

## Observations of damage ratios to buildings in the epicentral region of the 1992 Roermond earthquake, the Netherlands (extended abstract)

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The UK-based Earthquake Engineering Field Investigation Team (EEFIT) mounted a three-day visit to the epicentral area about one week after the earthquake. The aim of the visit was to attempt to quantify, in terms of damage ratios, the amount of damage experienced by buildings in the epicentral region. Damage ratio is defined as the percentage of buildings of a certain type that experienced a certain level of damage. The aim was achieved by visiting villages and towns in the region and counting how many buildings of selected types had experienced slight or moderate damage. Thirty-eight locations were visited in total. In each location a minimum number of 20 buildings had to be observed of a particular type to be considered statistically significant.

The damage scale used in the survey is shown in Table 1. It generally conforms to that used in the definitions of the MSK intensity scale. The only building type to regularly occur in sufficient numbers was residential masonry. They were subdivided into those built before 1920, those built between 1920 and 1960 and those built since 1960. It has been found from damage surveys after previous earthquakes that older masonry buildings experience greater damage ratios (EEFIT 1991). The results of the survey are shown in Table 2. During the survey it was rapidly established that the only building type which had systematically experienced damage was residential masonry buildings built before 1920 (Classified as type RM20). The latter part of the survey therefore concentrated on this building type.

The results of the survey for damage ratio of type RM20 buildings with at least damage level D1 are shown in Fig. 1. The greatest damage ratio was observed in Oberbruch, about 4 km east of Heinsberg in Germany, with 67% of type RM20 buildings experiencing at least slight damage. A further 18 villages, generally within 10 km of Heinsberg, had damage ratios over 30%. It must be emphasised that the EEFIT team did not visit Herkenbosch which clearly experienced significant damage. It is therefore not known whether Herkenbosch would plot as a local greater damage ratio or whether it would conform to the pattern shown in Fig. 1.

In terms of the MSK intensity scale we have assigned a maximum value of VI defined as damage D1 to a few masonry buildings and to most rural and field stone houses. This intensity extends out to about the 30% damage ratio contour and encloses an area of about 300 km<sup>2</sup>. It is interesting to note that in Roermond, which probably experienced the greatest damage cost because of its relatively large population, only about 22% of type RM20 buildings were observed to experience slight damage or worse.

Figure 1 indicates that the centre of damage does not coincide with the recorded epicentral location. Whilst there may be a geological reason for this, it is also possible that there is a systematic variation in the level of building maintenance across the area of damage. The level of complexity raised by this possible variation is beyond the scope of this study, however.

### Reference

EEFIT 1991 The Newcastle Australia Earthquake of 28 December 1989 – Institution of Structural Engineers, London

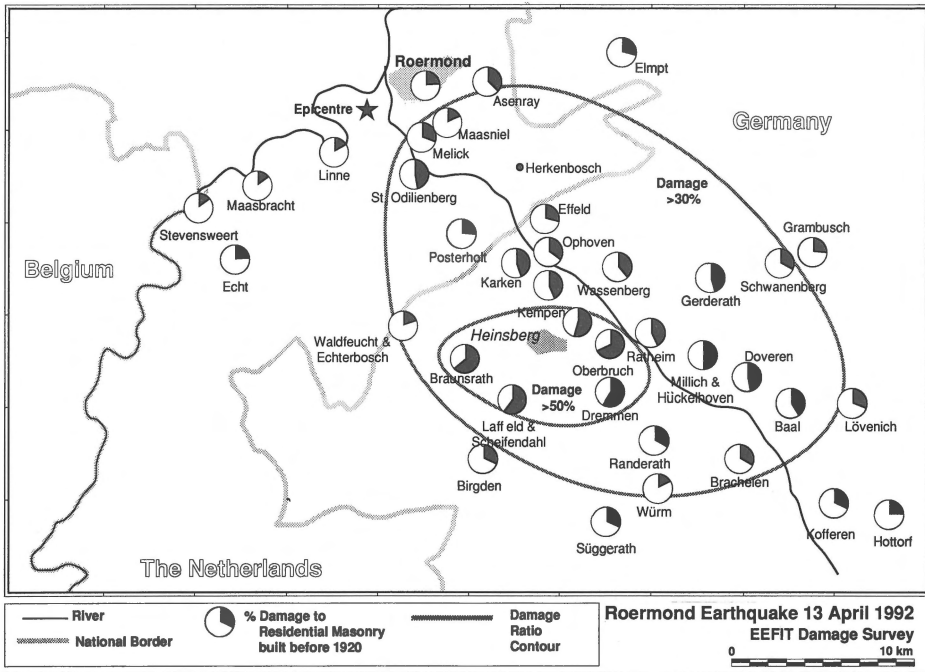


Fig. 1. Damage to residential masonry following the 1992 Roermond earthquake. Percentages as in Table 2.

Table 1. Definition of damage levels.

Damage level	Definition for loadbearing masonry	Definition for RC framed buildings
D0 undamaged	No visible damage	No visible damage
D1 Slight damage	Hairline cracks	Infill panels damaged
D2 Moderate damage	Cracks 5–20 mm	Cracks 10 mm in structure
D3 Heavy damage	Cracks 20 mm or wall material dislodged	Heavy damage to structural members, loss of concrete
D4 Partial destruction	Complete collapse of individual wall or individual roof support	Complete collapse of individual structural member or major deflection to frame
D5 Collapse	More than one wall collapsed or more than half of roof	Failure of structural members to allow fall of roof or slab

RC – reinforced concrete.

