BC BUILDING CODE INTERPRETATION COMMITTEE

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AIBC, EGBC, BOABC

File No: 18-0304 **INTERPRETATION**

Interpretation Date:	February 13, 2024
Building Code Edition:	BC Building Code 2018
Subject:	Seismic Force Resisting Systems (SFRS)
Keywords:	seismic, force, resisting, systems, SFRS
Building Code Reference(s):	4.1.8.9.(1) & (4), Table 4.1.8.9.

Question:

When using Table 4.1.8.9. for Seismic Force Resisting Systems (SFRS):

1. Does a sloping site affect the measurement of the maximum height of an SFRS?
2. When a building contains a sloping roof, is the maximum height of an SFRS measured to the uppermost roof surface?
3. When a building's SFRS consists of multiple vertically varying systems (e.g. a 5-storey wood frame structure on top of a 1 storey concrete podium), does Sentence 4.1.8.9.(4) limit the overall SFRS height to that of the system with the larger RdRo ratio?

Interpretation:

1. No.

For the purposes of calculating building height when using Table 4.1.8.9., grade is defined in Division A, Article 1.4.1.2. as the lowest of the average levels of finished ground adjoining each exterior wall of the building.

First storey is defined in Division A, Article 1.4.1.2. as the uppermost storey having its floor level not more than 2m above grade.

Building height is defined in Division A, Article 1.4.1.2. as the number of storeys contained between the roof and the first storey.

Refer to Item 153 below from the Structural Commentary for further clarification.

Patrick Shek, P.Eng., CP, FEC, Committee Chair

Determining the Number of Storeys for the Purpose of NBC Sentences 4.1.8.10.(4), 4.1.8.11.(12) and 4.1.8.12.(12)

153. NBC Sentences 4.1.8.10.(4), 4.1.8.11.(12) and 4.1.8.12.(12) apply to buildings constructed with more than 4 storeys of continuous wood construction up to a maximum of 6 storeys. For the purpose of determining the number of storeys for the application of these Sentences, all storeys of continuous wood construction above the base need to be considered, including any full or partial storeys of wood construction below the first storey, and wood cripple walls (sometimes referred to as knee walls or pony walls) are to be considered as a full storey. Many factors can affect the location of the base, including the slope and location of the grade, the location and stiffness of the SFRS elements, openings in basement walls, and the proximity to adjacent buildings. Additional information on determining the location of the base can be found in ASCE/SEI 7. Unless the subdivided portions of a building are separated in accordance with the requirements of NBC Article 4.1.8.14., a building subdivided with firewalls is considered as one building for the purpose of determining the number of storeys in the application of the above-noted Sentences. See Figure J-21 for examples of 5-storey buildings.

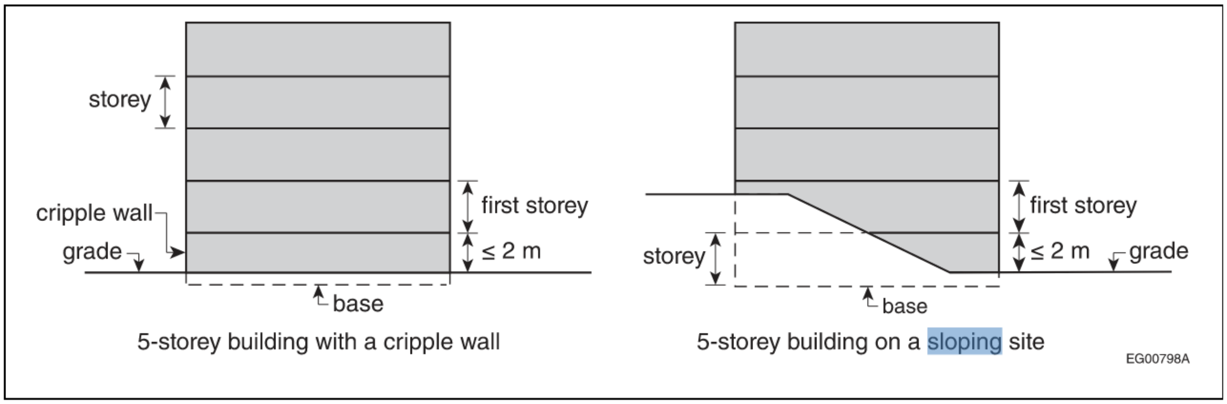

Figure J-21
Examples of 5-storey buildings for the purposes of NBC Sentences 4.1.8.10.(4), 4.1.8.11.(12) and 4.1.8.12.(12)

2. No.

The maximum height of an SFRS is measured to the top of the vertical seismic resisting structural elements, which would typically be the uppermost height of the shear walls. If the uppermost storey has a horizontal ceiling, it would be the height of the uppermost ceiling.

