B: Canadian Code System

B1 :BCBC 2012 Part4 or NBCC 2010 Part-4 Structural Design subsection 4.1.8 earthquake load and effects

This seismic design code is primarily for the design of new buildings the evaluation and upgrading of existing buildings. This seismic design code is based on elastic spectrum and ductility, 2% probability of exceedance of earthquake within a 50 year period. At present this code is the basic seismic design code in Canada.

B2: NBC 2010 Structural Commentary J:Design for seismic effects

This document provides commentary to NBCC 2010 part-4 subsection 4.1.8 earthquake load and effects

B3 NBC 2010 Structural Commentary L:Application of NBC part 4 for the structural evaluation and upgrading of existing buildings This commentary addresses the principles of structural evaluation and upgrading of existing buildings, not newly constructed structure or addition, to achieve an appropriate level of performance complying to NBCC 2010 part 4.

BESI' Comments: Basically this commentary is based on the code for new structures, not based on performance based methodology, therefore it maybe not suitable seismic retrofit code for existing buildings.

B4: J.H.Rainer,D.E.Allen and A.M. Jablonski, Manual for screening of buildings for seismic investigation. Institute for Research in Construction, National Research Council Canada, Ottawa,1992,NRCC 36943.This document is the tool to help property managers to determine which buildings need an engineering evaluation and rank them with respect to their need for attention. The method is based on an about one hour rapid inspection.

B5: D.E.Allen,J.H.Rainer and A.M.Jablonski, Guideline for the seismic evaluation of existing buildings. Institute for research in construction, NRCC, Ottawa, 1992, NRCC36941.This document provides the means of conducting consistent and cost-effective engineering evaluations of all buildings except Part- 9 small buildings.

The seismic base shear of the existing building after the seismic loading condition is changed can be determined in accordance to BCBC 2012 Part 4 sec.4.1.8. When the calculations show that the existing building SFRS is not able to withstand 60% of the above seismic load, it should be upgraded.

Appendix of C of this guideline provides a master list of 123 potential deficiencies

BESI' Comments: This guideline is based on the code of new building design to evaluate existing buildings, code of new building design to evaluate existing buildings, it maybe not suitable for some instances, using ASCE41(=FEMA356) may be more competitive.

After the seismic loading condition of existing buildings is changed, to determine the seismic load, engineers may assume the existing building SFRS belongs to conventional construction, i.e. RdR0=1.5*1.3=2; it may be not difficult to find an evidence from the existing building SFRS to prove it is not ductile, belongs to conventional construction. Typically existing buildings were designed with low ductility, assuming existing buildings belong to conventional construction may be acceptable. If evidence shows the existing building SFRS is ductile, how to determine the RdRo? See Technical Discussions-design question -1.

B6 D.E.Allen, Guideline for Seismic Upgrading of building structures, Institute for research in construction, NRCC, Ottawa, 1995, NRCC38857.This document describes various seismic retrofits and provides guidance on making the right choices for specific projects. The reduced seismic load (60%) in evaluation should be considered suitable as a triggering criterion to seismic upgrading, for design of the upgrading, seismic load should not be reduced. The seismic base shear for upgrading existing SFRS after the retrofit solution is incorporated can be determined in accordance to BCBC 2012 Part 4.

Appendix A of this guideline provides a checklist of seismic upgrading techniques.

BESI' Comments: After the retrofit solution is incorporated, to determine the seismic load, engineers may assume the retrofitted SFRS belongs to conventional construction, i.e. RdRo=2. If retrofit objective is to retrofit the existing SFRS ductile, then how would you determine the RdRo? See Technical Discussions design question-2.

The choice of techniques for seismic upgrading depends on seismic deficiencies. Appendix C of the Guideline for seismic evaluation provides a master list of 123 potential deficiencies. Various retrofit solutions require engineers make right choice for specific projects. Most of the retrofits **are conventional retrofit techniques** including:

- reinforcing existing SFRS, such as overlays, in fills
- building new sub-systems such as shear walls, bracing systems or additional foundation elements, and connecting them to existing SFRS
- placing connectors between existing structural components
- anchoring masonry and other heavy components to the building structure.

