THREE DIMENSIONAL FINITE-DIFFERENCE MODELING OF STRONG GROUND-MOTION SITE EFFECTS DUE TO THE FINITE-EXTENT SOURCE - 1356 BASEL EARTHQUAKE, UPPER RHINE GRABEN

IUGG 2003 General Assembly

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ABSTRACT

The Basel earthquake of October 18, 1356 (I0=IX, M=6.9) is considered to be one of the most disastrous European events. The Basel area - Upper Rhine Graben - belongs today to seismically modest regions. Reducing the seismic risk by anti-seismic design needs the knowledge of the strong ground motion. The lack of the real data may be effectively estimated by numerical modeling using the finite differences (FD). The 3D explicit FD method is designed for topography models on irregular rectangular grids. The single-template approximation to the hyperbolic partial differential equation (PDE) is solved explicitly in the spatial and the time domain. The boundary conditions at the interfaces (including the topographic free surface) are satisfied via a treatment of the material parameters. The medium is Hooke's isotropic inhomogeneous body, with a particle-velocity dependent term added to the PDE to approximate viscoelastic behavior of the medium. The 3D FD modeling is computed for the recently established P and S-wave velocities structure of the Basel area (Kind, 2002), including the topography. The relatively simple finite-extent source features are combined with strong site effects. The finite-extent source is adjacent to the free surface, since the fault has been recognized through trenching on the Reinach fault. Several rupture histories are tested because the 1356 Basel earthquake source features are not possible to be determined. The macroseismic information of the Basel area as well as recently established 2D computations serve as a comparison to the results.

The FD method

3D FD scheme on irregular rectangular grid

-one FD approximation everywhere (easy to implement)

-thus, the topographic free surface approximated by vacuum formalism

-displacement formulation of the 2nd order accuracy

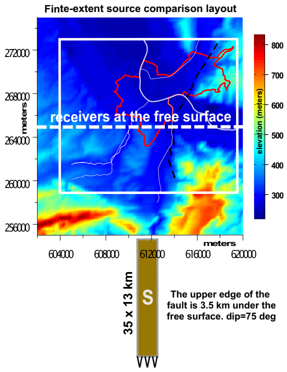
-a simplified employment of a variable Qp=Qs=Q(x,y,z)=c*f where f is the prevailing frequency of the signal.

-stable at high Vp/Vs ratios

-stable at high (Vp/Vs) ratios contrast

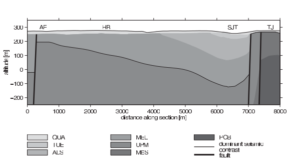
GEOLOGICAL MODEL

Finite-extent source comparison layout



The upper edge of the fault is 3.5 km under the free surface. dip=75 deg

The topography of the computational model. The lines denote as follows: red - Basel-city limits, dashed black - the surface trace of the Rhine Graben master fault, grey - rivers, thick grey - the Rhine river, the white rectangle demarks the area shown in the amplification-ratio results. The brown patch S denotes a part of the finite-extent source, the dashed white line is the profile of the receivers placed at the free surface, the coordinates are in meters (the Swiss coordinate system).



Abbreviation	Stratigraphy
QUA	Quaternary sediments
TUE	Tüllinger layers (Tertiary); marls and argillaceous marls
ALS	Molasse Alsacienne (Tertiary); sandy marls
MEL	Meletta layers (Tertiary); sandy and argillaceous marls
UPM	lower Tertiary/ first Mesozoic sediments; Sannoisien (Tertiary) and upper Mesozoic sediments down to Lias
MES	lower Mesozoic; Mesozoic sediments of the Lias and older
PCB	lowest Mesozoic sediments ("Buntsandstein"), Paleozoic sediments ("Rotliegendes") and crystalline basement.

Representative cross-section of the geology in Basle. The dominant seismic S-wave velocity contrasts is indicated as a line between MEL and UPM. The table represents the stratigraphic units represented by the abbreviations (Kind, 2002).

The slip models M1, M2

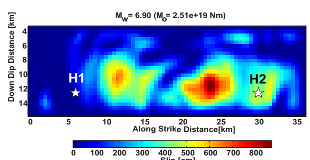
-Kostrov approximation of local slip-velocity source-time function in frequency domain (Mai, M., 2001)

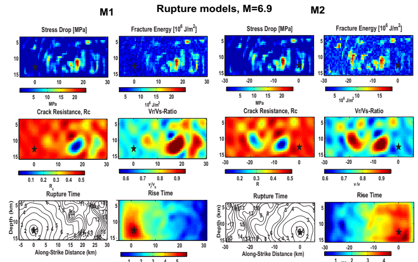
-strong ground motion by DWN-FE code (Spudich, 2002)

