DQ-58 – C78

Date : 7 février 2007

QUESTION

Dans un avis daté du 24 janvier 2007, Ressources naturelles Canada signale à la commission que « *toutes les questions d'ordre sismique soulevées par Ressources naturelles Canada ont été traitées de façon satisfaisante par le promoteur, sauf pour un point technique dans l'étude sismique locale qui reste en suspens où notre expert demande plus de détails quant à la justification des valeurs d'amplification utilisées et pourquoi ces valeurs sont différentes de celles fournies antérieurement ».* Pouvez-vous fournir à la commission cette justification?

RÉPONSE

La réponse de l'expert sismologue, Gail Atkinson, est jointe. Même si elle est datée du 4 décembre 2006, nous avons malencontreusement omis de l'acheminer à Ressources naturelles Canada (audiences du BAPE en cours avant ce jour). Nous avons conservé cette réponse dans sa version originale anglaise, comme c'est le cas de l'ensemble des rapports déposés sur ce sujet.

En résumé, notre expert préconise l'utilisation d'une méthode plus récente d'évaluation des facteurs d'amplification des sols (Atkinson and Boore - 2006). Cette méthode permet une évaluation plus précise que la méthode utilisée précédemment (Adams and Halchuk - 2003) notamment dans le Code national du bâtiment (2005).

Justification for site amplification values used in the Rabaska project to convert Class A results to results for NEHRP B/C boundary

Gail Atkinson, Dec. 4, 2006.

The Rabaska seismic hazard estimates are performed for Site Class A (hard rock), and converted to equivalent results for NEHRP B/C, as described in the following.

Extract from: « Earthquake hazard analysis - Rabaska LNG facilities, Québec »
Preliminary report – Gail Atkinson – September 2006

Conversion of Results from NEHRP A to NEHRP B/C

The seismic hazard computations were performed for hard-rock site conditions (NEHRP A, with near-surface shear-wave velocities > 1500 m/s), as most of the ENA ground-motion relations are only available for this site condition. The recent relations of Atkinson and Boore (2005) are provided as separate equations for two site conditions: hard-rock (NEHRP A) and the NEHRP B/C boundary (shear-wave velocity 760 m/s). By taking the ratio of the response spectra for NEHRP B/C to that for NEHRP A, the dependence of the site amplification on magnitude and distance may be evaluated. This is shown in Figure 12. The site amplification has a weak dependence on distance and magnitude, except for PGA, for which the distance dependence is strong. (This is a consequence of the changing frequency content of PGA with distance.)

