



Resilient Vertical Forest Renovation of Reinforced Concrete
Structures in Seismic Prone Areas
(H.F.R.I. Project Number 015376)

Recorded results and photos of damages of tested
as built structure

Deliverable D2.3 Work package 2

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TABLE OF CONTENTS

Acknowledgements.....	v
TABLE OF CONTENTS.....	vi
LIST OF ACRONYMS	xix
Abstract	xx
ΠΕΡΙΛΗΨΗ	xxi
1) Earthquake excitation time history and instrumentation.....	1
2) Development of a smart PZT monitoring system for the vertical forest (VF) structure.....	10
3) APPLIED TESTING METHODOLOGY.....	13
3.1) White noise before EQ0,1g.....	14
3.2) Earthquake 0,1g.....	37
3.3) White noise before EQ0,2g.....	60
3.4) Earthquake EQ0,2g	83
3.5) White noise test before EQ0,5g	106
3.6) Earthquake EQ0,5g	126
3.7) White noise test before EQ0,8g	146
3.8) Earthquake EQ0,8g	169
3.9) White noise test before earthquake EQ1,1g	192
3.10) Earthquake EQ1,1g.....	216
3.11) White noise test after EQ1,1g	240
3.12) Measurements of advanced PZT sensors and characteristic photos.....	264
3.13) Characteristic photos.....	277
4) Mechanical properties of materials.....	280
4.1 Concrete and steel.....	280
4.2 Hollow clay bricks, binding mortar and brick wall interface of triplets	283
References.....	293

LIST OF TABLES

Table 1.1: Detailed list of accelerometers, draw wire meters and strain gauges placed inside and on the structure	8
Table 3.1: List of all performed tests	13
Table 3.12.1: Location and amount of PZTs.....	265
Table 4.1: Summary of compressive strength test results.	281
Table 4.2: Summary of split tensile test results.	282
Table 4.1: Compressive strength of clay bricks with loading direction parallel to the holes.....	284
Table 4.2: Compressive strength of bricks for infill masonry with the loading direction perpendicular to the holes.	285
Table 4.3: Experimental results of three-point bending test of lime-cement mortar prisms.	284
Table 4.4: Experimental results of compression test of lime-cement mortar prisms' pieces.	287
Table 4.5: Experimental results of the direct shear test of clay bricks triplet.....	290

LIST OF FIGURES

Figure 1.1 Basis for the time history executed by the DUTH seismic table (ay component of Thessaloniki (Volvi) 1978 earthquake excitation record).....	1
Figure 1.2 Position of accelerometers (specimen's view perpendicular to the direction of the seismic table movement)	2
Figure 1.3 Position of the draw wire sensors on the concrete structure slab and foundation beams (specimen's view parallel to the direction of the seismic table movement).....	3
Figure 1.4 Position of the diagonal draw wire sensors, along the diagonals of the partial infill (specimen's view parallel to the direction of the seismic table movement).....	3
Figure 1.5 Floor plan with strain gauges at the bottom of the columns (DE)	4
Figure 1.6 Floor plan with strain gauges at the top of the columns (UE).....	5
Figure 1.7 View of the structure with strain gauges in frame of Columns 2-3	6
Figure 1.8 View of the structure with strain gauges in frame of columns 1-4.....	6
Figure 1.9 View of the infill wall with strain gauges in frame 1-4	7
Figure 1.10 View of the infill wall with strain gauges in frame 2-3	7
Figure 2.1 Location of the PZT sensors inside the beams	10
Figure 2.2 Location of the PZTs inside the columns.....	11
Figure 2.3 Location of PZT sensors inside the slab	12
Figure 3.1.1 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 1 (b) Accelerometer 4	14
Figure 3.1.2 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 7 (b) Accelerometer 10	15
Figure 3.1.3 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 2 (b) Accelerometer 5	16
Figure 3.1.4 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 9 (b) Accelerometer 8	17
Figure 3.1.5 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 3 (b) Accelerometer 6	18
Figure 3.1.6 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 11 (b) Accelerometer 12	19
Figure 3.1.7 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Draw wire sensor W1 and (b) Draw wire sensor W2	20
Figure 3.1.8 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Draw wire sensor W3 and (b) Draw wire sensor W4	21
Figure 3.1.9 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Draw wire sensor W5 and (b) Draw wire sensor W6	22
Figure 3.1.10 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Draw wire sensor W7 and (b) Draw wire sensor W8	23
Figure 3.1.11 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Diagram of displacement Slab – Base.....	24
Figure 3.1.12 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge SG1 and (b) strain gauge SG2.....	25
Figure 3.1.13 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 3 and (b) strain gauge 4.....	26
Figure 3.1.14 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 7 and (b) strain gauge 8.....	28

Figure 3.1.15 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12	29
Figure 3.1.16 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 13 and (b) strain gauge 14	30
Figure 3.1.17 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 15 and (b) strain gauge 16	31
Figure 3.1.18 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 17 and (b) strain gauge 18	32
Figure 3.1.19 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 5 and (b) strain gauge 6	33
Figure 3.1.20 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 9 and (b) strain gauge 10	34
Figure 3.1.21 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 19 and (b) strain gauge 20	35
Figure 3.2.1 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 1 (b) Accelerometer 4	37
Figure 3.2.2 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 7 (b) Accelerometer 10	38
Figure 3.2.3 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 2 (b) Accelerometer 5	39
Figure 3.2.4 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 8 (b) Accelerometer 11	40
Figure 3.2.5 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 3 (b) Accelerometer 6	41
Figure 3.2.6 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 9 (b) Accelerometer 12	42
Figure 3.2.7 Characteristic results for phase A (0,1g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2	43
Figure 3.2.8 Characteristic results for phase A (0,1g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor 4	44
Figure 3.2.9 Characteristic results for phase A (0,1g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6	45
Figure 3.2.10 Characteristic results for phase A (0,1g earthquake): (a) Draw wire sensor 7 and (b) Draw wire sensor 8	46
Figure 3.2.11 Characteristic results for phase A (0,1g earthquake): (a) Diagram of displacement Slab – Base	47
Figure 3.2.12 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 1 and (b) strain gauge 2	48
Figure 3.2.13 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 3 and (b) strain gauge 4	49
Figure 3.2.14 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 7 and (b) strain gauge 8	50
Figure 3.2.15 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12	51
Figure 3.2.17 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 15 and (b) strain gauge 16	54
Figure 3.2.18 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 17 and (b) strain gauge 18	55

Figure 3.2.19 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 5 and (b) strain gauge 6	56
Figure 3.2.20 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 9 and (b) strain gauge 10	57
Figure 3.2.21 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 19 and (b) strain gauge 20	58
Figure 3.3.1 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 1 (b) Accelerometer 4	60
Figure 3.3.2 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 7 (b) Accelerometer 10	61
Figure 3.3.3 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 2 (b) Accelerometer 5	62
Figure 3.3.4 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 9 (b) Accelerometer 11	63
Figure 3.3.5 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 3 (b) Accelerometer 8	64
Figure 3.3.6 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 6 (b) Accelerometer 12	65
Figure 3.3.7 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2	66
Figure 3.3.8 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor	67
Figure 3.3.9 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6	68
Figure 3.3.10 Characteristic results for phase A (white noise before 0,2g earthquake) : (a) Draw wire sensor 7 and (b) Draw wire sensor 8	69
Figure 3.3.11 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Diagram of displacement Slab – Base	70
Figure 3.3.12 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 1 and (b) strain gauge 2	71
Figure 3.3.13 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 3 and (b) strain gauge 4	72
Figure 3.3.14 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 7 and (b) strain gauge 8	73
Figure 3.3.15 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 11 and (b) strain gauge 12	74
Figure 3.3.16 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 13 and (b) strain gauge 14	76
Figure 3.3.17 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 15 and (b) strain gauge 16	77
Figure 3.3.18 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 17 and (b) strain gauge 18	78
Figure 3.3.19 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 5 and (b) strain gauge 6	79
Figure 3.3.20 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 9 and (b) strain gauge 10	80
Figure 3.3.21 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 19 and (b) strain gauge 20	81

Figure 3.4.1 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 1 (b) Accelerometer 4	83
Figure 3.4.2 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 7 (b) Accelerometer 10	84
Figure 3.4.3 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 2 (b) Accelerometer 5	85
Figure 3.4.4 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 8 (b) Accelerometer 11	86
Figure 3.4.5 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 3 (b) Accelerometer 6	87
Figure 3.4.6 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 9 (b) Accelerometer 12	88
Figure 3.4.7 Characteristic results for phase A (0,2g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2	89
Figure 3.4.8 Characteristic results for phase A (0,2g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor 4	90
Figure 3.4.9 Characteristic results for phase A (0,2g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6	91
Figure 3.4.10 Characteristic results for phase A (0,2g earthquake) : (a) Draw wire sensor 7 and (b) Draw wire sensor 8	92
Figure 3.4.11 Characteristic results for phase A (0,2g earthquake): (a) Diagram of displacement Slab – Base	93
Figure 3.4.12 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 1 and (b) strain gauge 2	94
Figure 3.4.13 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 3 and (b) strain gauge 4	95
Figure 3.4.14 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 7 and (b) strain gauge 8	96
Figure 3.4.15 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 11 and (b) strain gauge 12	97
Figure 3.4.16 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 13 and (b) strain gauge 14	99
Figure 3.4.17 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 15 and (b) strain gauge 16	100
Figure 3.4.18 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 17 and (b) strain gauge 18	101
Figure 3.4.19 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 5 and (b) strain gauge 6	102
Figure 3.4.20 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 9 and (b) strain gauge 10	103
Figure 3.4.21 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 19 and (b) strain gauge 20	104
Figure 3.5.1 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 1 (b) Accelerometer 4	106
Figure 3.5.2 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 7 (b) Accelerometer 10	107
Figure 3.5.3 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 2 (b) Accelerometer 5	108

Figure 3.5.4 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 8 (b) Accelerometer 11	109
Figure 3.5.5 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 3 (b) Accelerometer 6	110
Figure 3.5.6 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 9 (b) Accelerometer 12	111
Figure 3.5.7 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2	112
Figure 3.5.8 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor 4	113
Figure 3.5.9 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6	114
Figure 3.5.10 Characteristic results for phase A (white noise before 0,5g earthquake) : (a) Draw wire sensor 7 and (b) Draw wire sensor 8	115
Figure 3.5.11 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Diagram of displacement Slab – Base.....	116
Figure 3.5.12 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 1 and (b) strain gauge 2.....	117
Figure 3.5.13 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 3 and (b) strain gauge 4.....	118
Figure 3.5.14 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 7 and (b) strain gauge 8.....	119
Figure 3.5.15 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 11 and (b) strain gauge 12	120
Figure 3.5.16 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 13 and (b) strain gauge 14	122
Figure 3.5.17 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 15 and (b) strain gauge 16	123
Figure 3.5.18 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 17 and (b) strain gauge 18	124
Figure 3.6.1 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 1 (b) Accelerometer 4.....	126
Figure 3.6.2 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 7 (b) Accelerometer 10	127
Figure 3.6.3 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 2 (b) Accelerometer 5	128
Figure 3.6.4 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 8 (b) Accelerometer 11	129
Figure 3.6.5 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 3 (b) Accelerometer 6	130
Figure 3.6.6 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 9 (b) Accelerometer 12	131
Figure 3.6.7 Characteristic results for phase A (0,5g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2	132
Figure 3.6.8 Characteristic results for phase A (0,5g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor 4	133
Figure 3.6.9 Characteristic results for phase A (0,5g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6	134

Figure 3.6.10 Characteristic results for phase A (0,5g earthquake): (a) Draw wire sensor 7 and (b) Draw wire sensor 8	135
Figure 3.6.11 Characteristic results for phase A (0,5g earthquake): (a) Diagram of displacement Slab – Base.....	136
Figure 3.6.12 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 1 and (b) strain gauge 2	137
Figure 3.6.13 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 3 and (b) strain gauge 4	139
Figure 3.6.14 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 7 and (b) strain gauge 8	140
Figure 3.6.15 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 11 and (b) strain gauge 12	141
Figure 3.6.16 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 13 and (b) strain gauge 14	142
Figure 3.6.17 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 15 and (b) strain gauge 16	143
Figure 3.6.18 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 17 and (b) strain gauge 18	144
Figure 3.7.1 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 1 (b) Accelerometer 4	146
Figure 3.7.2 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 7 (b) Accelerometer 10	147
Figure 3.7.3 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 2 (b) Accelerometer 5	148
Figure 3.7.4 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 8 (b) Accelerometer 11	149
Figure 3.7.5 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 3 (b) Accelerometer 6	150
Figure 3.7.6 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 9 (b) Accelerometer 12	151
Figure 3.7.7 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2	152
Figure 3.7.8 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor 4	153
Figure 3.7.9 Characteristic results for phase A (white noise before 0,8g earthquake) : (a) Draw wire sensor 5 and (b) Draw wire sensor 6	154
Figure 3.7.10 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Draw wire sensor 7 and (b) Draw wire sensor 8	155
Figure 3.7.11 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Diagram of displacement Slab – Base.....	156
Figure 3.7.12 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 1 and (b) strain gauge 2.....	157
Figure 3.7.13 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 3 and (b) strain gauge 4.....	158
Figure 3.7.14 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 7 and (b) strain gauge 8.....	159
Figure 3.7.15 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 11 and (b) strain gauge 12	160

Figure 3.7.16 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 13 and (b) strain gauge 14	161
Figure 3.7.17 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 15 and (b) strain gauge 16	162
Figure 3.7.18 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 17 and (b) strain gauge 18	163
Figure 3.7.19 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 5 and (b) strain gauge 6	165
Figure 3.7.20 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 9 and (b) strain gauge 10	166
Figure 3.7.21 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 19 and (b) strain gauge 20	167
Figure 3.8.1 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 1 (b) Accelerometer 4	169
Figure 3.8.2 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 7 (b) Accelerometer 10	170
Figure 3.8.3 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 2 (b) Accelerometer 5	171
Figure 3.8.4 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 8 (b) Accelerometer 11	172
Figure 3.8.5 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 3 (b) Accelerometer 6	173
Figure 3.8.6 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 9 (b) Accelerometer 12	174
Figure 3.8.7 Characteristic results for phase A (0,8g earthquake): (a) Draw wire sensor W1 and (b) Draw wire sensor W2	175
Figure 3.8.8 Characteristic results for phase A (0,8g earthquake): (a) Draw wire sensor W3 and (b) Draw wire sensor W4	176
Figure 3.8.9 Characteristic results for phase A (0,8g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6	177
Figure 3.8.10 Characteristic results for phase A (0,8g earthquake): (a) Draw wire sensor 7 and (b) Draw wire sensor 8	178
Figure 3.8.11 Characteristic results for phase A (0,8g earthquake): (a) Diagram of displacement Slab – Base	179
Figure 3.8.12 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 1 and (b) strain gauge 2	180
Figure 3.8.13 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 3 and (b) strain gauge 4	181
Figure 3.8.14 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 7 and (b) strain gauge 8	182
Figure 3.8.15 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 11 and (b) strain gauge 12	183
Figure 3.8.16 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 13 and (b) strain gauge 14	185
Figure 3.8.17 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 15 and (b) strain gauge 16	186
Figure 3.8.18 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 17 and (b) strain gauge 18	187

