Master's Thesis Engineering Technology

2019-2020

Simulation of the dynamic behaviour of unreinforced non-structural masonry components under combined horizontal and vertical seismic inputs

Eerdekens Dries

Master of Civil Engineering Technology

Weetjens Tom

Master of Civil Engineering Technology

Introduction

Unreinforced masonry (URM)

Influence of the vertical acceleration component of ground motions on the seismic behaviour of masonry buildings

Reference experimental campaign

Experimental investigation of the effects of vertical accelerations on URM buildings

At the University of Pavia (UniPV) and the European Centre for Training and Research in Earthquake Engineering (EUCENTRE)

***Trilly* software**

Numerical tool for the nonlinear time-history analysis of local URM mechanisms

Single-degree of freedom systems simulating the OOP response of walls, accounting also for the effect of vertical input accelerations

Validation of the numerical model; tuning of input model parameters through comparison with experimental data

Seismic input motions

SC1 - 2018 Zeerijp earthquake, M_W 3.4

Groningen gas field (NL)

Induced seismicity

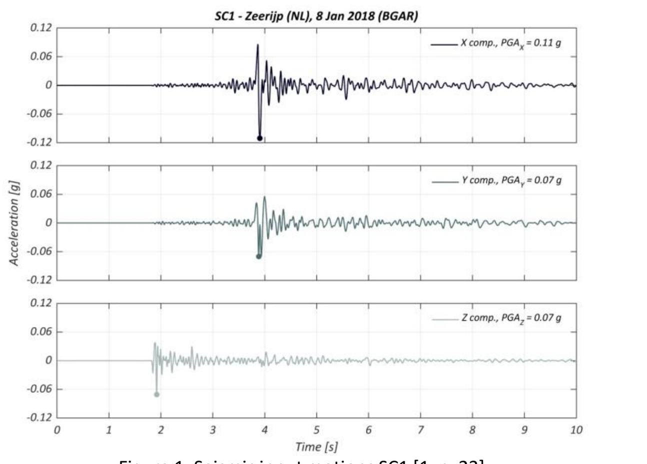

Figure 1: Seismic input motions SC1 [1, p. 23]

SC2 - 2016 Central Italy earthquake, M_W 5.9

Visso (IT) (event of 26 October 2016)

Tectonic seismicity

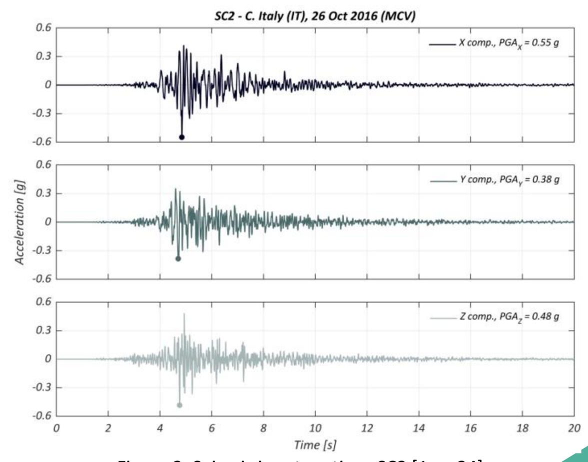

Figure 2: Seismic input motions SC2 [1, p. 24]

