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Attenuation of seismic ground motion due to the 1992 Roermond earthquake, the Netherlands (extended abstract)

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Introduction

The Roermond earthquake of April 13, 1992, 01 h 20 m UTC, with local magnitude of $M_L = 5.9$ provided an excellent database for the investigation of the attenuation of seismic ground motion in western central Europe. The database consists of digital seismograms from the German Regional Seismic Network (GRSN), the seismic networks of the Universities of Cologne and Karlsruhe, the Geological Survey of Northrhine-Westphalia (GLA), and accelerograms from the nuclear power plant at Mülheim-Kärlich (KKW) and station Karlsruhe-West (KRW).

Peak ground displacement

Figure 1 shows the eight broadband station sites of the GRSN together with the Roermond earthquake epicentre and the area of perceptibility. The epicentral distances cover a range between 99 and 545 km. Due to their 24-bit resolution none of the broadband stations had clipped recordings. The stations Hamburg HAM, Berlin BRL and Fürstenfeldbruck FUR were excluded from the present investigation because of their situation on soft ground; their ground displacement amplitudes can therefore not be compared to those of stations on hard rock.

In the Figs 2a–c the maximum amplitudes of ground displacement are depicted for the five GRSN stations on hard rock. The maximum displacement amplitudes are generated by shear and surface waves with periods between 1.5 and 4 seconds. Figures 2b and c show the vector summations of the two horizontal (2D) and all three seismogram traces (3D), respectively.

From the data of the five broadband stations we find that the peak ground displacement decreases with hypocentral distance R as $R^{-1.40}$ (2D) and $R^{-1.54}$ (horizontal, one component), respectively.

Horizontal peak ground acceleration

At distances larger than 60 km from the epicentre a large number of seismic stations recorded the Roermond mainshock unclipped (Table 1). Most of these recordings were digital time series of ground velocity, which have been transferred to acceleration time series by differentiation. There were two stations with original acceleration records (KKW and KRW).

Due to the trigger level of 1% g, i.e. 10 cm/s^2, only one of the accelerometer facilities at the central European nuclear power plants was triggered by the mainshock. At Mülheim-Kärlich (KKW), situated in the Middle Rhine Valley about 140 km SE of the epicentre, a peak horizontal acceleration (PHA) of 44 cm/s^2 was measured at the surface on one horizontal component.

Ground acceleration at station TGA

Due to the relatively low seismicity in western central Europe most of the seismic stations are adjusted to amplitudes which can be expected in cases of local microearthquakes and teleseismic signals. Therefore, the registrations of the Roermond mainshock from the nearby seismic stations are generally clipped at the shear wave amplitude maximum. The nearest stations with unclipped recordings are located in the Rhen-