Figure 3.8.19 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 5 and (b) strain gauge 6	188
Figure 3.8.20 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 9 and (b) strain gauge 10	189
Figure 3.8.21 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 19 and (b) strain gauge 20	190
Figure 3.9.1 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 1 (b) Accelerometer 4	192
Figure 3.9.2 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 7 (b) Accelerometer 10	193
Figure 3.9.3 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 2 (b) Accelerometer 5	194
Figure 3.9.4 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 8 (b) Accelerometer 11	195
Figure 3.9.5 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 3 (b) Accelerometer 6	196
Figure 3.9.6 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 9 (b) Accelerometer 12	197
Figure 3.9.7 Characteristic results for phase A (white noise before 1,1g earthquake): (a) draw wire sensor 1 and (b) draw wire sensor 2	198
Figure 3.9.8 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Draw wire sensor 3 and (b) Draw wire sensor 4	199
Figure 3.9.9 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Draw wire sensor 5 and (b) Draw wire sensor 6	200
Figure 3.9.10 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Draw wire sensor 7 and (b) Draw wire sensor 8	201
Figure 3.9.11 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Diagram of displacement Slab – Base	202
Figure 3.9.12 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Strain gauge 1 and (b) Strain gauge 2	203
Figure 3.9.13 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Strain gauge 3 and (b) Strain gauge 4	204
Sg3	205
Figure 3.9.14 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 7 and (b) Strain gauge 8	205
Figure 3.9.15 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Strain gauge 11 and (b) Strain gauge 12	206
Figure 3.9.16 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 13 and (b) Strain gauge 14	208
Figure 3.9.17 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 13 and (b) Strain gauge 14	209
Figure 3.9.18 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 13 and (b) Strain gauge 14	210
Figure 3.9.19 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 6 and (b) Strain gauge 9	212
Figure 3.9.20 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 19 and (b) Strain gauge 20	213
Figure 3.9.21 Characteristic results for phase A (white noise before 1,1g earthquake) (a) strain gauge 5 and (b) strain gauge 10	214

Figure 3.10.1 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 1 (b) Accelerometer 4.....	216
Figure 3.10.2 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 7 (b) Accelerometer 10.....	217
Figure 3.10.3 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 2 (b) Accelerometer 5.....	218
Figure 3.10.4 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 8 (b) Accelerometer 11.....	219
Figure 3.10.5 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 3 (b) Accelerometer 6.....	220
Figure 3.10.6 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 9 (b) Accelerometer 12.....	221
Figure 3.10.7 Characteristic results for phase A (1,1g earthquake): (a) Draw wire sensor W1 (b) Draw wire sensor W2.....	222
Figure 3.10.8 Characteristic results for phase A (1,1g earthquake): (a) Draw wire sensor W3 (b) Draw wire sensor W4.....	223
Figure 3.10.9 Characteristic results for phase A (1,1g earthquake): (a) Draw wire sensor W5 (b) Draw wire sensor W6.....	224
Figure 3.10.10 Characteristic results for phase A (1,1g earthquake): (a) Draw wire sensor W7 (b) Draw wire sensor W8.....	225
Figure 3.10.11 Characteristic results for phase A (1,1g earthquake): (a) Diagram of displacement Slab – Base.....	226
Figure 3.10.12 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 1 and (b) strain gauge 2	227
Figure 3.10.13 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 3 and (b) strain gauge 4	228
Figure 3.10.14 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 7 and (b) strain gauge 8	229
Figure 3.10.15 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12	231
Figure 3.10.16 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 13 and (b) strain gauge 14.....	233
Figure 3.10.17 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12.....	234
Figure 3.10.18 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12.....	235
Figure 3.10.19 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 5 and (b) strain gauge 10	236
Figure 3.10.20 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 6 and (b) strain gauge 9	237
Figure 3.10.21 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 6 and (b) strain gauge 9\.....	238
Figure 3.11.1 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 1 (b) Accelerometer 4	240
Figure 3.11.2 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 7 (b) Accelerometer 10	241
Figure 3.11.3 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 2 (b) Accelerometer 5	242

Figure 3.11.4 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 8 (b) Accelerometer 11	243
Figure 3.11.5 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 3 (b) Accelerometer 6	244
Figure 3.11.6 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 9 (b) Accelerometer 12	245
Figure 3.11.7 Characteristic results for phase A (white noise after 1,1g earthquake) : (a) Draw wire sensor W1 and (b) Draw wire sensor W2	246
Figure 3.11.8 Characteristic results for phase A (white noise after 1,1g earthquake) : (a) Draw wire sensor 3 and (b) Draw wire sensor 4	247
Figure 3.11.9 Characteristic results for phase A (white noise after 1,1g earthquake) : (a) Draw wire sensor 5 and (b) Draw wire sensor 6	248
Figure 3.11.10 Characteristic results for phase A (white noise after 1,1g earthquake) : (a) Draw wire sensor 7 and (b) Draw wire sensor 8	249
Figure 3.11.11 Characteristic results for phase A (white noise after 1,1g earthquake) : (a) Diagram of displacement Slab – Base.....	250
Figure 3.11.12 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 1 and (b) strain gauge 2.....	251
Figure 3.11.13 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 3 and (b) strain gauge 4.....	253
Figure 3.11.14 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 7 and (b) strain gauge 8.....	253
Figure 3.11.15 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12	254
Figure 3.11.16 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 13 and (b) strain gauge 14	256
Figure 3.11.17 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 15 and (b) strain gauge 16	257
Figure 3.11.18 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 17 and (b) strain gauge 18	258
Figure 3.11.19 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 5 and (b) strain gauge 6.....	259
Figure 3.11.20 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 9 and (b) strain gauge 10.....	261
Figure 3.11.21 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 19 and (b) strain gauge 20	262
Figure 3.12.1: Location of the masonries.	265
Figure 3.12.2: Design and code names of the SAs on beams (highlighted).....	266
Figure 3.12.3: Voltage frequency response of the PZT sensors 3A, 3B and 3D	267
Figure 3.12.4: Design and code names of the SAs on columns (highlighted).....	268
Figure 3.12.5: Voltage frequency responses of the PZT sensors Y1M and Y2M.....	269
Figure 3.12.6: Voltage frequency responses of the PZT sensors Y3M and Y4M.....	269
Figure 3.12.7: Design and code names of the SAs on Joints (highlighted).....	270
Figure 3.12.8: Voltage frequency responses of the PZT sensors 2AC and 2BC.	271
Figure 3.12.9: Design and code names of the SAs on the Slab (highlighted) and voltage frequency response of the PZT sensor SL1	272
Figure 3.12.10 Voltage frequency responses of the SA sensor SL1	273
Figure 3.12.11: Design and code names of the PZTs on Masonry, MOUR and MOUL (highlighted) ..	274
Figure 3.12.12: Voltage frequency responses of the PZT sensor MOUL.....	275

Figure 3.12.13: Voltage frequency responses of the PZT sensor MOUR.....	275
Figure 3.12.14: Design and code names of the SAs on Cantilevers, 1AP and 1CP (highlighted).....	276
Figure 3.12.15: Voltage frequency responses of the PZT sensors 1AP and 1CP	276
Figure 3.13.1 View of masonry 3-4 (a) transverse to the direction of movement of the seismic table and (b) of masonry 4-1 parallel to the direction of movement of the seismic table.....	277
Figure 3.13.2 View of masonry 2-3 parallel to the direction of movement of the seismic table (a) with PZTs and (b) wall infill-column and slab debonding	278
Figure 3.13.3 Interior side of masonry 3-4, transverse to the direction of movement of the seismic table	279
Figure 4.1 Concrete compressive strength test: (a) standard test setup (b) typical failure mode.....	280
Figure 4.2 Split tensile test: (a) standard test setup (b) typical failure mode.....	281
Figure 4.3 Instrumentation of steel bar under direct tension	282
Figure 4.4: Brick compression test setup parallel to the holes.....	283
Figure 4.5: Clay brick compression test setup perpendicular to the holes.	284
Figure 4.6: Experimental setup for three-point bending of a lime-cement mortar prism and failure mode after the test.	284
Figure 4.7: Experimental results of three-point bending tests of lime-cement mortar prisms.....	285
Figure 4.8: Failure modes of three-point bending tests of lime-cement mortar prisms.	285
Figure 4.9: Experimental compression test setup of lime-cement mortar prism.	286
Figure 4.10: Failure mode of compression tests of lime-cement mortar prism piece.....	286
Figure 4.12: Triplet of clay bricks for the direct shear test with an intermediate connecting lime-cement mortar joint of 10 mm.	288
Figure 4.13: Experimental direct shear test setup of clay bricks triplet.	289
Figure 4.14: Types of failure modes of brick triplets subjected to shear test. Shear failure at the brick/mortar interface (A1) at one or (A2) between two interfaces.	290
Figure 4.15: Failure modes of brick triplets subjected to shear testing. Shear failure at the brick/mortar interface (A1) at one or (A2) between two interfaces (a)-(f).....	291

LIST OF ACRONYMS

VF	Vertical Forest
RC	Reinforced Concrete
PZT	Piezoelectric sensors or piezoelectric transducers
3D	3 Dimensions
etc	et cetera
D23	Deliverable 23
e.g.	for example
SHM	Structural Health Monitoring
EMI	Electromechanical Impedance
DUTH	Democritus University of Thrace
NTUA	National Technical University of Athens
SAs	Smart aggregates
AUTH	Aristotle University of Thessaloniki

Abstract

GREENERGY aims to assess the dynamic performance of old type deficient structures. This deliverable concerns the recorded results and photos of damages of tested as-built structure within the framework of workpackage of the experimental dynamic assessment of physical model structure towards holistic renovation. The 3d structure is fully instrumented with internal strain gauges on the steel bar surfaces and embedded smart aggregates with PZT sensors. Further, externally bonded PZT patches, attached accelerometers, displacement wire-meters and externally bonded strain gauges are utilized. Two types of tests have been performed, i.e. dynamic shake table tests and tests for determination of dynamic characteristics of the as-built structure. The dynamic shake table tests comprised of gradually increasing maximum input intensity level (peak acceleration of the excitation) from 0,1g to 1,1g based on the adopted earthquake of Thessaloniki 1978. Minor concrete cracking and infill wall partial debonding from the surrounding concrete frames is evidenced without infill wall collapse, at SLS performance level. The PZTs reveal remarkable sensitivity to minor damages inside concrete columns or at the brick infill wall – concrete frame interfaces. Finally, the report gathers the results on material properties for concrete, steel, brick, binder for brick infill construction and for the brick-binder interface (shear strength). Next deliverable D25 will conclude the assessment of the performance of the as-built tested structure in order to receive the Vertical Forest renovation construction.

Keywords: experiment, seismic table, reinforced concrete, brick wall infills, seismic excitation, Vertical Forest, resilience, renovation, structural, structural health monitoring, PZT

ΠΕΡΙΛΗΨΗ

Το έργο GREENERGY στοχεύει να διερευνήσει την δυναμική συμπεριφορά και επιτελεστικότητα παλαιού τύπου ανεπαρκών κατασκευών. Αυτό το παραδοτέο αφορά στα καταγεγραμμένα αποτελέσματα και φωτογραφίες βλαβών της υφιστάμενης κατασκευής, μέσα στα πλαίσια του πακέτου εργασίας της πειραματικής δυναμικής αξιολόγησης της κατασκευής προς την ολιστική ανακαίνιση. Η κατασκευή είναι πλήρως εντοπισμένη με εσωτερικά επικολλημένα παραμορφωσιόμετρα στην εξωτερική επιφάνεια διαμήκων οπλισμών υποστυλωμάτων και με εσωτερικά έξυπνα αδρανή που περιέχουν αισθητήρες PZT. Επιπλέον, περιλαμβάνονται εξωτερικά επικολλημένα PZTs, επιταχυνσιόμετρα, επιμηκυνσιόμετρα εκτυλισσόμενου σύρματος καθώς και εξωτερικά επικολλημένα παραμορφωσιόμετρα. Εκτελούνται δύο είδη πειραματικών δοκιμών στη σεισμική τράπεζα: σεισμικές διεγέρσεις και δοκιμές για τον προσδιορισμό των δυναμικών χαρακτηριστικών πριν και μετά από αυτές. Οι σεισμικές διεγέρσεις περιλαμβάνουν ιστορικό βασισμένο στον σεισμό της Θεσσαλονίκης 1978 με σταδιακά αυξανόμενη ένταση (μέγιστη επιτάχυνση της διέγερσης) από 0,1g έως 1,1g. Παρατηρείται επουσιώδης ρηγμάτωση του σκυροδέματος και μερική αποκόλληση της τοιχοπλήρωσης από το περιβάλλον πλαίσιο σκυροδέματος, χωρίς κατάρρευση της τοιχοπλήρωσης, σε επίπεδα επιτελεστικότητας ΟΚΛ. Τα PZTs εμφανίζουν αξιοσημείωτη ευαισθησία στην ανίχνευση επουσιωδών βλαβών μέσα στο σκυρόδεμα ή στην διεπιφάνεια τοιχοπλήρωσης – σκυροδέματος. Τέλος, η έκθεση αυτή συγκεντρώνει τα αποτελέσματα των μηχανικών ιδιοτήτων των υλικών σκυροδέματος, χάλυβα, τούβλου, κονιάματος χτισίματος των τούβλων, καθώς και της διατμητικής ικανότητας της διεπιφάνειας τούβλου-κονιάματος σε χτισμένες τριπλέτες. Στο επόμενο παραδοτέο Π25 θα παρουσιαστεί η αποτίμηση της επιτελεστικότητας της δυναμικής συμπεριφοράς της υφιστάμενης κατασκευής, έτσι ώστε στη συνέχεια να κατασκευαστεί η ολιστική ανακαίνιση με Κάθετα Δάση.

Λέξεις κλειδιά: πείραμα, σεισμική τράπεζα, οπλισμένο σκυρόδεμα, τοιχοπληρώσεις, τούβλα, σεισμική διέγερση, Κάθετα Δάση, ανθεκτικότητα, ανανηπτικότητα, ανακαίνιση, δομικός, δομοστατικός, παρακολούθηση δομικής υγείας SHM, PZT

1) Earthquake excitation time history and instrumentation

The excitation executed by the shake table of DUTH is based on the severe Thessaloniki (Volvi) earthquake of 1978.

The building is excited gradually to the damage initiation level of the regular as-built infill walls, than steel yielding in longitudinal reinforcements of the columns. The concrete frames will suffer only concrete cracking. As the brick wall infills that are excited in plane, cover only a part of the frame span and they have low length compared to their height, higher lateral drifts are expected.