Numerical Simulations

Three identical full-scale building specimens

EUC-BUILD-8.1: Horizontal (X) acceleration component

EUC-BUILD-8.2: Horizontal (X) and vertical (Y) acceleration component

EUC-BUILD-8.2: Two horizontal (X,Z) and vertical (Y) acceleration component

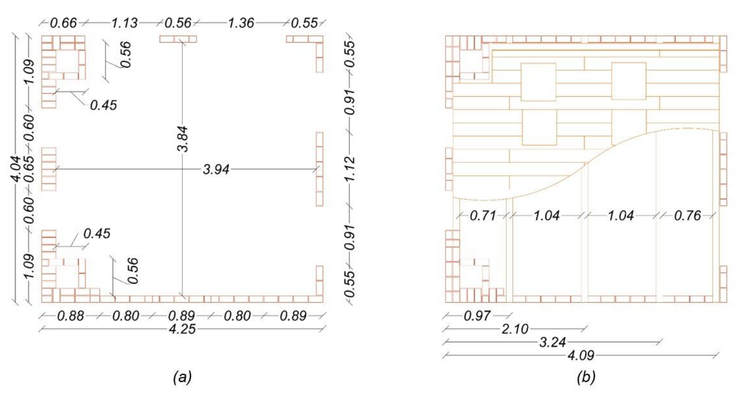

Figure 3: Full scale building: (a) ground-floor plan [m]; (b) first-floor plan [m] [1, p.5]

Five building components

- Gable wall: h = 1.95 m
- Slender chimney: h = 2.04 m
- South parapet: h = 0.84 m
- East parapet: h = 0.66 m
- West parapet: h = 0.66 m

Cracked vs uncracked tests

Determining whether the component has cracked during experimental testing

Based on the reference experimental campaign

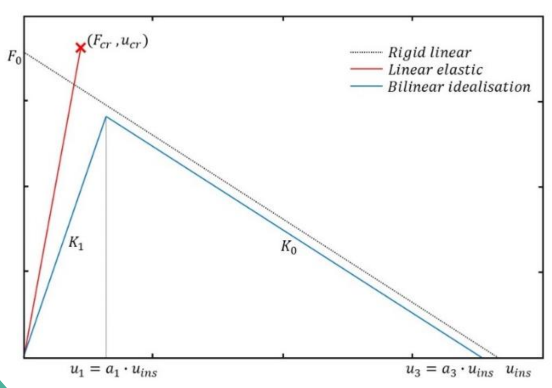

Figure 4: Bilinear force-displacement idealisation

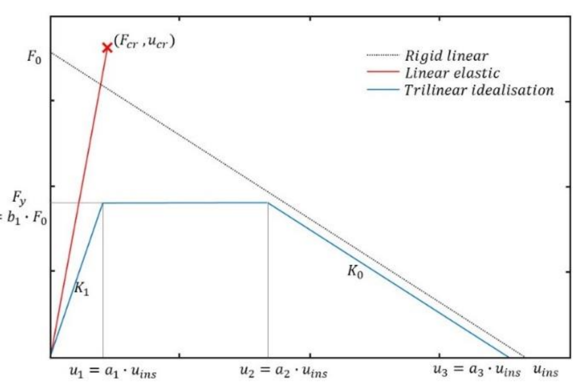

Figure 5: Trilinear force-displacement idealisation

Numerical simulation

Changing input parameters, depending on cracking condition

Cracked tests

Height h, a_1, a_3, correction coefficient and $F_{0,ratio}$ (= b_1)

Uncracked tests

Elastic damping ratio, Young's modulus E_{m1}, masonry flexural strength f_w, and the height h

Comparison of EVD models

Comparing three equivalent viscous damping models

Constant damping coefficient (CDC)

Constant damping ratio (CDR)

Stiffness-proportional damping ratio (SDR)

Results & Conclusions

Table 1: Comparison of the cracked input parameters, organized per building component

	Building specimen	Height h [m]		a_1		a_3		*CorrCoeff*		$F_{0,Ratio}$	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Gable wall	EUC-BUILD-8.1	2.231	2.328	0.012	0.034	0.945	0.99	0.25	0.38		
	EUC-BUILD-8.2	1.552	1.746	0.011	0.030	0.90	1.00	0.195	0.495		
	EUC-BUILD-8.3	1.649	2.134	0.018	0.020	0.945	0.998	0.330	0.500		
Slender chimney	EUC-BUILD-8.1	1.734	2.488	0.001	0.034	0.800	0.900	0.175	0.980	0.50	0.80
	EUC-BUILD-8.2	1.632	2.346	0.018	0.024	0.850	0.850	0.560	1.050	0.60	0.90
	EUC-BUILD-8.3	1.632	2.244	0.007	0.033	0.800	0.893	0.600	1.015	0.55	0.90
South parapet	EUC-BUILD-8.1	0.672	0.756	0.026	0.084	0.893	0.893	0.80	0.808		
	EUC-BUILD-8.2	0.672	1.008	0.016	0.084	0.808	0.893	0.56	0.95		
	EUC-BUILD-8.3	0.840	0.924	0.040	0.104	0.85	0.893	0.72	0.92		
East parapet	EUC-BUILD-8.1	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.		
	EUC-BUILD-8.2	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.		
	EUC-BUILD-8.3	0.693	0.792	0.009	0.063	0.760	0.998	0.713	0.808		