Patrick Shek, P.Eng., CP, FEC, Committee Chair

3. Various Options are Available.

   Items 142 to 145 of 2015 NBCC Structural Commentary J describe how to deal with superimposed structures that have variable RdRo. It should be noted that the "DRAFT" version of the 2020 NBCC Structural Commentary J appears to have deleted Item 145.

Commentary J

NBC Sentence 4.1.8.9.(4)

142. A building may also incorporate different types of SFRSs along its height. For example, a ductile steel or concrete moment-resisting frame with a high R_dR_o value may be used in the upper tower part of a building, and a limited-ductility wall or braced frame system with a lower R_dR_o value may be used in the lower podium part of the building.

143. The provisions of NBC Sentence 4.1.8.9.(4) relating to vertical variations of R_dR_o along the height of a building were introduced to provide a practical design approach for cases where maintaining a constant R_dR_o value would be impractical and unnecessary for achieving good structural behaviour in an earthquake. The following are examples of such cases:
- (a) a ductile SFRS supported on a non-ductile foundation, which must be designed to have factored shear and overturning resistances that are greater than the lateral load capacity of the supported SFRS, in accordance with NBC Sentence 4.1.8.16.(2);
- (b) a ductile above-grade SFRS over a strong and stiff below-grade structure surrounded by walls;
- (c) a tall ductile structure over a low above-grade podium, particularly a podium that contains additional walls and lateral elements; and
- (d) a ductile wood-frame shear wall structure over a stiff, limited-ductility one- or two-storey concrete structure.

144. It is not appropriate simply to take a load distribution determined by a linear static or dynamic analysis based on an R_dR_o value of 1.0, to divide the upper storey loads in the distribution by the larger R_dR_o value, and to divide the lower storey loads in the distribution by the smaller R_dR_o value. In general, a non-linear analysis is required. However, simple, approximate and conservative linear approaches for two special cases are outlined in the following:
- (1) For regular structures where the change in R_dR_o is near grade, analyze the entire structure using the ESFP or the Modal Response Spectrum Method for the forces calculated using both values of R_dR_o, design the upper part of the structure for the forces calculated using the larger R_dR_o value, and design the lower part of the structure for the larger of
  - (a) the forces from the entire structure calculated using the smaller R_dR_o value, and
  - (b) the forces related to the lateral capacity of the upper part of the structure.
- (2) For structures described in case (d) in Paragraph 143 for which the stiffness of the storey(s) in the lower structure is greater than three times that of each of the storeys in the upper structure:
  - (a) follow approach 1(a), but use the Modal Response Spectrum Method for analysis; or
  - (b) where permitted, use the ESFP; idealize the upper structure as a separate building with a fixed base starting at the top of the lower structure and with a period appropriate for its height; analyze this building for the forces calculated using the larger R_dR_o value; idealize the lower structure as a separate short building with a period appropriate for its height; analyze this short building for the forces calculated using the smaller R_dR_o value with the addition of the forces generated by applying the lateral capacity calculated at the base of the upper structure as a load to the top of the lower structure.

145. In both of these special cases, the design forces need not exceed those calculated using an R_dR_o value of 1.3, but a weak storey is not permitted.

For all structures with vertical variations of R_dR_o, the total height of the structure must not exceed the limit for the larger R_dR_o value, and the height of the lower portion of the structure must not exceed the limit for the smaller R_dR_o value.

Patrick Shek, P.Eng., CP, FEC, Committee Chair

For a 5-storey wood frame structure over top of a 1 storey concrete podium, common practice is to measure the height of the wood frame portion from the top of the concrete podium. This is clarified in ASCE-22 as indicated below:

ASCE 7-22 is more specific regarding two-stage analysis for vertical combination of LFRS:

1) For the purpose of establishing that the stiffness of the lower part is more than 10 times the stiffness of the upper part, it is permitted to calculate the stiffness of each portion of the structure as the ratio of the base shear determined from Equivalent Lateral Force (ELF) to the elastic displacement δ_e computed at the top of that portion of the structure.
2) The structural height of the upper portion should not exceed the height limits for the SFRS of the upper portion, where the height is measured from the base of the upper portion.

Patrick Shek, P.Eng., CP, FEC, Committee Chair