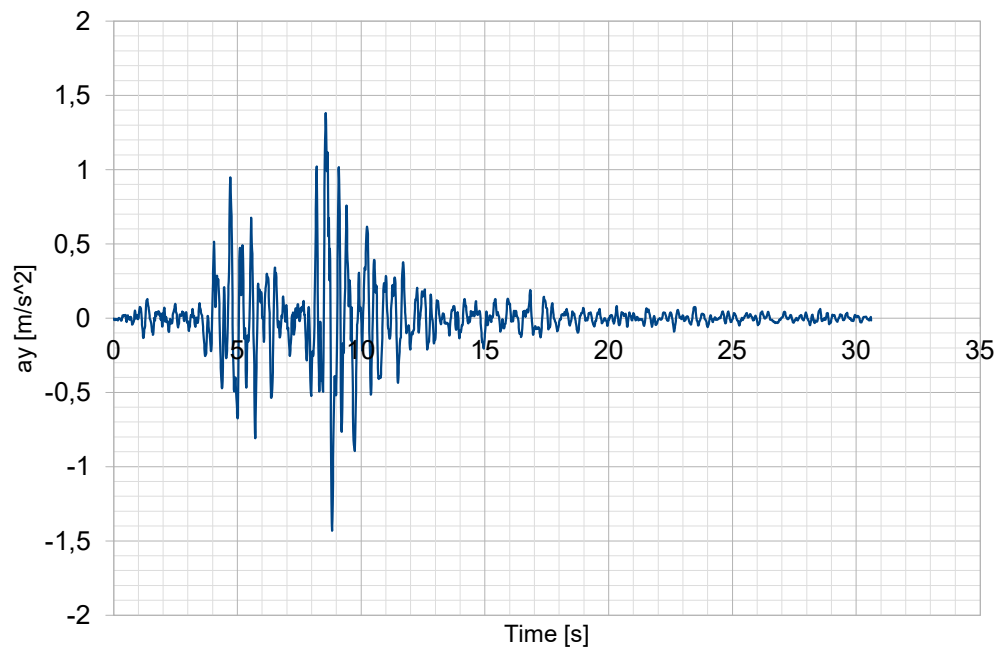


Figure 1.1 Basis for the time history executed by the DUTH seismic table (ay component of Thessaloniki (Volvi) 1978 earthquake excitation record)

The instrumentation includes 12 uniaxial accelerometers (ACC) located at the 4 positions indicated in Figure 1.2. Three accelerometers provide the three components of acceleration at each point, that is in- and out-of-plane accelerations at the center of the full infills, as well as the accelerations of the top slab and of the bottom foundation beam. Four draw wire sensors (W) measure the horizontal displacement of the foundation beams and of the top slab as depicted in Figure 1.3. Further, 2 draw wire sensors measure the change of distance along the 2 diagonals of the two partial infills (in-plane deformation) Figure 1.3 (total of 4 draw wire meters). Draw-wire displacement sensors measure linear displacement using a highly flexible and relatively rigid under tension, steel wire. The cable drum is attached to a sensor element which provides a displacement-proportional output signal. During construction, 16 strain gauges (S) were glued on the longitudinal reinforcement of the columns (see Figure 1.5-1.10). Two strain gauges were placed on the lower side of each column and two on the upper side. Finally, 48 PZTs (P) were placed inside the concrete mass of the columns and of the top slab, as well as on the infill walls (more details can be found in 2 and in 3.12).

Accelerometers

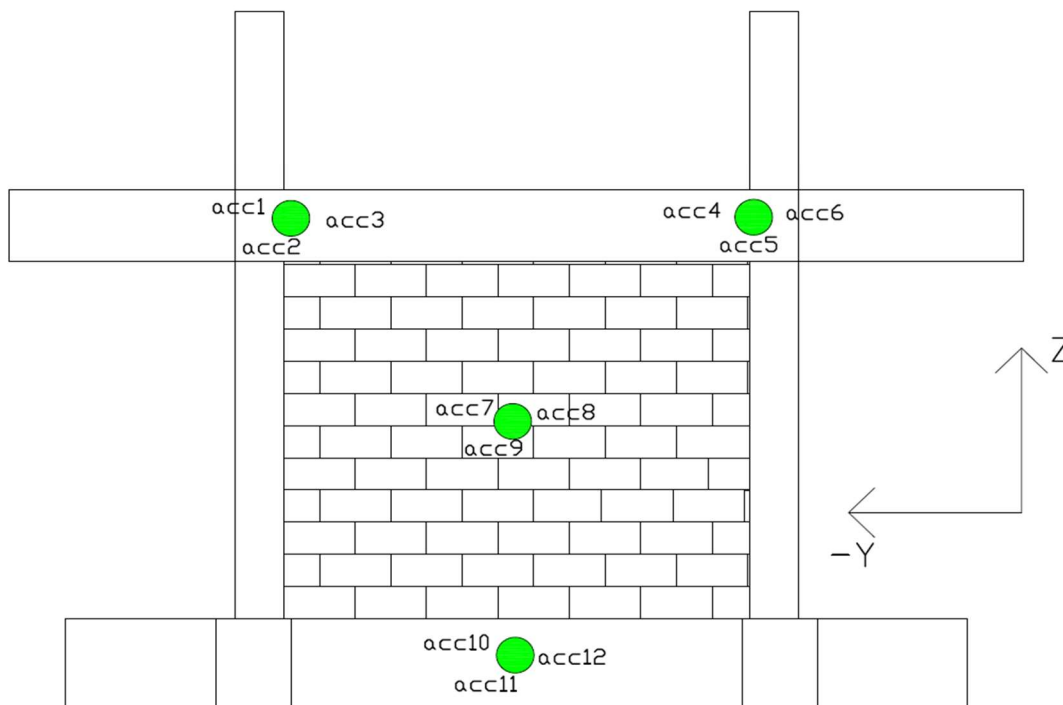


Figure 1.2 Position of accelerometers (specimen's view perpendicular to the direction of the seismic table movement)

Draw wire sensors

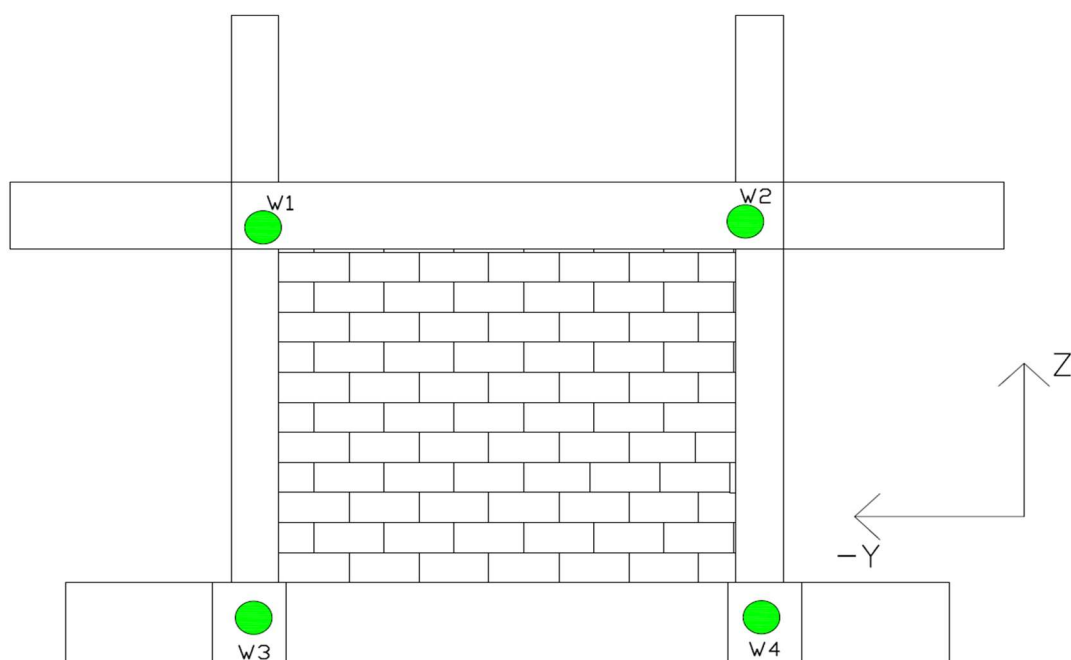


Figure 1.3 Position of the draw wire sensors on the concrete structure slab and foundation beams (specimen's view parallel to the direction of the seismic table movement)

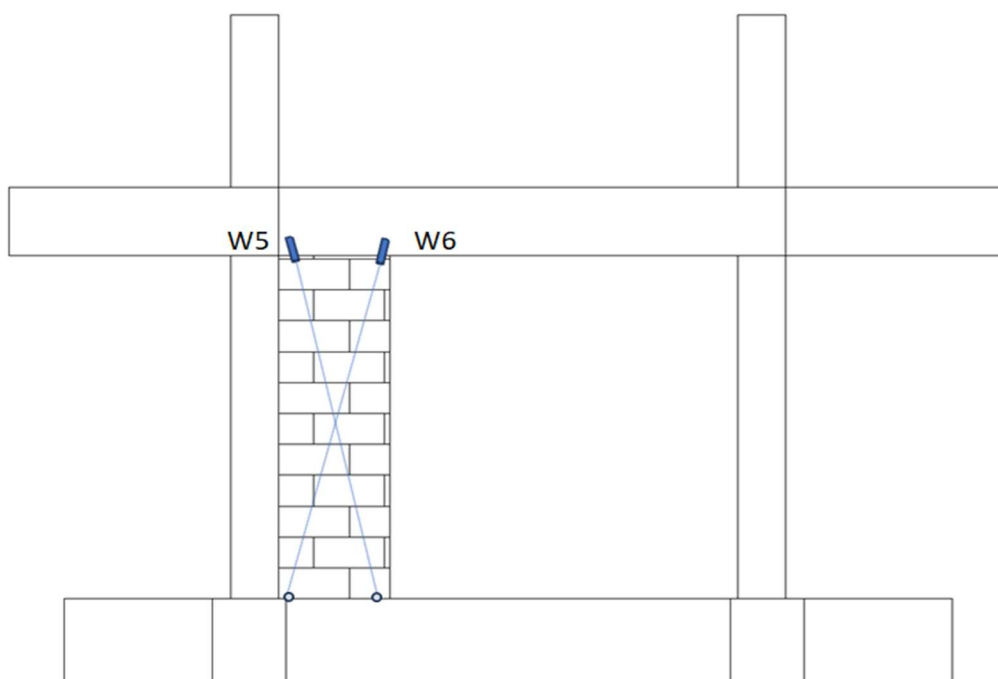


Figure 1.4 Position of the diagonal draw wire sensors, along the diagonals of the partial infill (specimen's view parallel to the direction of the seismic table movement)

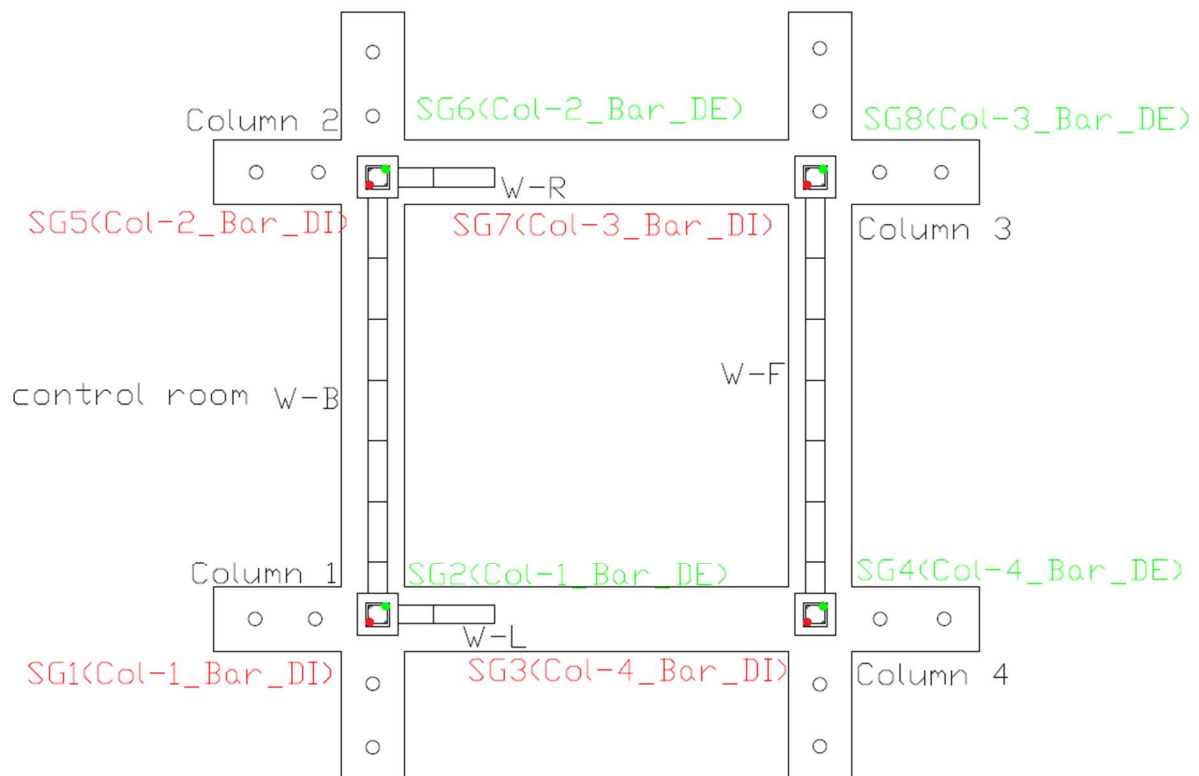


Figure 1.5 Floor plan with strain gauges at the bottom of the columns (DE)