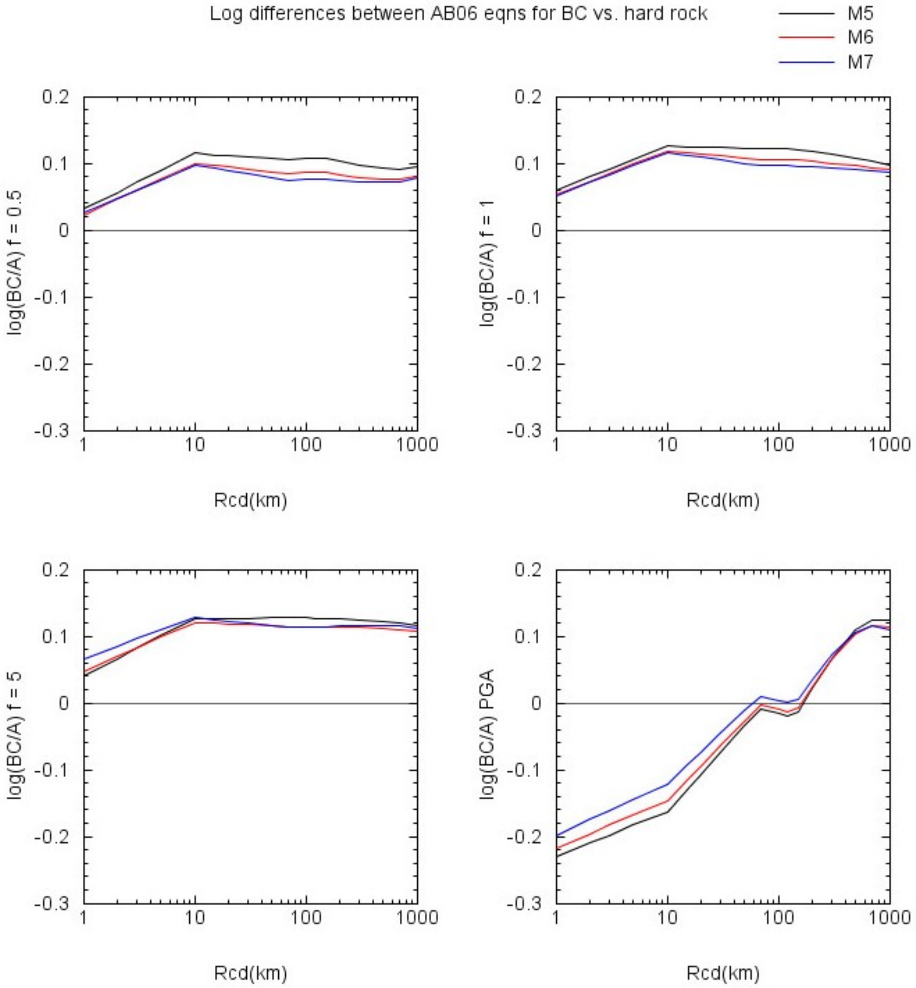

Figure 12 – Log$_{10}$ of the ratio of predicted ground motions for NEHRP BC boundary (760 m/s) to that for NEHRP A (>1500 m/s), based on Atkinson and Boore (2005). Ratio is shown for frequencies of 0.5, 1 and 5 Hz, and for PGA, for magnitudes 5, 6 and 7, as a function of closest distance to the fault.

To accurately model the implications of the site amplification, it is best to perform the seismic hazard analysis directly for the site conditions of interest. Since this can only be done for the AB05 relations (as the others are not available for B/C boundary), the following approach is adopted. The hazard is calculated at Rabaska, using Model A and the AB05 ground-motion relations, for both NEHRP A and B/C boundary. We then take the ratio of the calculated UHS ground motion, at several probability levels covering the complete range of interest, to determine the net effect of the site amplification at Rabaska on the UHS. As shown on Figure 13, the amplification factor depends only weakly on the probability of the ground motion. A smoothed curve that is a good representation of the amplification for all probabilities of interest is therefore adopted as the B/C amplification factor (black line on Figure 13). This function results in amplification, by as much as a factor of 1.4, over most frequencies. At very high frequencies (>10 Hz), and for PGA, there is actually a de-amplification (factor<1), due to the high-frequency energy absorption of the softer rock materials in the near surface.