Table 2. EEFIT damage survey, Roermond earthquake, 13 April 1992. For damage ratio definitions see Table 1. Localities are shown in Fig. 1.

Location	Residential masonry Built before 1920						Residential masonry Built 1920–1960					Residential masonry Built 1960–1992						
	D0 %	D1 %	D2 %	D3 %	D1–3 %	Survey size	D0 %	D1 %	D2 %	D1,2 %	Survey size	D0 %	D1 %	D2 %	D1,2 %	Survey size		
<b>Netherlands</b>																		
<b>Roermond</b>																		
Centrum	78	18	4	0	22	231	93	7	0	7	68	100	0	0	0	68		
Roermondse Veld	86	14	0	0	14	22	88	12	1	12	217	100	0	0	0	27		
Roerzicht	72	25	3	0	28	60	96	4	0	4	27	99	1	0	1	79		
St. Jacobs	66	31	3	0	34	29	100	0	0	0	12					0		
<i>Total Roermond</i>	<i>76</i>	<i>20</i>	<i>4</i>	<i>0</i>	<i>24</i>	<i>342</i>	<i>90</i>	<i>10</i>	<i>1</i>	<i>10</i>	<i>324</i>	<i>99</i>	<i>1</i>	<i>0</i>	<i>1</i>	<i>179</i>		
Assenray	64	23	14	0	36	22	90	7	3	10	29	100	0	0	0	26		
Maasniel	81	14	5	0	19	21												
Melick	70	23	7	0	30	30	90	8	3	10	39	100	0	0	0	55		
St. Odilienberg	53	27	17	3	47	30	90	7	3	10	69	97	2	1	3	90		
Posterholt	74	22	4	0	26	23	95	5	0	5	44	100	0	0	0	76		
Linne	80	13	7	0	20	15	98	2	0	2	41	100	0	0	0	13		
Maasbracht	79	18	3	0	21	34	95	4	1	5	77	100	0	0	0	115		
Stevensweert	84	13	4	0	16	55	100	0	0	0	20	87	13	0	13	30		
Echt	76	16	8	0	24	25	100	0	0	0	23	100	0	0	0	24		
<i>Netherlands:</i>	<i>Total no. of buildings:</i>					<i>597</i>	<i>Total no. of buildings:</i>					<i>668</i>	<i>Total no. of buildings:</i>					<i>603</i>
<b>Germany</b>																		
Oberbruch	33	48	15	3	67	91	89	8	3	11	297	99	1	0	1	178		
Kempen	56	44	0	0	44	18					0					0		
Karken	61	35	4	0	39	46					0					0		
Waldfeucht & Echterbosch	85	15	0	0	15	26	92	8	0	8	24	100	0	0	0	24		
Braunsrath	36	49	16	0	64	45	66	32	3	34	38	93	7	0	7	44		
Elmpt	78	18	4	0	22	49	97	3	0	3	104	100	0	0	0	38		
Laffeld & Scheifendahl	35	53	13	0	65	40	77	23	0	23	35	96	4	0	4	53		
Dremmen	42	42	14	2	58	57	67	28	4	33	46	91	6	3	9	36		
Ratheim	59	41	0	0	41	22	89	11	0	11	38	100	0	0	0	22		
Millich & Hückelhoven	52	48	0	0	48	33	95	5	0	5	38	100	0	0	0	13		
Doveren	53	47	0	0	47	30	88	12	0	12	25	100	0	0	0	9		
Baal	62	34	3	0	38	29	89	11	0	11	19	95	5	0	5	20		
Lövenich	71	29	0	0	29	55												
Kofferen	66	34	0	0	34	29												
Hottorf	75	22	3	0	25	36												
Brachelen	67	33	0	0	33	49												
Randerath	65	35	0	0	35	34												
Birgden	71	28	1	0	29	75												
Süggerath	72	28	0	0	28	18												
Würm	80	20	0	0	20	15												

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Table 2. continued.

Location	Residential masonry Built before 1920						Residential masonry Built 1920–1960					Residential masonry Built 1960–1992						
	D0 %	D1 %	D2 %	D3 %	D1–3 %	Survey size	D0 %	D1 %	D2 %	D1, 2 %	Survey size	D0 %	D1 %	D2 %	D1, 2 %	Survey size		
Grambusch	73	27	0	0	27	22												
Schwanenberg	68	26	5	0	32	19												
Gerderath	53	40	7	0	47	30												
Wassenberg	64	36	0	0	36	45												
Unterbruch	45	50	5	0	55	40												
Ophoven	62	31	8	0	38	26												
Effeld	71	29	0	0	29	21												
<i>Germany:</i>	<i>Total no. of buildings:</i>					<i>1000</i>	<i>Total no. of buildings:</i>					<i>664</i>	<i>Total no. of buildings:</i>					<i>436</i>
<b>Netherlands and Germany:</b>						<b>1597</b>						<b>1330</b>						<b>1039</b>