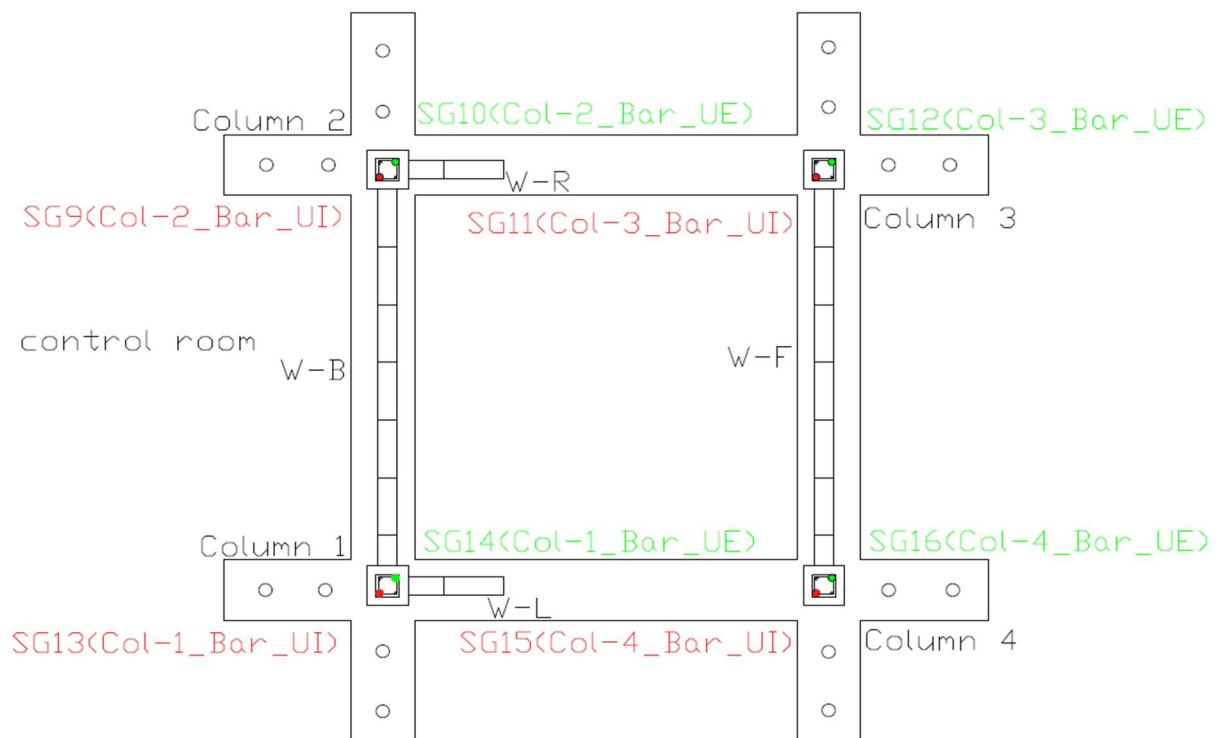


Figure 1.6 Floor plan with strain gauges at the top of the columns (UE)

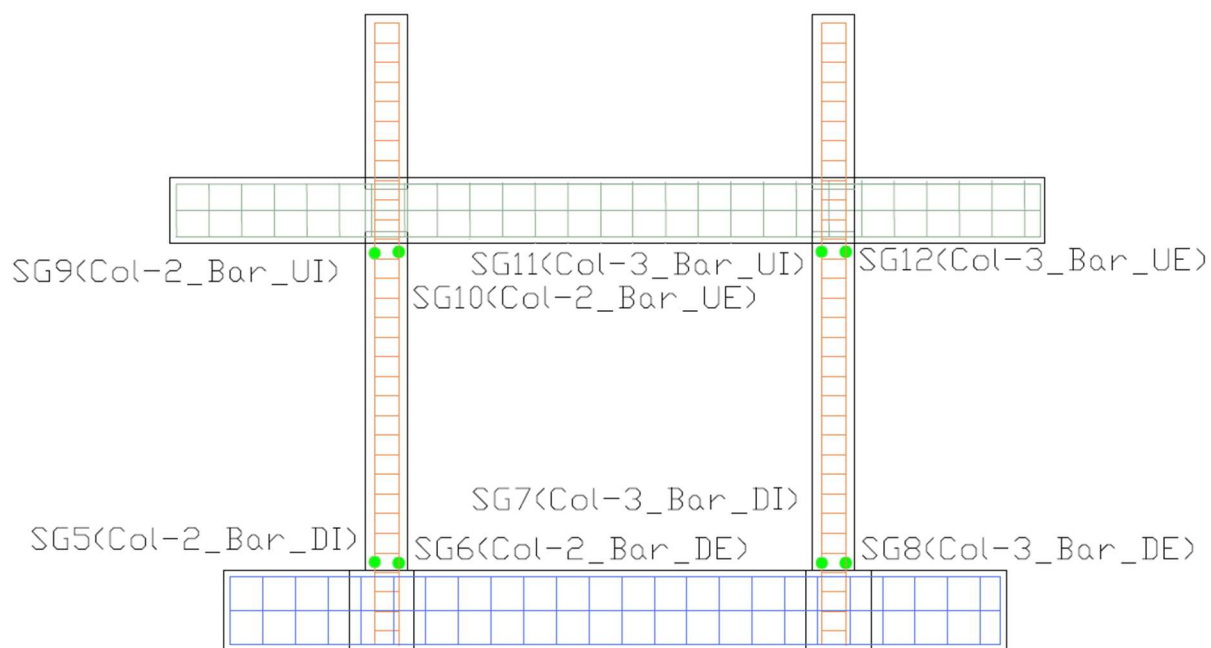


Figure 1.7 View of the structure with strain gauges in frame of Columns 2-3

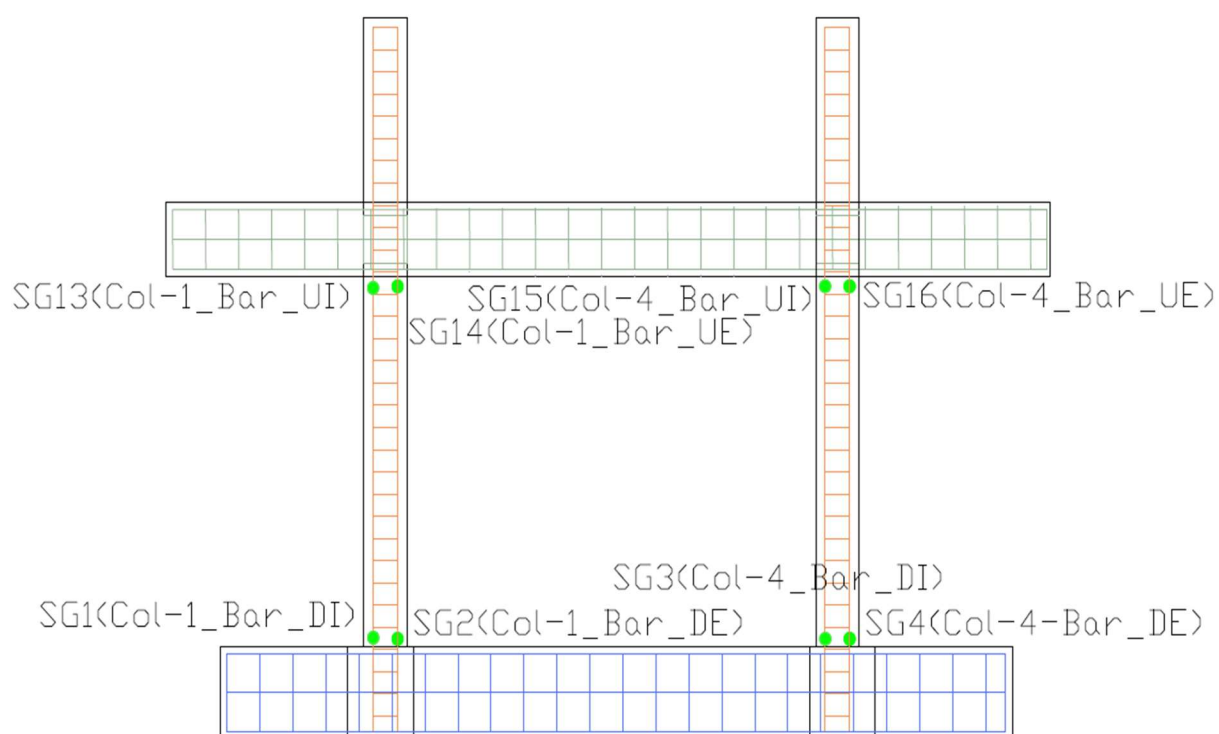


Figure 1.8 View of the structure with strain gauges in frame of columns 1-4

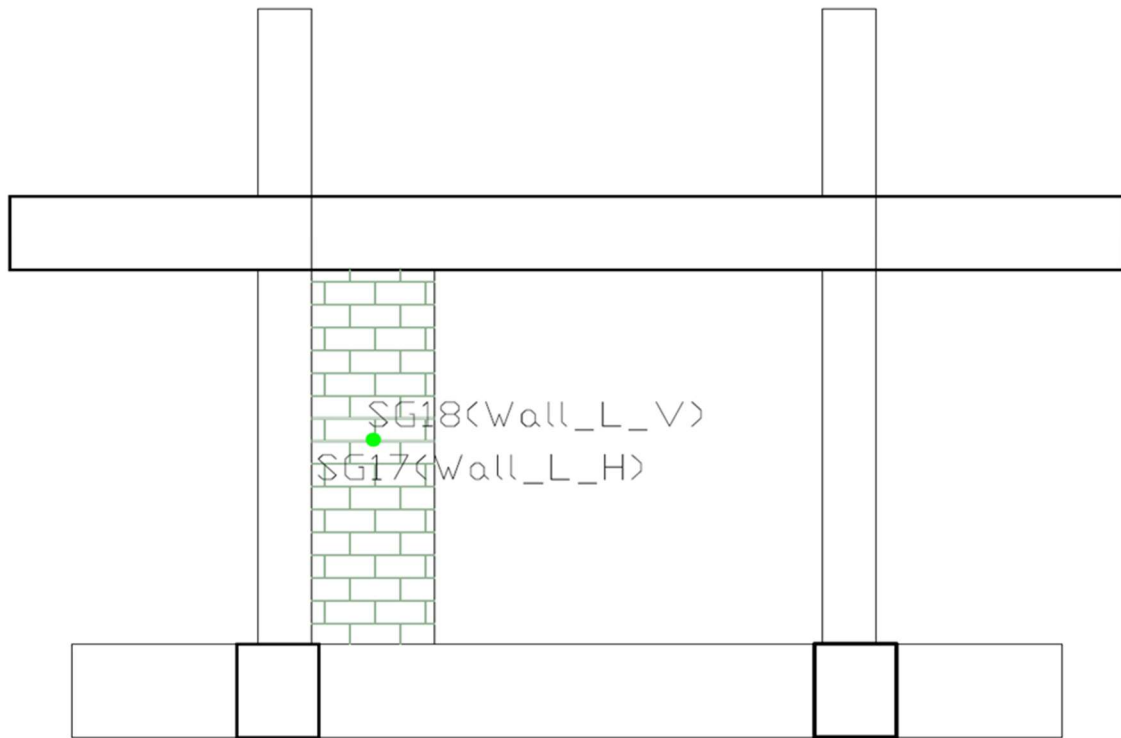


Figure 1.9 View of the infill wall with strain gauges in frame 1-4

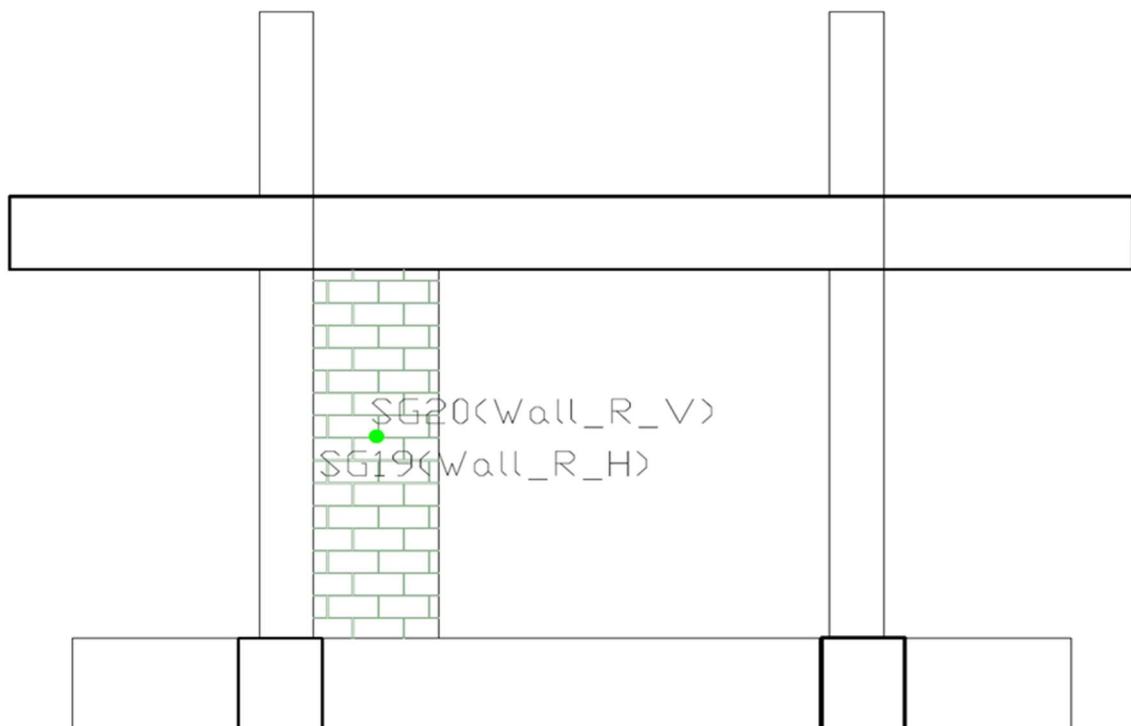


Figure 1.10 View of the infill wall with strain gauges in frame 2-3

Table 1.1: Detailed list of accelerometers, draw wire meters and strain gauges placed inside and on the structure

Ch No.	Channel name	Type of instrument	Measured quantity (units)	Position
1	ACC 1	Accelerometer	Acceleration (g)	On the slab, on the left corner, dir. (x)
2	ACC 2			On the slab, on the left corner, dir. (y)
3	ACC 3			On the slab, on the left corner, dir. (z)
4	ACC 4			On the slab, on the right corner, dir. (x)
5	ACC 5			On the slab, on the right corner, dir. (y)
6	ACC 6			On the slab, on the right corner, dir. (z)
7	ACC 7			On the infill, on the center, dir. (x)
8	ACC 8			On the infill, on the center, dir. (y)
9	ACC 9			On the infill, on the center, dir. (x)
10	ACC 10			On the foundation, on the center, dir. (x)
11	ACC 11			On the foundation, on the center, dir. (y)
12	ACC 12			On the foundation, on the center, dir. (z)
13	W 1	Draw wire sensors	Length (mm)	On the slab, on the left side
14	W 2			On the slab, on the right side
15	W 3			On the foundation, on the left side
16	W 4			On the foundation, on the right side
17	W 5			along the partial masonry infill diagonal
18	W 6			along the partial masonry infill diagonal
19	W 7			along the partial masonry infill diagonal
20	W 8			along the partial masonry infill diagonal
21	S1	Strain gauges	Strain	In the longitudinal reinforcement, on the underside
22	S2			
23	S3			
24	S4			
25	S5			
26	S6			
27	S7			
28	S8			
29	S9			In the longitudinal reinforcement, on the upper side
30	S10			
31	S11			
32	S12			
33	S13			
34	S14			
35	S15			
36	S16			

37	S17			On the centre of partial masonry 1 along direction x
38	S18			On the centre of partial masonry 1 along direction z
39	S19			On the centre of partial masonry 2 along direction x
40	S20			On the centre of partial masonry 2 along direction z

2) Development of a smart PZT monitoring system for the vertical forest (VF) structure

The instrumentation includes a total of 48 PZT sensors inside and on the structure. Figures 2.1-2.3 highlight the main positions of the PZT sensors from the columns to the top slab. More details with characteristic figures and photos of the PZTs can be found in section 3.12.