Special retrofit techniques include using **base isolation system** and using **Energy dissipation system.**

Using energy dissipation system such as friction damped brace and buckling - restrained brace is appropriate for relatively flexible moment frame seismic retrofit. One of the principal benefits of this type of retrofit is avoidance of the need for foundation upgrading. BCBC 2012 PART 4 has not addressed the seismic design provisions for special seismic retrofit techniques; NBC 2010 Structural Commentary J has addressed that the non-linear dynamic response procedure using a structural analysis computer program such as SAP2000 shall be carried out when special retrofit techniques are selected; a manual calculation method (equivalent static procedure) for special retrofit techniques addressed by American seismic retrofit pre-standard of existing buildings , such as ASCE 41-13, may be used, see American Code System.

Special retrofit techniques are also applicable to new buildings seismic design, therefore American new buildings seismic design code such as FEMA 450 2003 edition, chapter 13 and chapter 15 has addressed seismic design provisions for base isolation system and energy dissipation system as well, see American Code System.

BESI' Comments :(1) The difficulty of using American seismic design code for a Canadian project is to determine the equivalent seismic hazard between the two code systems. In regions outside the USA, where the regulatory requirements for determining design ground motion differ from the ASCE 7 methods, the following method may be utilized:

(refer to API 650 Appendix E)

Canadian code provides the peak ground acceleration, PGA, based on 2% probability of exceedance within a 50-year period, then the following substitution shall apply: ***SS = 2.5 PGA*** ***S1 = 1.25 PGA***

SS is the mapped, maximum considered earthquake, 5% damped, spectral response acceleration parameter at a period of 0.2 second, as per ASCE 7.

S1 is the mapped, maximum considered earthquake, 5% damped, spectral response acceleration parameter at a period of 1 second, as per ASCE 7.

(2)It is not easy to fully understand seismic design provisions of special seismic techniques such as base isolation system and energy dissipation system in FEMA 356 or 450.

A Canadian code based article below recommends preliminarily a seismic static design method for displacement dependent energy dissipation system may be easier to use, see B7

B7: D.L.Anderson, R.H.Devall,R.J.Loeffler,C.E.Ventura. **Preliminary 'Guidelines' for non-linear analysys and design of hysteretic** (displacement dependent) energy dissipation devices in buildings, 1999.

This article using Canadian seismic code recommends design method for displacement dependent energy dissipation system. This system is assumed to be equivalent to ductile tension-compression CBF with Rd=5, Ro=0.(CBF is concentrated braced frame.)

Besi' Comments:

(1)Inelastic structural behaviour dissipates seismic energy, as a consequence, the design lateral seismic forces are reduced, the NBC accounts for this by the force modification factors RdR0. Supplemental damping devices, when appropriately installed to an elastic structure, allow seismic design to be shifted from the conventional reliance on ductilityof the main structural elements to energy dissipation in the added devices. Therefore, adding supplemental damping devices can be equivalent to increasing the damping ratio

of the elastic structure with equivalent stiffness.

(2)For special seismic resistance technologies, American seismic design code FEMA 356 or 450 bases the seismic load calculation on equivalent damping ratio, not ductility,

this article bases seismic load calculation on ductility, its study is not extensive amount yet, therefore this recommended method is only for preliminary design.

B8: BC Ministry of Education, APEGBC, UBC , Bridging guidelines for the performance-based seismic retrofit of BC school buildings, 1st edition, 2005, in conjunction with NBCC2005

These guidelines are for low-rise BC school buildings of 1-3 storeys in height above the basement where applicable. These provisions use performance based criteria, which ranges from collapse prevention, limited safety structure, life safety to immediate occupancy.

BESI' Comments:

(1)BCBC 2012 PART 4 sec. 4.1.8 is for new buildings seismic design, may be not suitable for existing buildings seismic retrofit design, using this code to retrofit   may result in too

conservative/costly design. (it's not an issue of being correct or wrong, but an issue of being ideal or not ideal, competitive or not competitive.)

(2)new buildings seismic design code is based on collapse prevention only(for normal buildings), its drift control criteria is too comprehensive for various SFRS and material, not wide ennough or specific

enough to satisfy BC school building seismic retrofit requirements. This BC school building retrofit guidelines broaden the seismic design criteria based on 4 performance

level which has a considerable amount of prototype experiment background of various SFRS and building material.

(3)Using this guidelines may get a cost efficient retrofit design, but the application is limited to BC 1-3 storey school buildings only.

(4)This guideline is not completely same as ASCE 41 in methodology, but same in performance based retrofit concept, so this guideline is an alternative performance based seismic retrofit code.