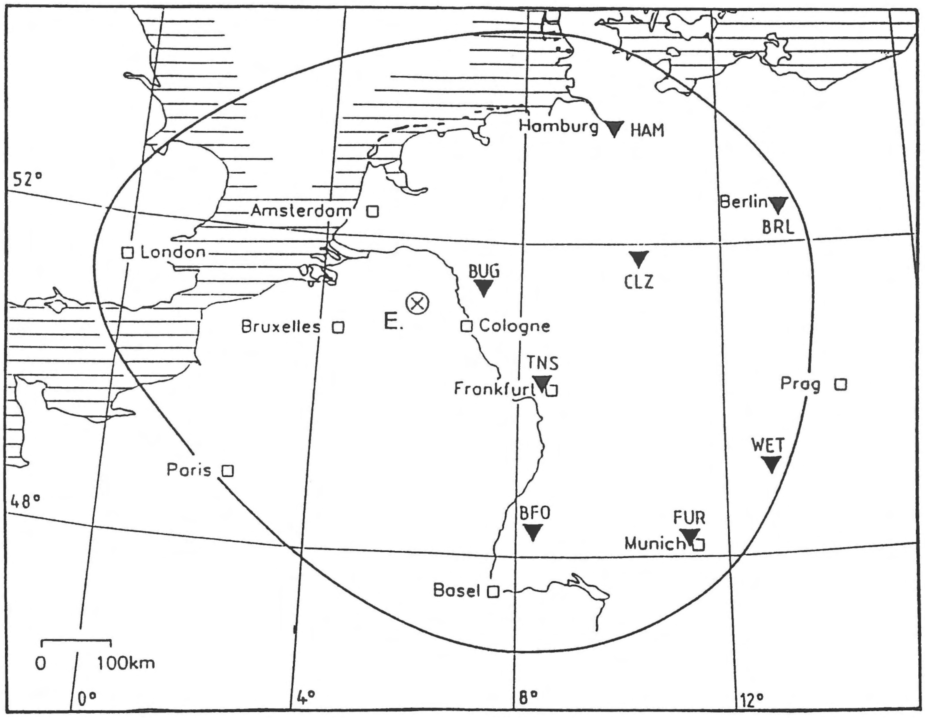

Fig. 1. Map of western and central Europe with the Roermond earthquake epicentre (E.), the broadband stations of the German Regional Seismic Network (triangles) and the area of perceptibility (solid line).

ish Brown Coal District northwest of Cologne around the towns of Bergheim and Bedburg (Table 1, stations MIL, KIR, TGA, SIN). The epicentral distance of these stations ranges from 51 to 60 km. The results of our investigations concerning the ground accelerations of the Roermond earthquake have been published by Ahorner (1992) and are summarized here. At station TGA, founded on more than 700 m-thick soft soils and at an epicentral distance of 55 km, the PHA reached values of 31, 26 and 36 cm/s^2 on the two horizontal components and their vectorial sum, respectively. The strong motion duration (with acceleration amplitudes of $A \geq 1/3\ A_{max}$) was about 7 seconds. The acceleration-response spectra with 5% damping for the two horizontal components were published by Ahorner (1992). They show a high-frequency plateau around 3% g and a broad maximum between periods of 0.1 and 1 second. The macroseismic intensity in the vicinity of station TGA reached V to VI on the MSK-scale.

Ground acceleration attenuation

Based on the data of 19 stations Ahorner (1992) presents a figure which depicts the dependence of PHA on distance. In the present paper the observations at stations CLZ and WET are added (Fig. 3). The PHA values of both horizontal components are plotted in the graph. The scattering of the data points is mainly due to the individual local ground conditions and different azimuthal positions of the seismic stations relative to the earthquake source. No contradiction was found between the PHA values and the observed macroseismic intensities. For example, in the area around Koblenz (Middle Rhine Valley) the local increase of the macroseismic intensities (Meidow & Ahorner 1994) coincides with the relatively high PHA-values of station KKW. In Fig. 3 the attenuation of PHA with hypocentral distance for earthquakes of M = 5.9 (a) and M = 5.3 (b) according to the empirical formula of Joyner & Boore (1981) for North American earthquakes is plotted for comparison:

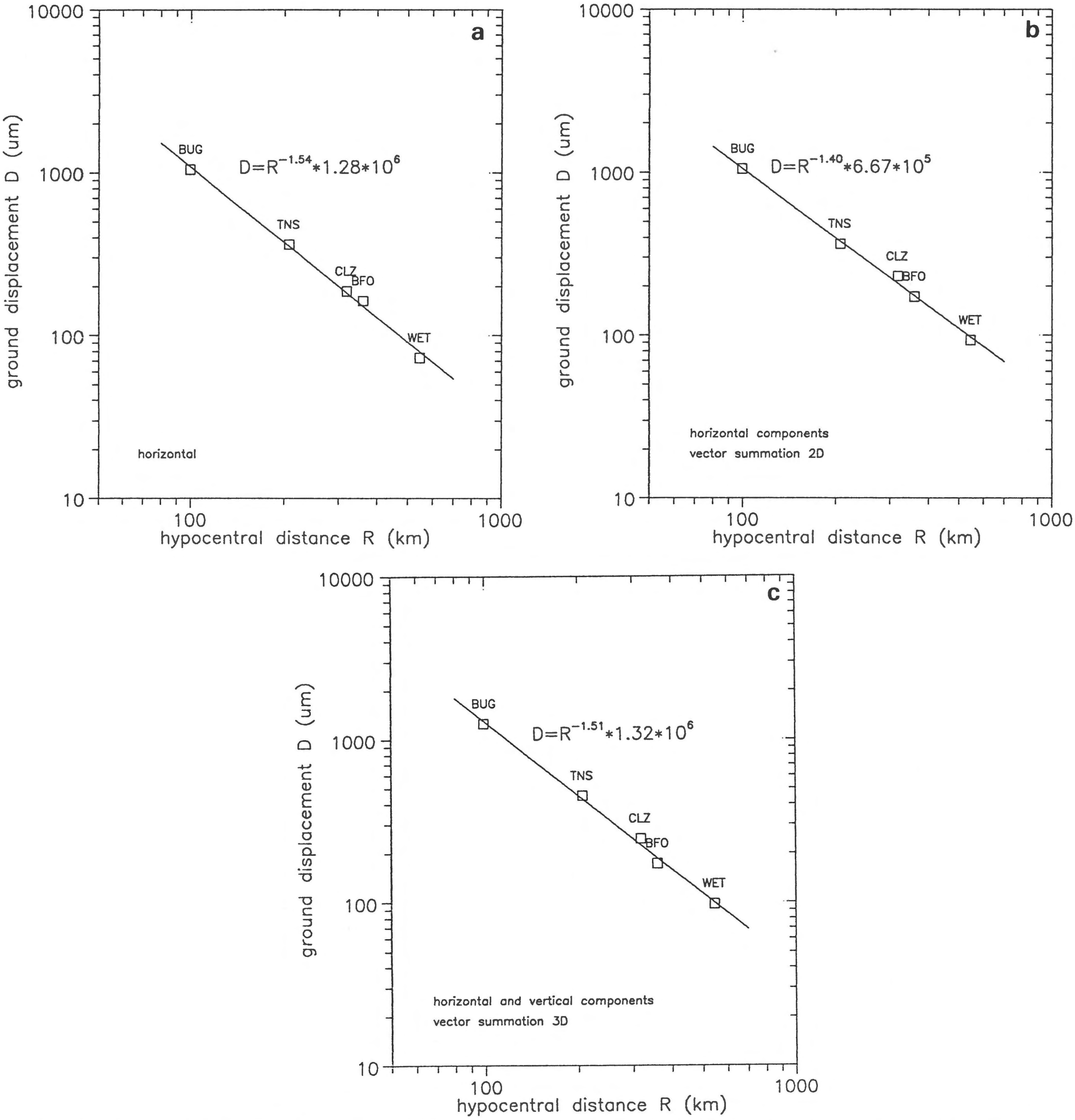

Fig. 2. Peak ground displacement (D in μm) vs. hypocentral distance (R in km) at GRSN stations. The solid line represents the regression function D which was fitted to the data points. a) Single horizontal component. b) Vector summation of the two horizontal components. c) Vector summation of all three components.

$$\log a_h = -1.02 + 0.249M - \log R - 0.00255R \quad (1)$$

where a_h is the PHA in g (9.81 m/s^2) and R is the hypocentral distance in km. Joyner & Boore used the moment magnitude M_W, which is estimated by Braunmiller et al. (1994) to be 5.3 for the Roermond earthquake. If we assume a focal depth of the mainshock in the range of 14 to 18 km, then the calculated PHA in the epicentral area reaches from 98 cm/s^2 (h = 18 km, M = 5.3) to 180 cm/s^2 (h = 14 km, M = 5.9).