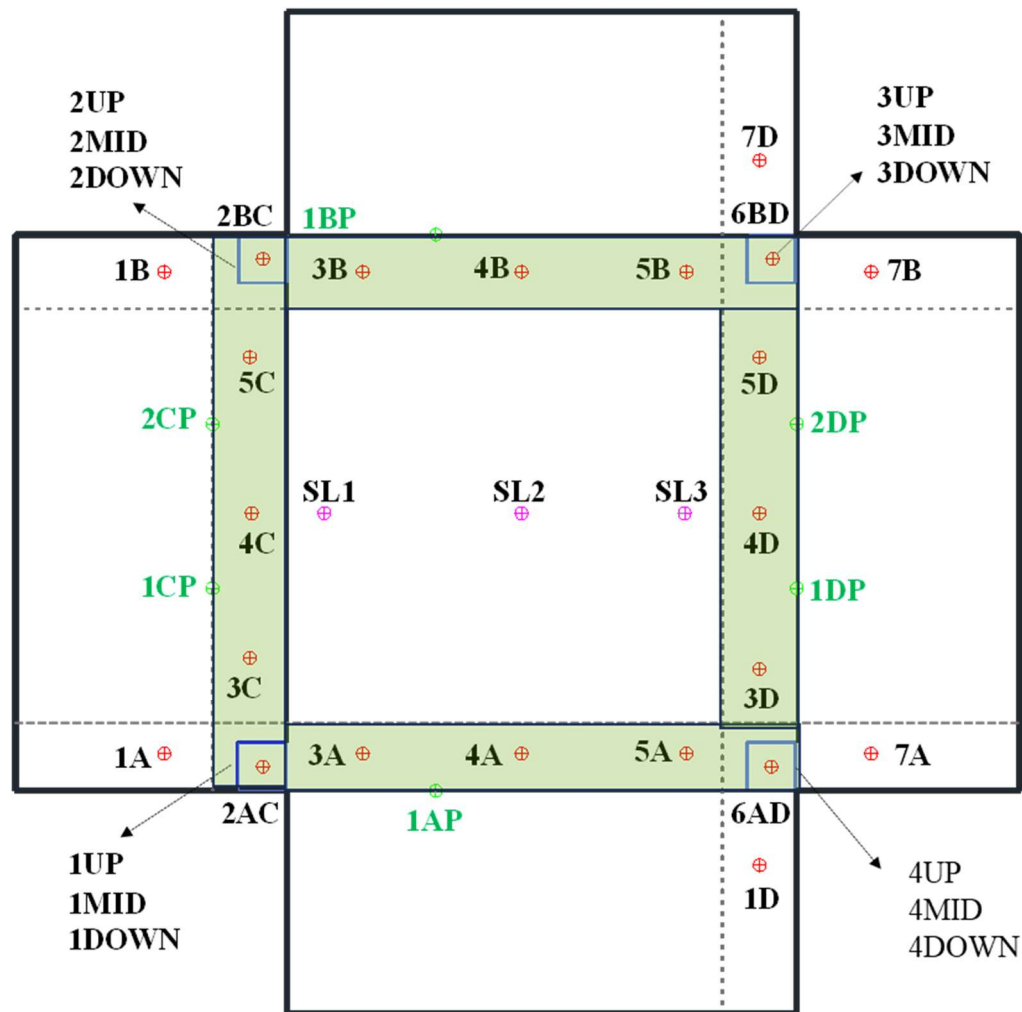


Figure 2.1 Location of the PZT sensors inside the beams

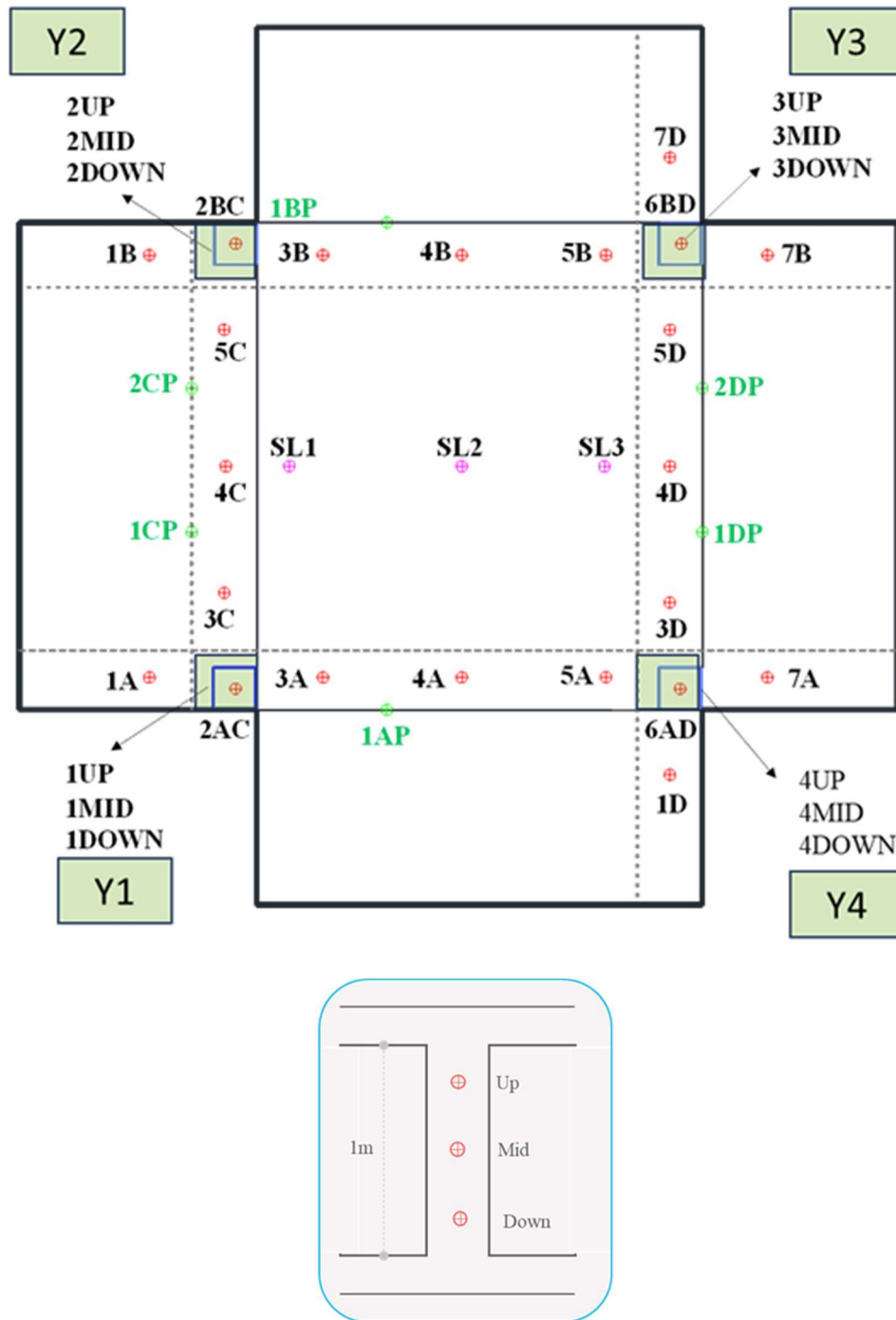


Figure 2.2 Location of the PZTs inside the columns

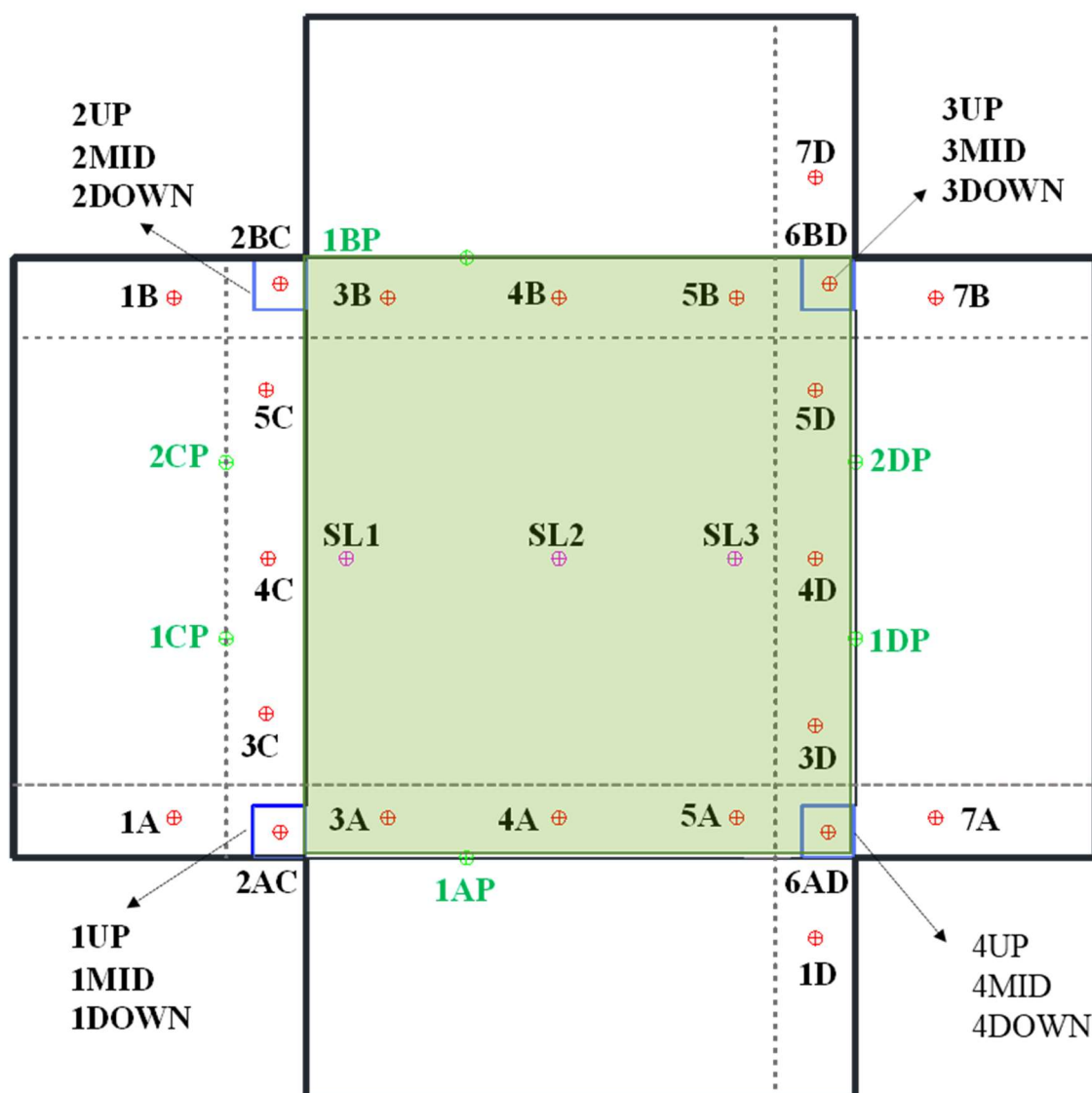


Figure 2.3 Location of PZT sensors inside the slab

3) APPLIED TESTING METHODOLOGY

For the purpose of the experimental investigations two types of tests have been performed, i.e. dynamic shake table tests and tests for determination of dynamic characteristics similarly to earlier seismic tests performed in INMASPOL by Rousakis et al. 2020. The dynamic shake table tests comprised of gradually increasing maximum input intensity level (peak acceleration of the excitation) from 0,1g to 1,1g based on the adopted earthquake Thessaloniki 1978. The 1,1g intensity was necessary in order to achieve SLS level damages on the brick infill walls and minor cracking of the concrete, while remaining below the yield strain of the internal longitudinal steel reinforcement of the columns. Major indicator for the successive levels of the peak acceleration was the identified damages and the lateral drift of the structure measured from the foundation to the top slab.

On the following Table, a complete list of performed dynamic and seismic tests is shown for the first phase of testing presented in this report. ST1 refers to Seismic Test 1. WNb0,1g refers to White Noise Test before the execution of Thessaloniki – based excitation with maximum acceleration of 0,1g. WNb0,1g has a maximum acceleration of 0,08g. EQ0,1g refers to earthquake excitation with maximum acceleration of 0,1g. Similarly, WNb0,2g has a maximum acceleration of 0,08g and is identical to WNb0,1g or WNb0,5g or WNb0,8g or WNb1,1g or WNa1,1g which stands for White Noise Test after the last earthquake excitation of 1,1g. Finally, EQ0,2g or EQ0,5g or EQ0,8g or EQ1,1g refer to Earthquake excitation based on Thessaloniki recording with maximum acceleration of 0,2g or 0,5g or 0,8g or 1,1g accordingly. Therefore, before and after each earthquake excitation, the structure was excited through the whole range of frequencies of the structure under low acceleration intensity in order to investigate changes in eigen periods of the structure.

