Influence of the local geology on amplitude, duration and frequency content of the earthquake ground motion in the Lower Rhine Embayment

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Introduction

Seismic activity in the Lower Rhine Embayment (LRE) between Cologne, Bonn, Düren, Jülich and Aachen belongs to the highest in Europe north of the Alps.
In this shallow sedimentary basin site-effects are important for accurate seismic hazard analysis. The primary goal of this Ph.D. project is to examine the influence of the local geology on amplitude, duration and frequency content of earthquake ground motion. Of particular interest is the nonlinear behavior of the unconsolidated sediments. In a first step a geological model of the sedimentary layers of the LRE is developed. From this model virtual boreholes with a spacing of 2x2 km are extracted. Shear wave velocity, density and damping parameters are assigned to the lithological units. These data are used for calculation of 1D S-wave amplification with a randomized version of SHAKE91 to consider the influence of the uncertainty of input parameters. The results will be verified with the measured data of a magnitude 5 earthquake from 22.07.2002 near Aachen. Maps of fundamental frequency and frequency dependent amplification for appropriate levels of groundmotion for the LRE will be created. These results will be incorporated into ongoing research of seismic hazard of the region.

Geological Model

The LRE is a shallow sediment basin with sediment thickness up to 1500 m in the area under investigation. It is broken in several blocks through NW-SE striking faults (Fig.1).

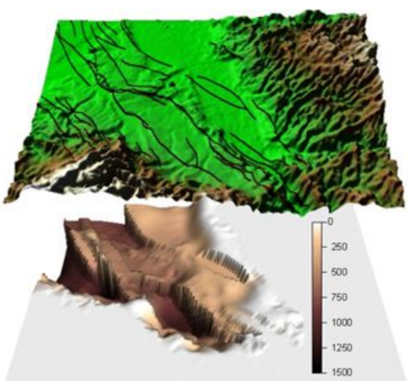

Fig. 1: The upper map shows the topography with faults of the LRE. The lower map presents the sediment thickness.

The geological model is based on the hydrogeological A-3 maps from Breddin (1960). These maps contain profiles with a spacing of 2 km and reach depths of 200 m. In addition, boreholes and profiles from RWE POWER AG and boreholes from the database of the Geological Survey NRW have been used. The program GSI3D, developed by H. Sobisch (2004) is used to create a geological fence model of the LRE (Fig. 2 and 3). Virtual boreholes with a spacing of 2 km are extracted from this fence model.

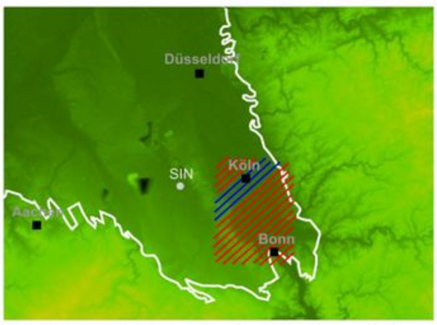

Fig. 2: DEM of the LRE. Red lines show the actual worked on profile lines. The blue lines mark the profiles in Fig. 3. The white line represents the border of the bedrock and is equal to the area under investigation.

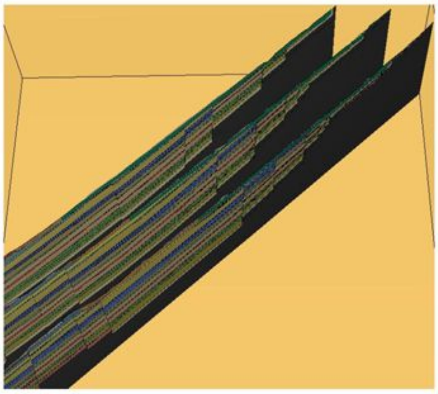

Fig. 3: 3D-View of the profiles (shown in Fig. 2) in GSI3D. The colored layers are loose sediments. The grey area represents the bedrock.

