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# Combining ambient noise Measurement with 1D numerical ground Modelling to constrain Site Effects in the Brussels-Capital Region, Belgium

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It is now well established that the seismic risk in densely populated areas is high even where the seismic hazard is low to moderate, as it is the case for the Brussels-Capital Region. Previous earthquakes, as the 1692 Verviers earthquake (M= 6 – 6 $^1/_4$) and the 1938 Oudenaarde earthquake ($M_s$ = 5.0) has caused damage (intensity VI to VII) all over the Brussels area, especially on chimneys and ornamental structures on facades.

Moreover, regarding to the local geologic conditions, the area of Brussels is prone to site effects with a sharp impedance contrast between unconsolidated Tertiary sediments and the underlying Paleozoic hard rock. The thickness of the unconsolidated sediments varies from less than 50 meters in the south to more than 150 meters at the higher elevated areas in the north.

To constrain the variation of the resonance frequency of the subsoil, we conducted 163 H/V ambient noise measurements. For the determination of spectral amplitudes, a 1D numerical ground modelling was performed to obtain the transfer functions of the subsoil based on the reflectivity method of Kennett (1983).

The H/V measurements gave predominantly very good results with one clear peak indicating a sharp impedance contrast. The spectral H/V frequency varies from 0.7 Hz at the higher elevated areas and in the north to 1.2 in the Senne Valley (centre of Brussels) to more than 1.5 Hz in the south of Brussels.

Because we located some of the ambient noise measurements as much as possible close to borings with good descriptions, we were able to retrieve useful relationships between the thickness of the entire unconsolidated layer, the H/V resonance frequency and the mean shear wave velocity.

Another equation was developed to calculate the shear wave velocity for each known layer of the unconsolidated sediments separately by using the mean cone resistance from CPT, the density and vertical effective stress of each layer. The validation of this equation was done by comparing the resulting fundamental frequency of the ambient noise measurements with the one obtained by the numerical ground modelling.

To evaluate the quality factor Q, the spectral slope method was applied. The seismic station at Uccle disposes of a seismometer at a depth of 140 meters in the bedrock and a second one was only recently installed at the surface for this project. From an explosion in the North Sea with $M_L$ 2.1, we calculated a mean quality factor of 9, which was in the line of expectations.

After the parameterisation, we considered two models, a 1-layer model and a multi-layer model (with 11 unconsolidated layers), to calculate the transfer functions for a grid of 220 $km^2$ with a spacing of 200 meters (1-layer model) and for a grid of 21 $km^2$ in the centre of Brussels with 100 meter spacing (multi-layer model). The two models give very similar results for the fundamental frequency and are also in good accordance with the results of the ambient noise measurements, although the resolution of the numerical modeling is much better. The amplitudes of the first mode are a bit higher in the Senne Valley in the centre and the South of Brussels and they vary from 4 to 5 for the 1-layer model and are one entity higher for the multi-layer model. Preliminary calculations of earthquake scenarios, through convolution of these transfer functions with real and synthetic earthquake signals, reveal that the PGA can be amplified with 1.5 to 3.5 times the PGA expected on bedrock. This depends largely on the spectral characteristics of the earthquake signals.