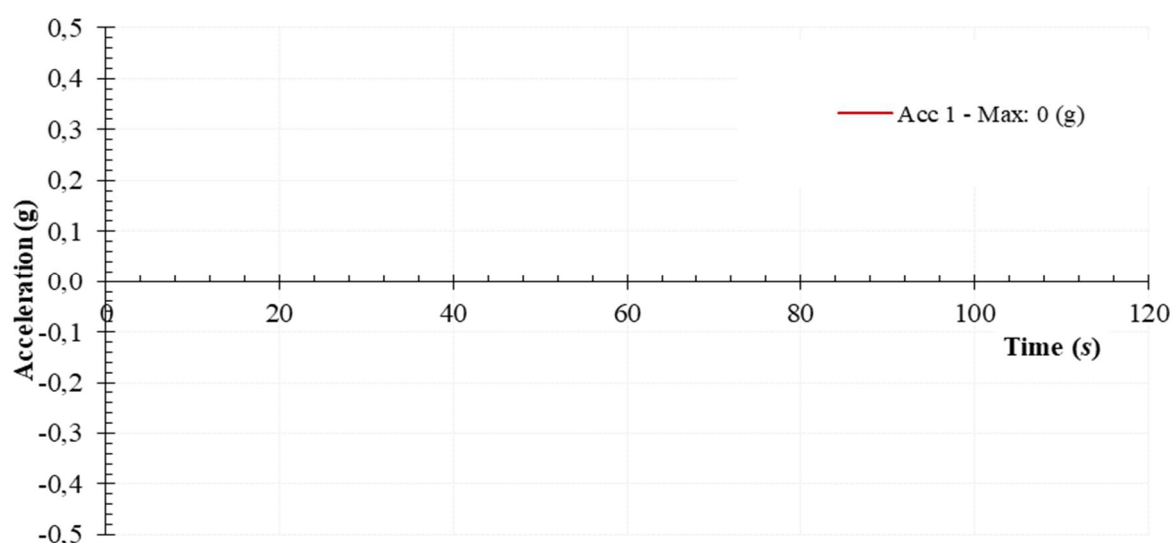
Table 3.1: List of all performed tests

Performed tests			
Test No.	Name	Type of excitation	Intensity (g)
Phase A			
ST1	WNb0,1g	White noise	0,08
ST2	EQ0,1g	Earthquake	0,10
ST3	WNb0,2g	White noise	0,08
ST4	EQ0,2g	Earthquake	0,20
ST5	WNb0,5g	White noise	0,08
ST6	EQ0,5g	Earthquake	0,50
ST7	WNb0,8g	White noise	0,08
ST8	EQ0,8g	Earthquake	0,80
ST9	WNb1,1g	White noise	0,08
ST10	EQ1,1g	Earthquake	1,10
ST11	WNa1,1g	White noise	0,08

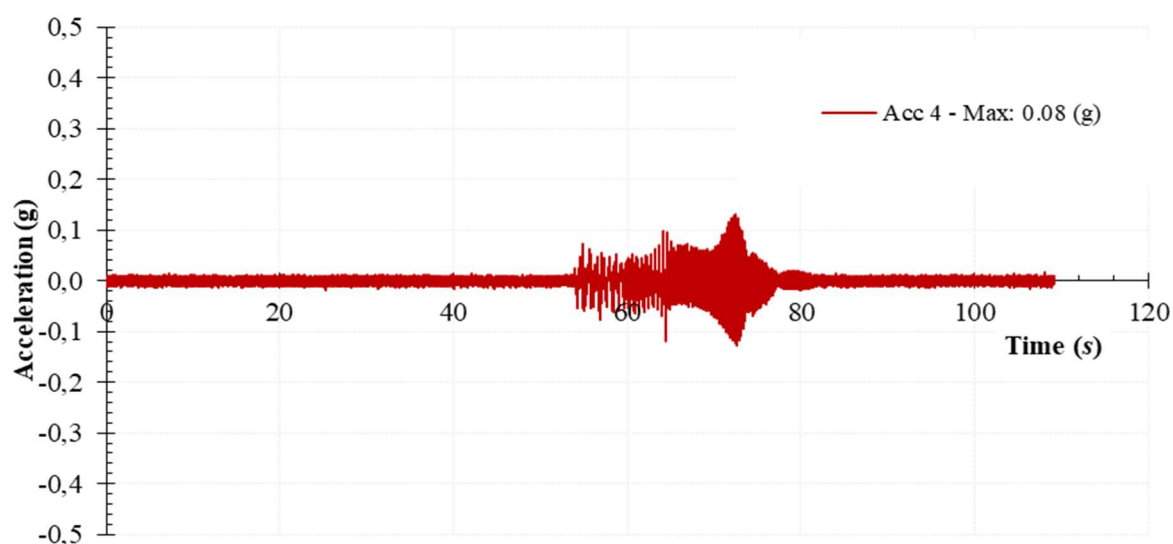
3.1) White noise before EQ0,1g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for white noise test before EQ0,1g. The max acceleration at the slab level on the accelerometer acc4 is 0,08g. The max acceleration at the foundation level on the accelerometer acc10 is 0,07g. Instrument Acc1 was not properly connected.

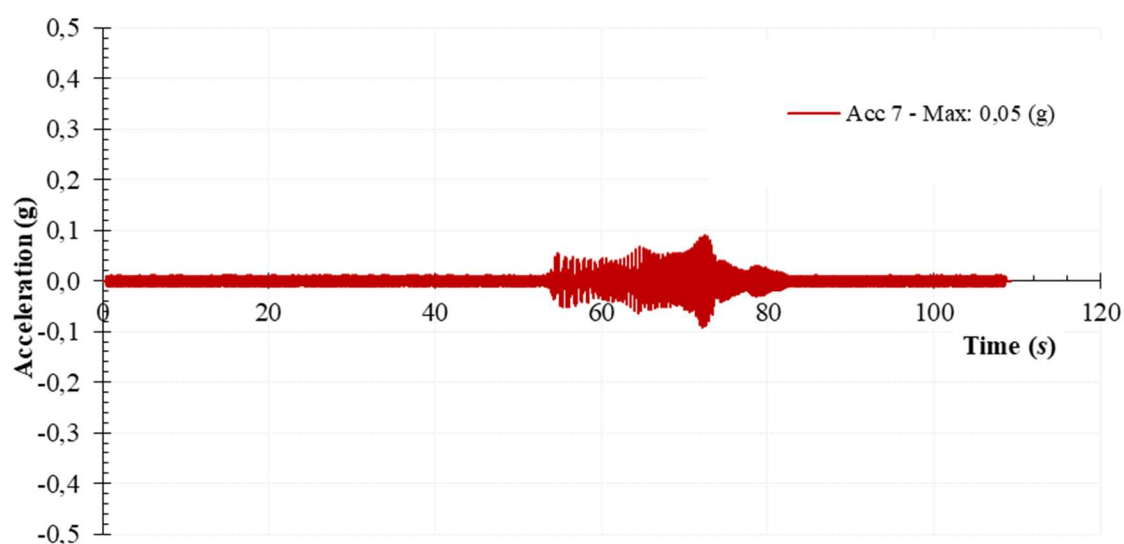


(a)

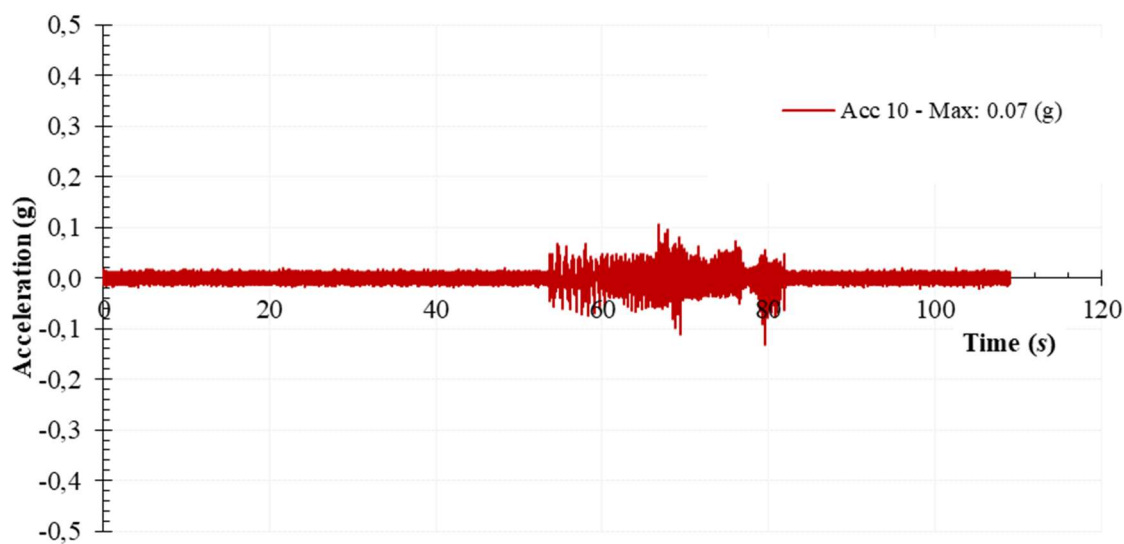


(b)

Figure 3.1.1 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 1 (b) Accelerometer 4

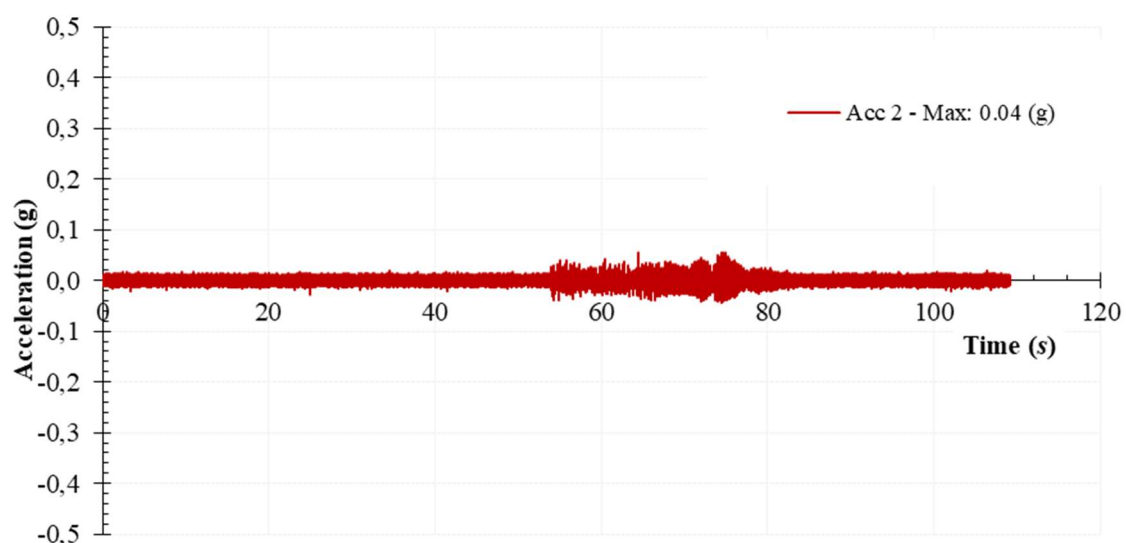


(a)

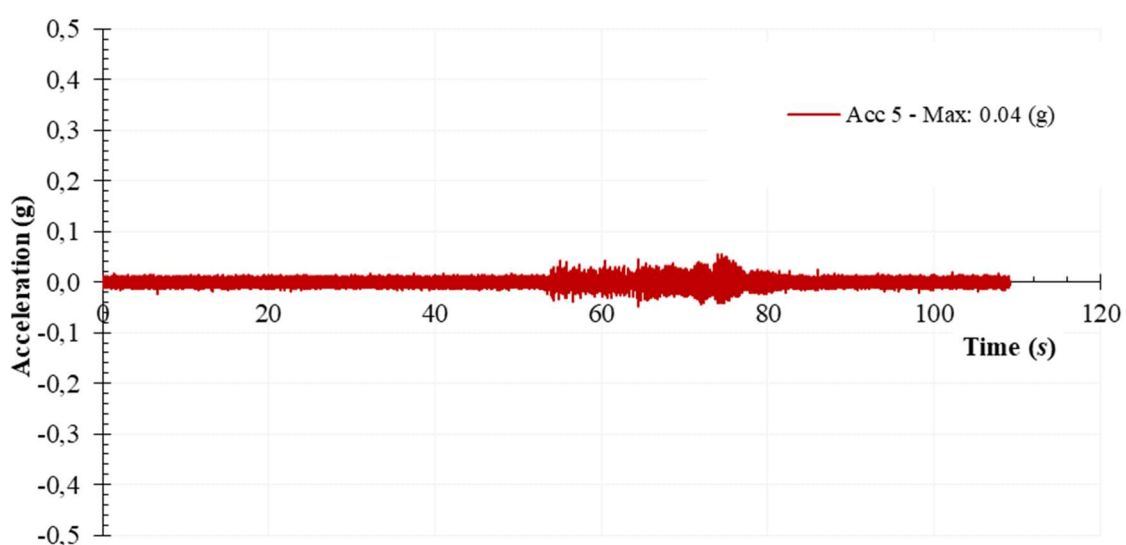


(b)

Figure 3.1.2 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

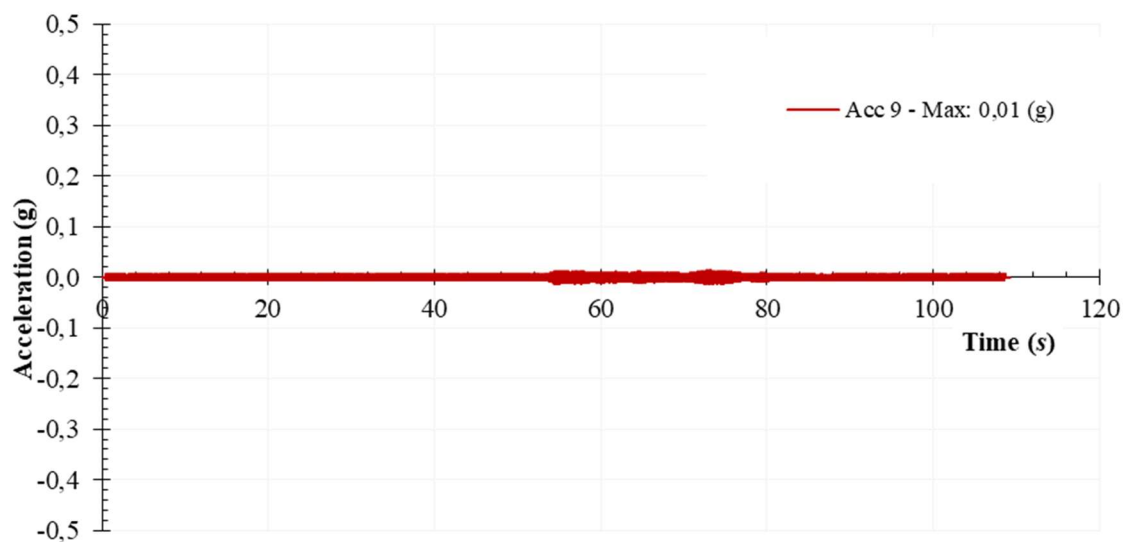


(a)

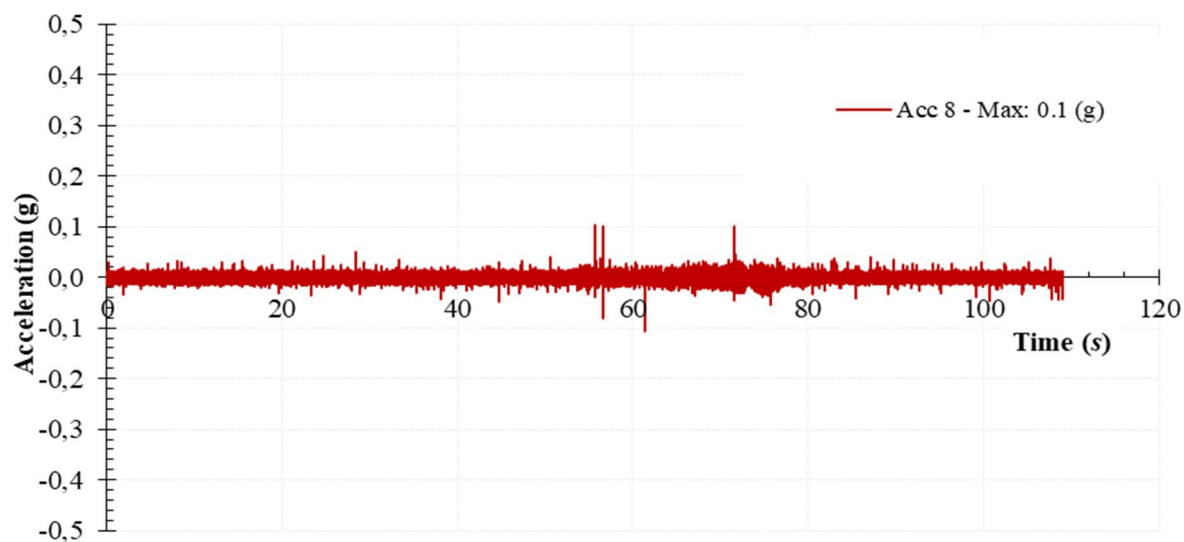


(b)