Table 1. Seismic stations and the observed values of peak ground motion during the Roermond mainshock (ground acceleration from Ahorner 1992) used in the attenuation analysis

Station		R	I	A (cm/s^2)				V ($\mu m/s$)				D (μm)			
Code	Name	(km)	(MSK)	NS	EW	Z	H	NS	EW	Z	H	NS	EW	Z	H
MIL *	Millendorf	51	IV–V	12,3	11,0	6,5	12,4								
KIR *	Bergheim	55	V–VI	37,0	36,8	27,7	40,0								
TGA *	Tagebau Bergheim	55	V–VI	31,0	26,4	29,6	36,4								
SIN *	Sindorf	60	V–VI	17,4	31,0	23,7	31,0								
GSH	Großhau	60	V–VI	25,0	–	–									
PLH	Pulheim (Borehole)	67	V–VI	9,8	7,6	7,3	9,8								
OLF	Oleftalsperre	84	V	18,4	14,5	7,8									
BUG	Bochum	99	V	9,2	9,0	5,7	12,4	5473	7248	5000	9052	907	1047	1010	1051
WBS	Wahnbachtalsperre	103	V	15,0	–	–									
KKW *	Mülheim-Kärlich	140	VI	44,0	40,0	–									
BGG	Burg Eltz	145	V	14,2	22,2	12,8	24,8								
KOE	Koeppel	151	V	7,1	7,8	3,2	8,1								
TNS	Taunus-Observatorium	209	V	3,6	3,7	2,7	3,9	2624	2061	1954	3130	362	256	340	365
KRW *	Karlsruhe-West	296	III–IV	4,4	4,6	1,3									
CLZ	Clausthal-Zellerfeld	318	II	0,86	0,73	0,63	0,89	680	739	752	739	187	181	166	230
BFO	Schiltach	360	II	0,30	0,42	0,74	0,48	363	516	60	518	77	163	89	172
GLO	Glottertal	376	II	0,40	0,52	0,44									
STA	Staufen	392	II	0,32	0,39	0,30									
SLB	Schlechtbach	412	I'	0,20	0,28	0,55									
BAS *	Basel	421	II	0,86	1,00	0,55									
WET	Wettzell	545	II	0,17	0,12	0,13	0,19	282	215	132	344	73	66	42	93

R – epicentral distance, I – intensity on MSK-scale, A – peak ground acceleration, V – peak ground velocity, D – peak ground displacement, * – Station founded on soft soil.
NS – horizontal component in NS direction, EW – horizontal component in EW direction, Z – vertical component, H – vectorial sum of horizontal components.

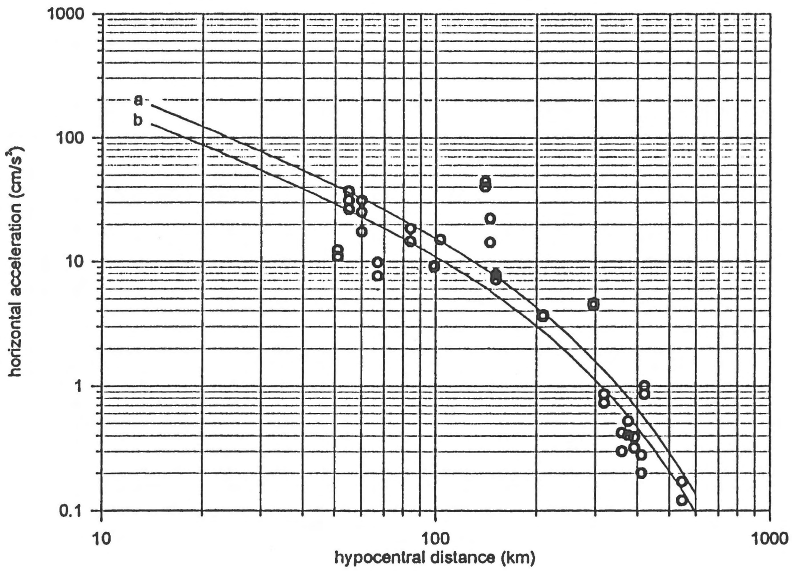

Fig. 3. Peak ground acceleration of both horizontal components vs. hypocentral distance. Data from Table 1 (partly from Ahorner 1992). The lines a and b represent the attenuation of peak horizontal acceleration with distance following the formula of Joyner & Boore (1981) with M_W = 5.9 (a) and M_W = 5.3 (b), respectively.

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