-two rupture histories starting at different nucleation points H1, H2

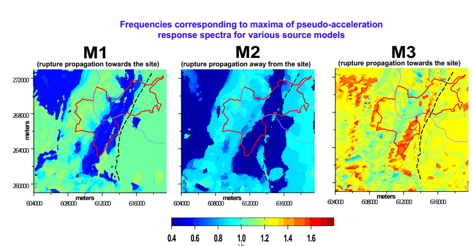
-balanced fracture energy <=> Vr/Vs < 1

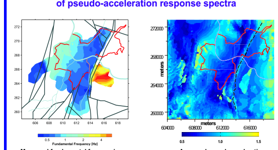
Basle site





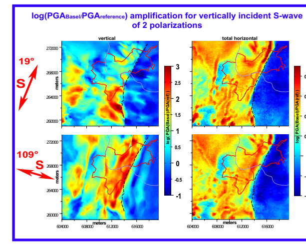
Model M3 is a 1999 (M=5.9) Athens earthquake finite-extent source model computed by PEXT method (Zahradnik, 2002). The rupture propagation towards the Basle region was applied.



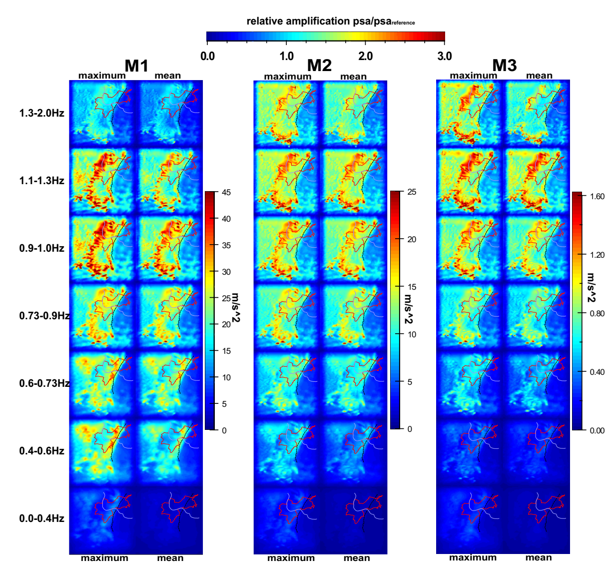


Measured fundamental frequencies in Basle area. The coordinates are in km (Kind, 2002).

Averaged pseudoacceleration response spectra (Hz) in Basle area for total horizontal component.

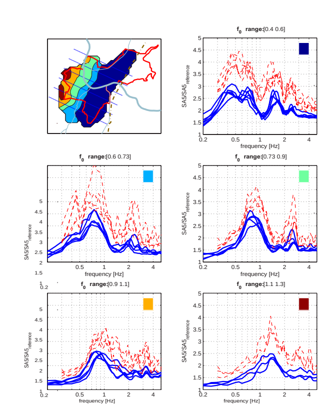


The absolute values of the pseudoacceleration response (damping=.05) for the M1,M2 and M3 finite-extent sources. Each of the rows corresponds to a given frequency band. The frequency bands between 0.4-1.3Hz are comparable to the response amplification shown below. The left and right sides of each column correspond to the maximum and mean amplitudes in a cooresponding band, respectively.



CONCLUSION

- The vertically incident S-wave amplification is strongly dependent on the polarization. The vertical component amplification is less spread along the master fault for 19° case because of weaker conversions, however the maximum has is approximately the same value.
- Combined effects of the source mechanism, position of the source, and the structure are shown. A strong difference between the amplification-belt sides along master fault correspond to the observed data.
-The regions of high amplification are very well aligned with the interfaces and low velocity layers in the geological model.
- The frequencies corresponding to the maxima of the pseudoacceleration spectra are well aligneg with the corresponding patches of the fundamental-frequencies map (up to 2.2Hz).
-The absolute values of the pseudoacceleration response are shown. A very good agreenemt is found between the 2D and 3D pseudoacceleration-response amplification.



(Kind, 2002) 2D Amplification zonation along the individual sections. Five frequency ranges are differentiated, their spatial extent is indicated in the sketch with the frequency increasing from the south east to the north west. For each section and frequency range a dashed line shows the maximum amplification from all scenarios and from all points with a fundamental frequency within the specific range. At each point of a section the average amplification over all scenarios is determined and the envelope of these curves from the same points is shown as continuous line. For the reasoning for the choice of frequency intervals see Kind (2002).

ACKNOWLEDGEMENTS:
This research was supported by research project of Czech Republic MSM 113200004 and ME354, Grant Agency of Czech Republic GACR 205/00/1047, GAUK grant 235/2003, EC projects EVG1-CT-1999-00001 PRESAP and EVG1-CT-2000-00023 SAFE (BBW Nr. 00.0336).

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