Figure 3.1.3 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

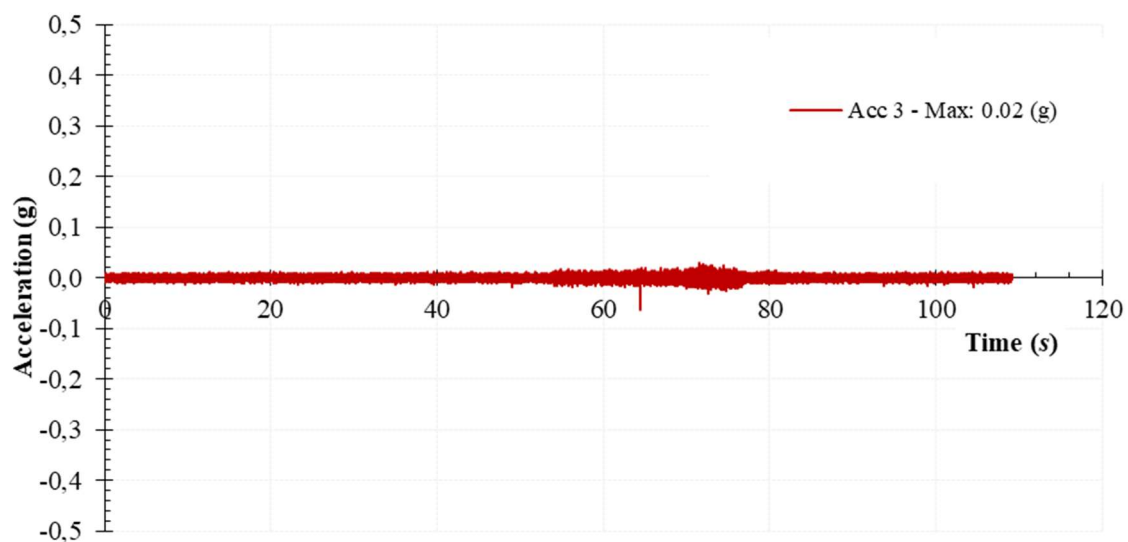


(a)

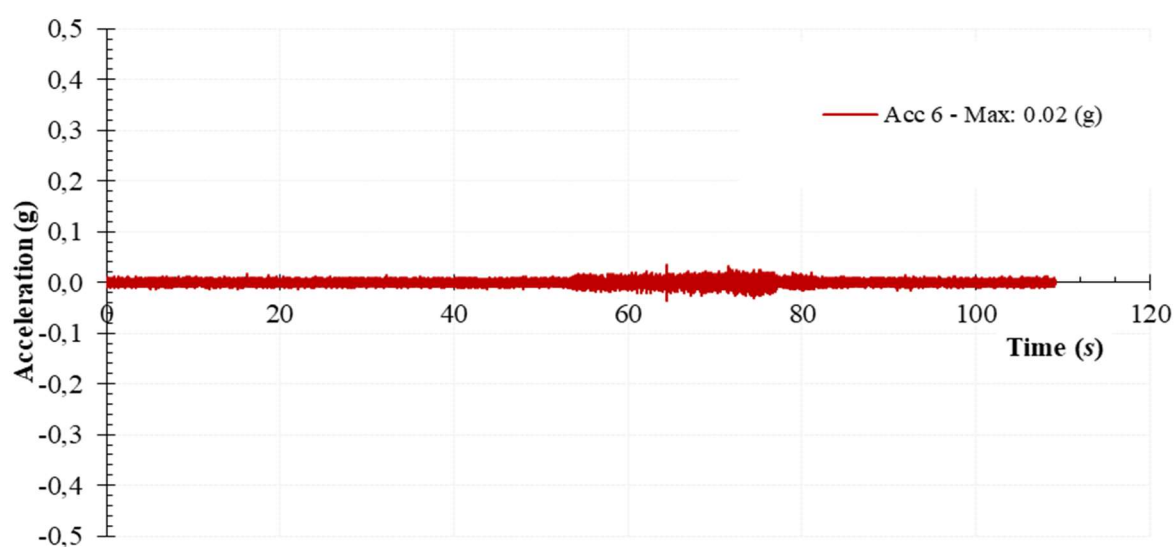


(b)

Figure 3.1.4 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 9 (b) Accelerometer 8

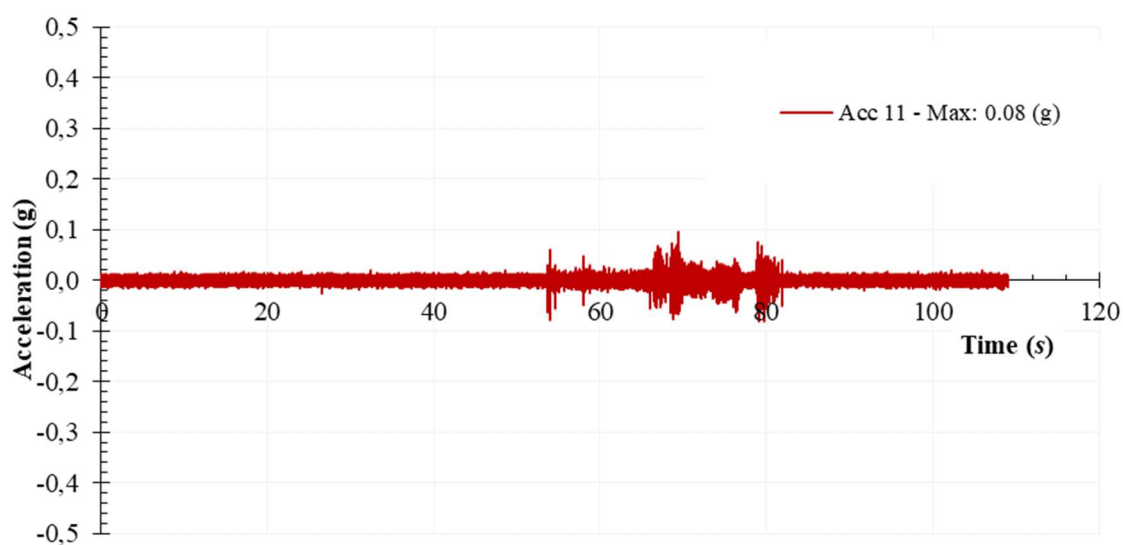


(a)

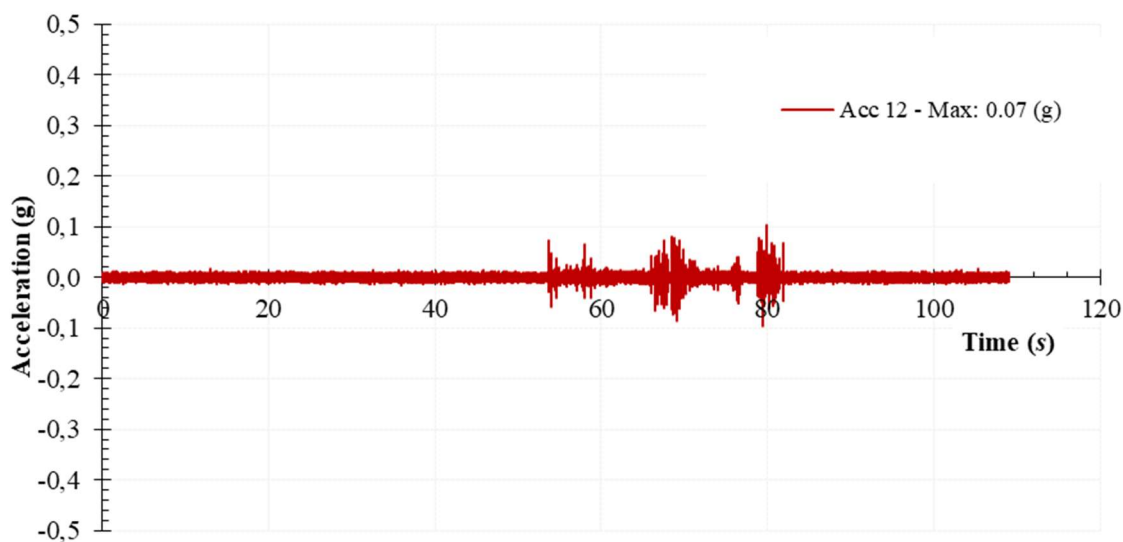


(b)

Figure 3.1.5 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 3 (b) Accelerometer 6

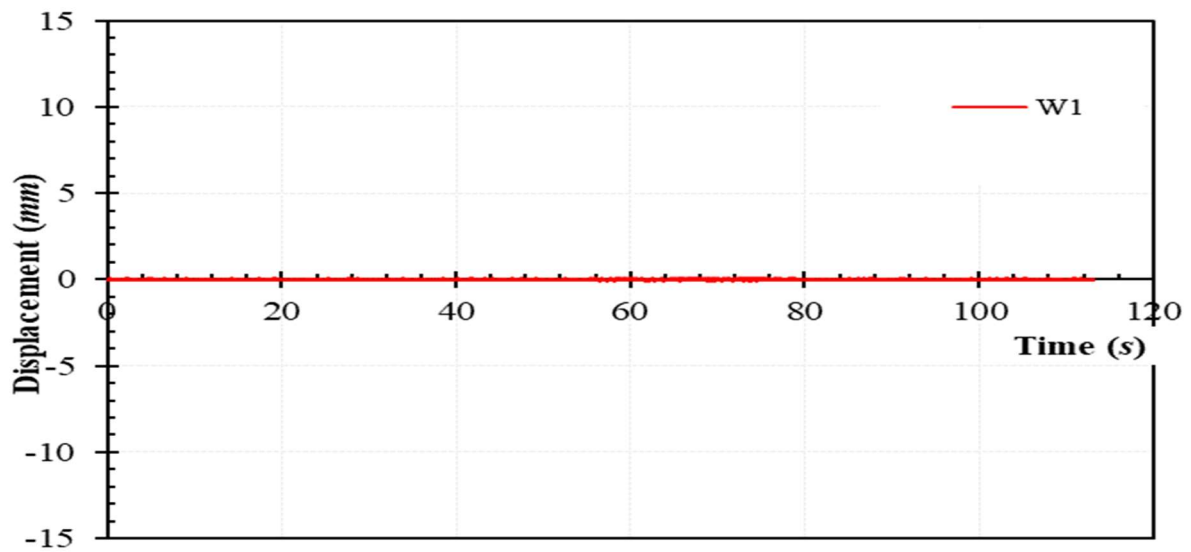


(a)

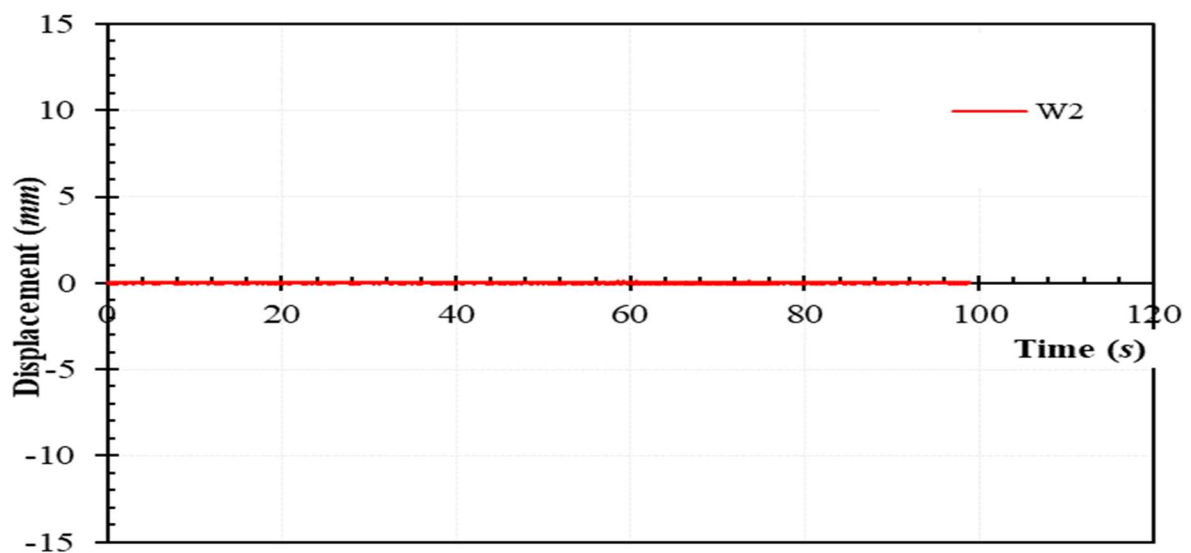


(b)

Figure 3.1.6 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Accelerometer 11 (b) Accelerometer 12



(a)



(b)

Figure 3.1.7 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Draw wire sensor W1 and (b) Draw wire sensor W2

Figure 3.1.7 shows draw wire sensors W1 and W2. More specifically, draw wire sensor W1 is located on the slab, on the left side and draw wire sensor W2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor W1 is 0,12 mm while the minimum is -0,14 mm. The maximum movement detected by draw wire sensor W2 is 0,13 mm while the minimum is -0,12 mm.

