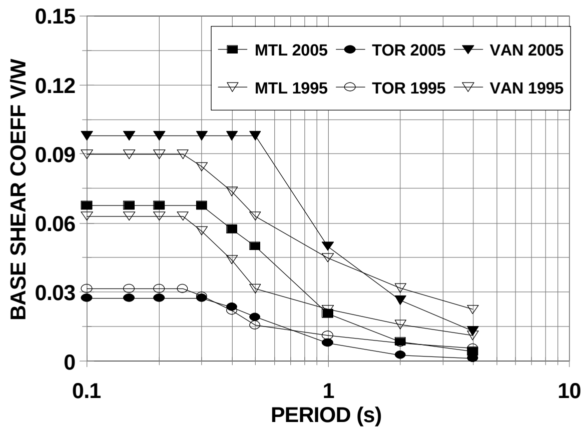

Figure 2 Ductile Reinforced Concrete Coupled Wall on Very Dense Soil and Soft Rock

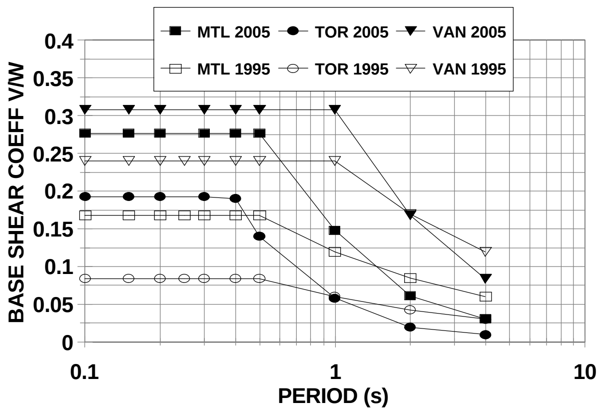

Figure 3 Conventional Construction Steel Moment Frame on Soft Soil

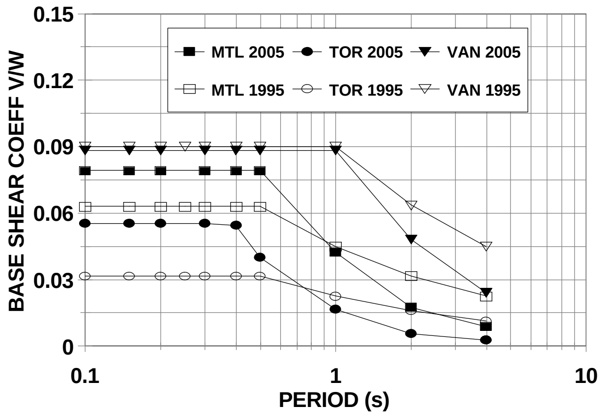

Figure 4 Ductile Reinforced Concrete Coupled Wall on Soft Soil

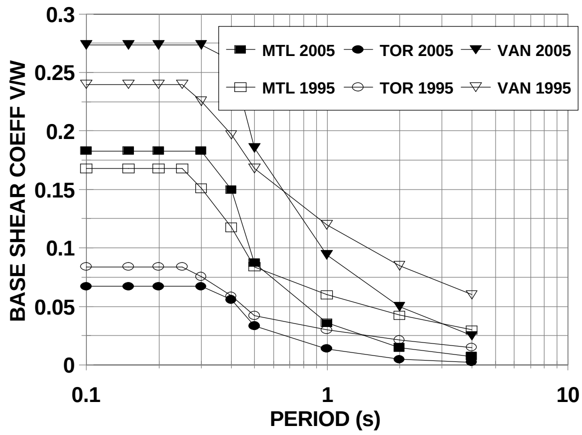

Figure 5 Conventional Construction Steel Moment Frame on Hard Rock

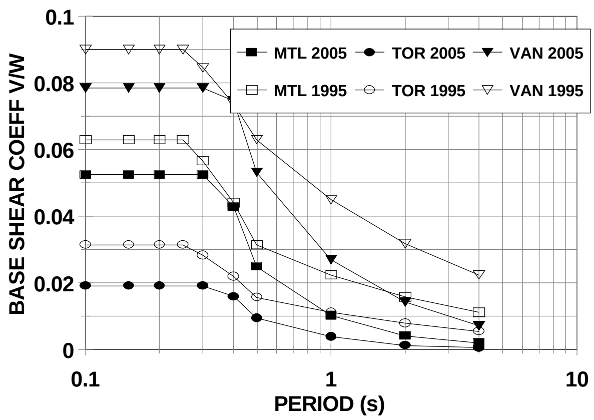

Figure 6 Ductile Reinforced Concrete Coupled Wall on Hard Rock