Table 2: Comparison of the uncracked input parameters, organized per building component

	Building specimen	Height h [m]		*Damp_el*		F_w [MPa]		E_{m1} [MPa]	
		Min	Max	Min	Max	Min	Max	Min	Max
Gable wall	EUC-BUILD-8.1	1.940	2.328	0.013	0.100	0.091	0.150	1200	2400
	EUC-BUILD-8.2	2.037	2.037	0.118	0.118	0.156	0.156	1400	1400
	EUC-BUILD-8.3	1.746	1.746	0.040	0.040	0.026	0.026	1200	1200
Slender chimney	EUC-BUILD-8.1	2.244	2.244	0.078	0.088	0.260	0.267	400	800
	EUC-BUILD-8.2	1.938	2.448	0.048	0.150	0.046	0.208	100	1900
	EUC-BUILD-8.3	2.244	2.448	0.018	0.038	0.143	0.156	800	1000
South parapet	EUC-BUILD-8.1	0.672	0.966	0.078	0.138	0.098	0.208	300	1600
	EUC-BUILD-8.2								
	EUC-BUILD-8.3	0.672	0.924	0.010	0.170	0.143	0.247	400	3700
East parapet	EUC-BUILD-8.1								
	EUC-BUILD-8.2								
	EUC-BUILD-8.3	0.759	0.792	0.045	0.050	0.078	0.091	800	800
West parapet	EUC-BUILD-8.1								
	EUC-BUILD-8.2								
	EUC-BUILD-8.3	0.660	0.792	0.030	0.073	0.052	0.137	500	2000

Conclusion

Satisfying simulations

Parameter ranges in Table 1 and Table 2

CDC damping model is best for 8.3-SC tests

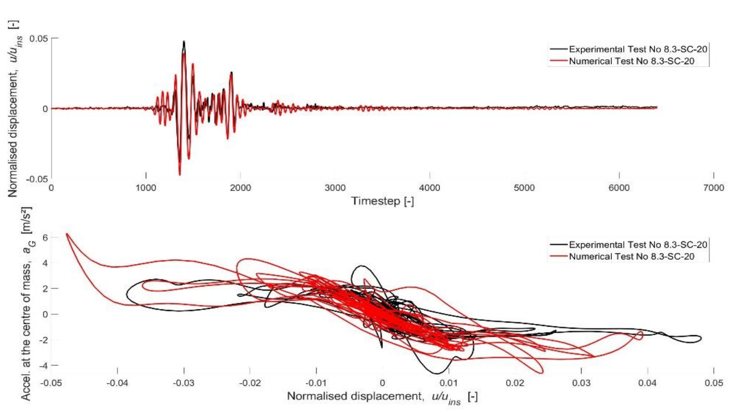

Figure 6: Comparison between experimental and numerical response of cracked slender chimney test 8.3-SC-20

[1] S. Kallioras, L. Grottoli, M. Panatti and F. Graziotti, "Shake-table experiments on three identical unreinforced clay-brick masonry buildings under uni-, bi-, and tri-directional seismic input motions," EUCENTRE, Pavia, 2020.

Supervisors / Cosupervisors:

Prof. dr. ir. Hervé DEGEE

Prof. Andrea PENNA

Dr. Stylianos KALLIORAS

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