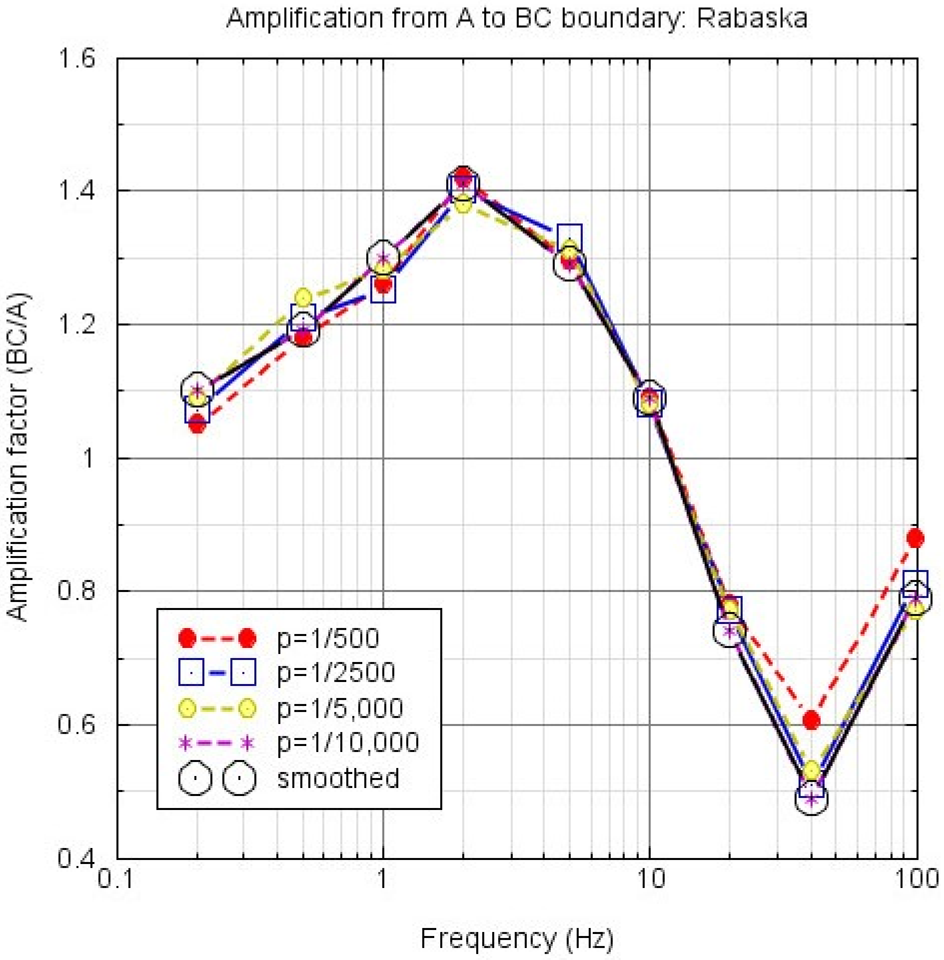

Figure 13 – Factors to convert hazard results for hard rock (NEHRP A) to results for B/C boundary, as calculated from the ratio of results for the AB05 relations for hard rock to the results for the AB05 relations for B/C boundary (under Model A). The smoothed valued (black dots) are adopted to convert the results for all models, over a wide range of probabilities.

To provide UHS results for the B/C boundary conditions on which the tanks will be situated, all UHS results computed for NEHRP A are multiplied by the smoothed factors shown in Figure 13, and listed in Table 1. For facilities to be located on soil, the B/C motions need to be further amplified for the overlying soils, based on a site-specific soil response analysis.

Table 1 – Amplification Factors at Rabaska for UHS ground-motions for B/C boundary, relative to computed results for NEHRP A.

Frequency (Hz)	Amplification Factor (BC/A)
0.2	1.1
0.5	1.2
1.0	1.3
2.0	1.4
5.0	1.35
10.	1.1
20.	0.8
40.	0.6
PGA	0.9

End of Extract

Justification of Approach

This approach differs from that used to develop "RGC factors" by Adams and Halchuk (2003) for the 2005 National Building Code, in that it is more comprehensive and specific. The earlier RGC values for the NBCC A to C conversion were derived using a combination of simplified assumptions based on the quarter-wavelength method, combined with the 1993 work by Boore, Joyner and Fumal on the dependence of site conditions on shear wave velocity. In the development of earlier ground motion relations (Atkinson and Boore, 1995), the amplification for ENA hard rock sites was neglected, and assumed it could be taken =1. Thus the RGC factor was defined to include all of the amplification expected to go from the mid-crust (velocity of 3.7 km/s) to a site condition of NEHRP C, around 600 m/s. This implies a large amount of amplification (up to a factor of$\sqrt{(3700/600)}$ = 2.5, neglecting kappa effects that should act to reduce these values at high frequencies).

In more recent work, Atkinson and Boore (2006) wanted to simulate not just hard rock, but also equations for B/C boundary, as this has become an important reference level in both hazard mapping in the US, and in site response studies (much recent site response research is geared to what happens relative to B/C boundary). Their simulations used the quarter-wavelength method, combined with information from H/V for ENA hard rock sites, to develop an amplification function for hard rock sites, and a separate function for B/C boundary. Simulations were performed separately for the 2 cases to better define the amplification effects on response spectra considering both the quarter-wavelength amplifications and the counter-acting reductions due to kappa effects at high frequencies.

By comparing the ground-motion predictions for the 2 site conditions, one can more accurately determine the difference between A and B/C (as shown in the report). The reason that separate equations for the 2 conditions are needed is that the scaling is not strictly linear (especially for PGA and PGV) due to frequency content issues. The new approach is methodologically more correct and less ad-hoc than what has been done previously, and provides our current best information on amplification effects.

It is reasonable to ask: why are the amplification factors that result significantly lower than those used in Adams and Halchuk (2003) to go from NEHRP A to C? There are three significant factors that account for the discrepancy. One is that in 1995 we assumed hard rock amps = 1, whereas we now believe that hard rock amps increase with frequency from about 1 at low frequency, to about 1.4 at high frequency. Thus the relative amplification of A to C would be off by a factor of 1.4 (relative to previous estimates). The second factor is that we are looking at B/C, not C. The factor from A to B/C is less than that from A to C. This can also be seen as an effect in the recent PEER NGA relations - they are all for B/C, and show lower amplitudes than previous California relations for C (at all magnitudes). The third change is the methodology, the tightening of which may have reduced the compounding of factors. The overall effect is that we do not expect that much amplification from ENA hard rock to softer ENA rock. I believe this finding is consistent with what we see on seismographic sites (harder rock and softer rock sites, or even good hard till sites, are fairly similar).