Dynamic Soil Properties

The velocity and density data measured by Budny (1984) was used to derive generalized depth dependent relations between shearwave velocity v_S, density ρ and geological parameters (material and depth z):

- Sand: $v_S=161\ (1+z)^{0.27}$ m/s $\rho=1800+69Ln(z)$ kg/m³
- Gravel: $v_S=160\ (1+z)^{0.28}$ m/s $\rho=1800+52Ln(z)$ kg/m³
- Clay: $v_S=203(1+z)^{0.17}$ m/s $\rho=1800+55Ln(z)$ kg/m³
- Lign. Coal: $v_S=71\ (1+z)^{0.31}$ m/s $\rho=1200+76Ln(z)$ kg/m³
- Loam: $v_S=187\ (1+z)^{0.21}$ m/s $\rho=1900$ kg/m³
- Silt: $v_S=216\ (1+z)^{0.17}$ m/s $\rho=1800+61Ln(z)$ kg/m³

To consider the influence of the uncertainty of input parameters the values for velocity and density are randomized in a 2σ–band of the residues in percent of the above fits (Fig. 4). These randomized velocities and densities are assigned to the geological units and for each virtual borehole 500 randomized soilprofiles are generated.

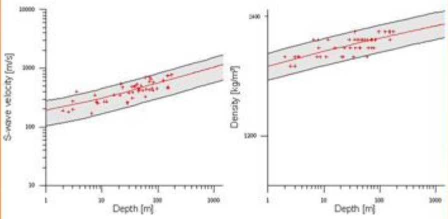

Fig. 4: Red crosses mark the velocity (left) and density values (right) for sand measured by Budny (1984). Red lines shows the fits for sand. Grey band represents the 2σ-range in which the random velocities and densities are generated.

The curves for the dependency between shearmoduli and damping on shearstrain are also random generated. The boundaries are defined through the extrem values of the different lithological compositions of the sediments. For example the randomized curves for sand are bounded through the curves from clayey and gravelly sand as shown in Figure 5.

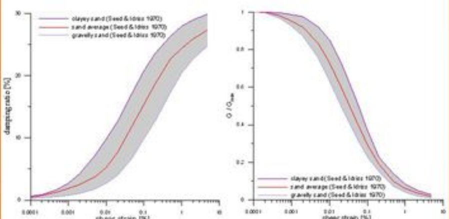

Fig. 5: Shearmoduli and damping curves for clayey sand, average sand and gravelly sand. The grey band defines the range for the randomized curves.

Transfer Functions

The transfer functions are calculated with a modified version of SHAKE91. For each virtual borehole 500 calculations with different dynamic soil parameters are progressed. The 0.16-, 0.84-fractile and the median is calculated. Figure 6 shows the transfer function of the blue soilprofile in Figure 7.

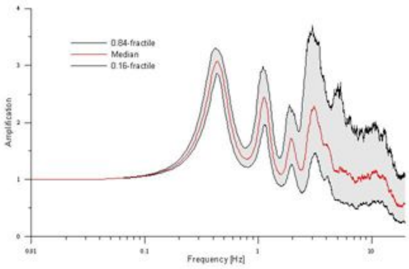

Fig. 6: Transfer function of the blue soil profile in Figure 7. The red line shows the median, the grey area is bounded through the 0.16- and 0.84-fractile.

The influence of the local geology particulary sediment thickness and composition can be displayed through the transfer function. The 3 colored arrows mark virtual boreholes with decreasing sediment thickness. For these 3 soilprofiles transfer functions were calculated and shown in Figure 8. With decreasing sediment thickness the first and second maxima moves to higher frequencies and amplitude. To show an example of large sediment thickness, the transfer function of the soilprofile of station SIN (Fig. 2) is also plotted in Figure 8. This transfer function shows a damping of frequencies above 2 Hz caused by a large sediment thickness of about 1300 m.

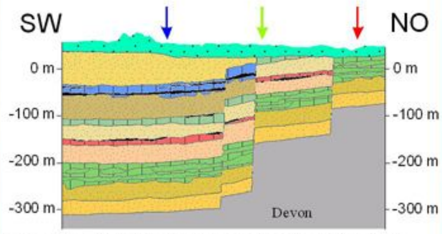

Fig. 7: Section of a profile, the colored arrows mark the position of soil-profiles with different thickness of unconsolidated sediments.

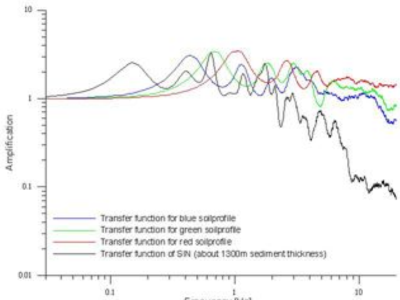

Fig. 8: Transfer functions of soilprofiles with different sediment thickness.

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