W1

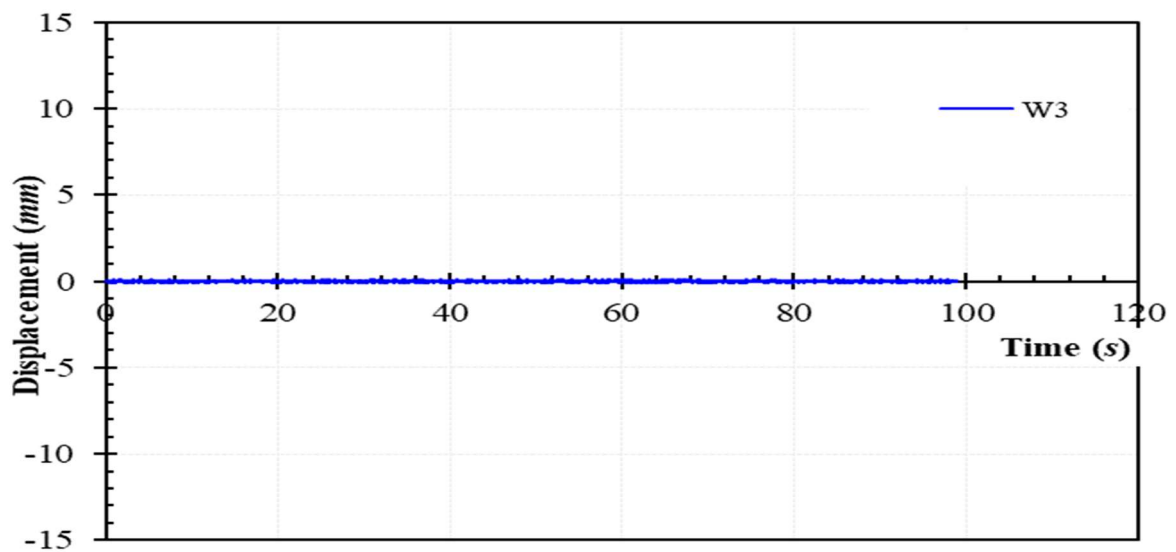
Max: 0,12 mm

Min: -0,14 mm

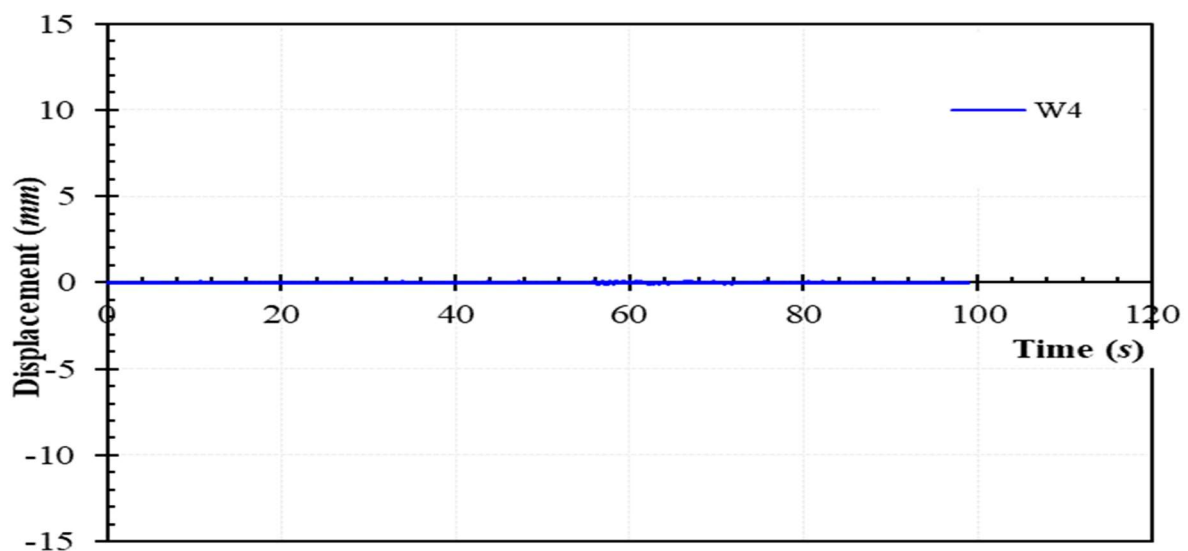
W2

Max: 0,13 mm

Min: -0,12 mm



(a)



(b)

Figure 3.1.8 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Draw wire sensor W3 and (b) Draw wire sensor W4

Figure 3.1.8 shows draw wire sensors W3 and W4. More specifically, draw wire sensor W3 is located on the foundation, on the left side and draw wire sensor W4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor W3 is 0,13 mm while the minimum is -0,12 mm. The maximum movement detected by draw wire sensor W4 is 0,12 mm while the minimum is -0,11 mm.

W3

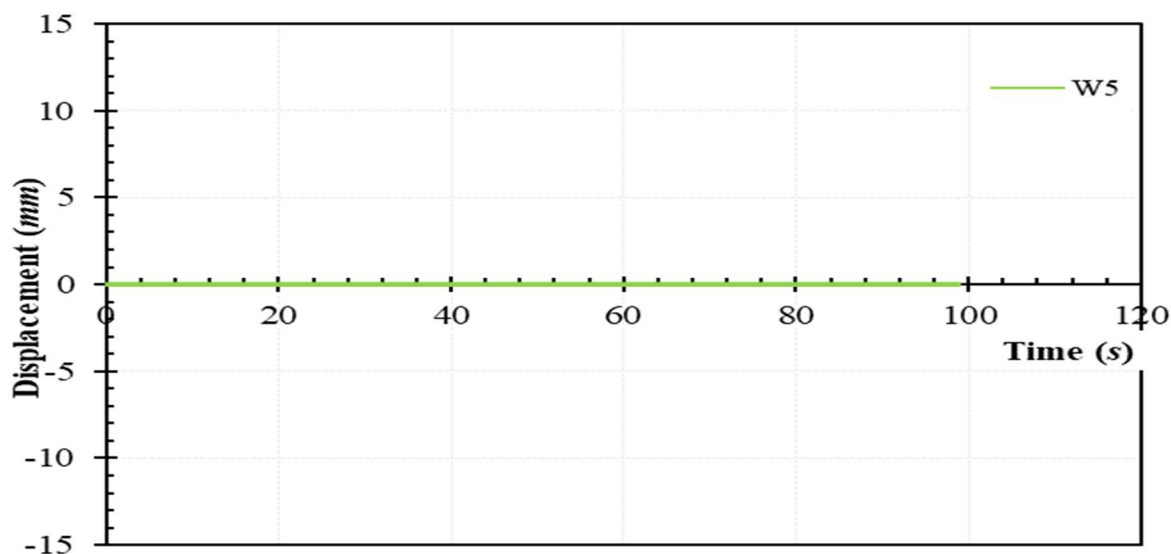
Max: 0,13 mm

Min: -0,12 mm

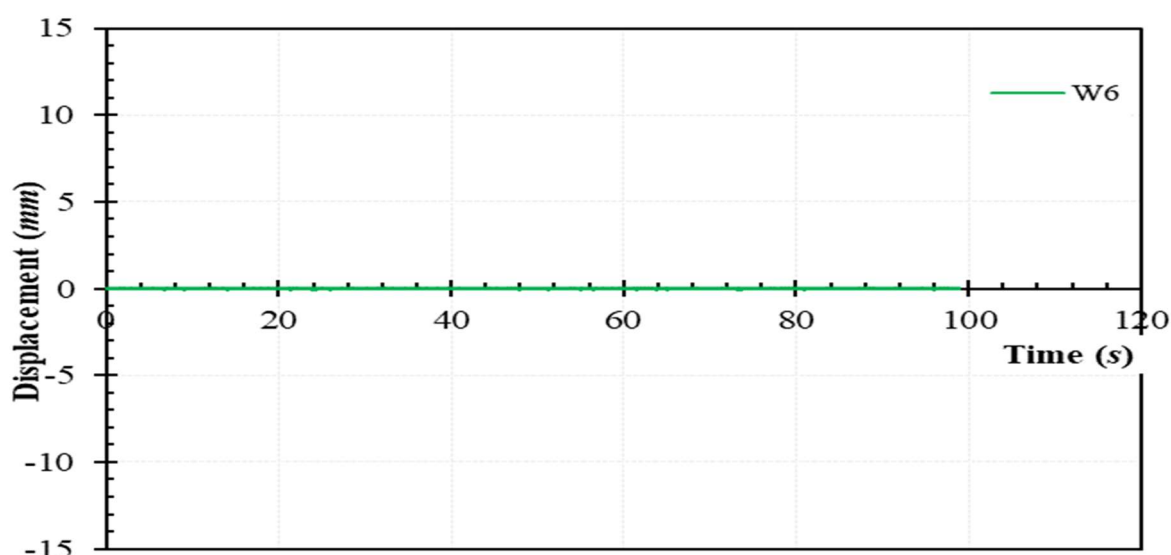
W4

Max: 0,12 mm

Min: -0,11 mm



(a)



(b)

Figure 3.1.9 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Draw wire sensor W5 and (b) Draw wire sensor W6

Figure 3.1.9 shows draw wire sensors W5 and W6. More specifically, draw wire sensor W5 is located along the partial masonry infill diagonal and draw wire sensor W6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W5 is 0,09 mm while the minimum is -0,09 mm. The maximum movement detected by draw wire sensor W6 is 0,07 mm while the minimum is -0,07 mm.

W5

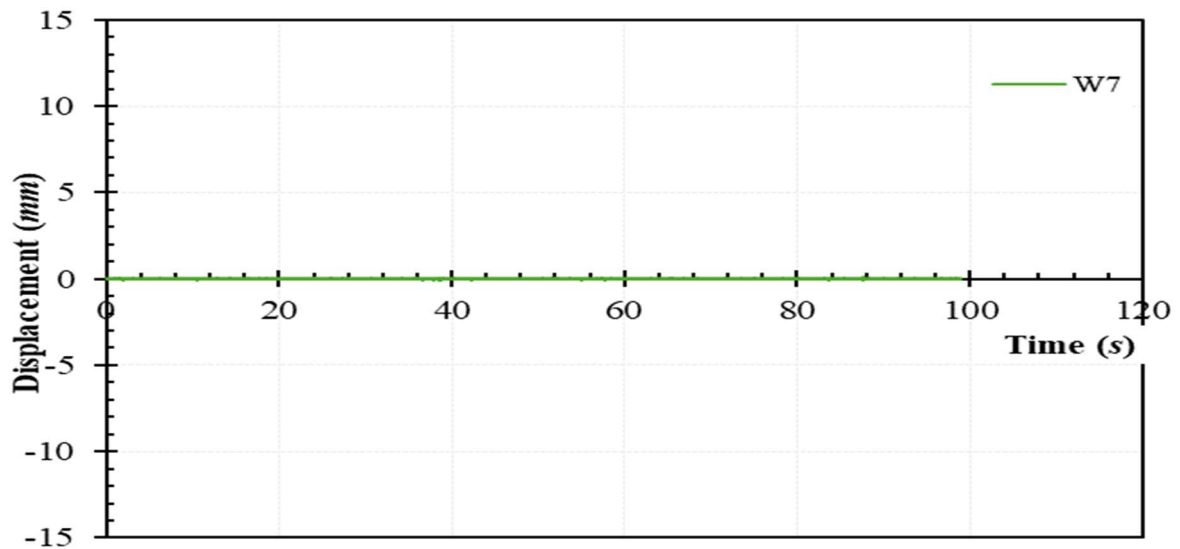
Max: 0,09 mm

Min: -0,09 mm

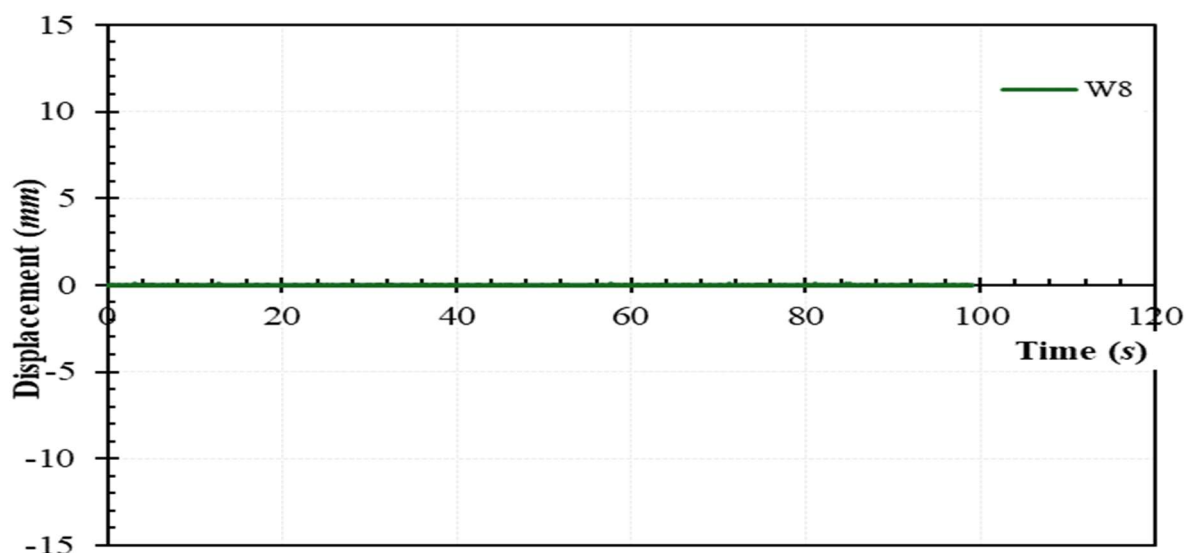
W6

Max: 0,07 mm

Min: -0,07 mm



(a)



(b)

Figure 3.1.10 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Draw wire sensor W7 and (b) Draw wire sensor W8

Figure 3.1.10 shows draw wire sensors W7 and W8. More specifically, draw wire sensor W7 is located along the partial masonry infill diagonal and draw wire sensor W8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W7 is 0,09 mm while the minimum is -0,08 mm. The maximum movement detected by draw wire sensor W8 is 0,07 mm while the minimum is -0,07 mm.

W7

Max: 0,09 mm

Min: - 0,08 mm

W8

Max: 0,07 mm

Min: - 0,07 mm

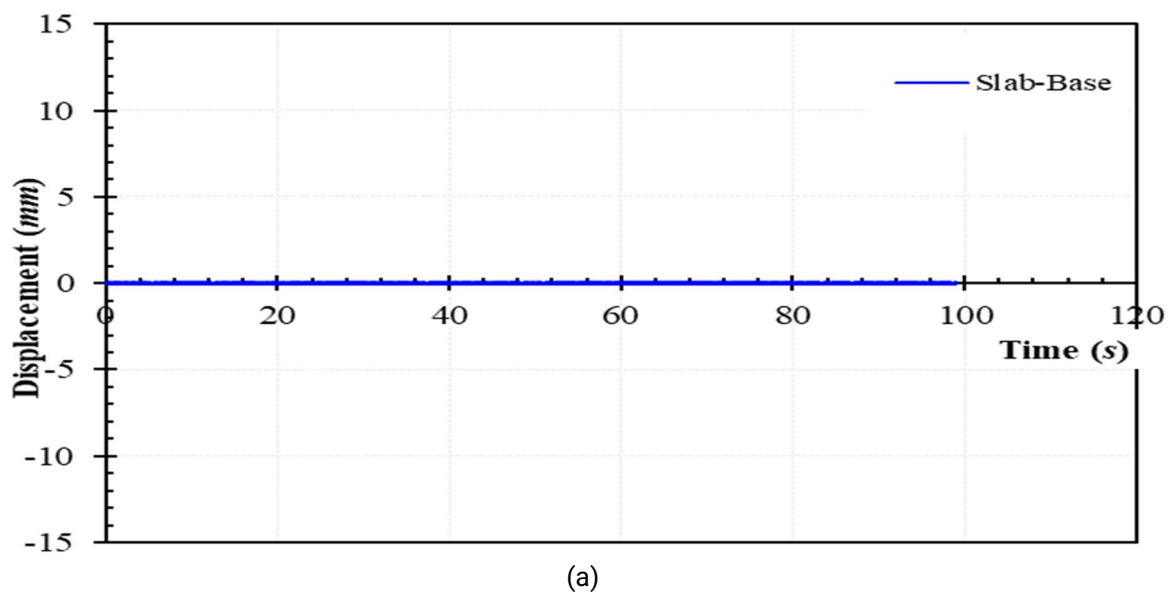


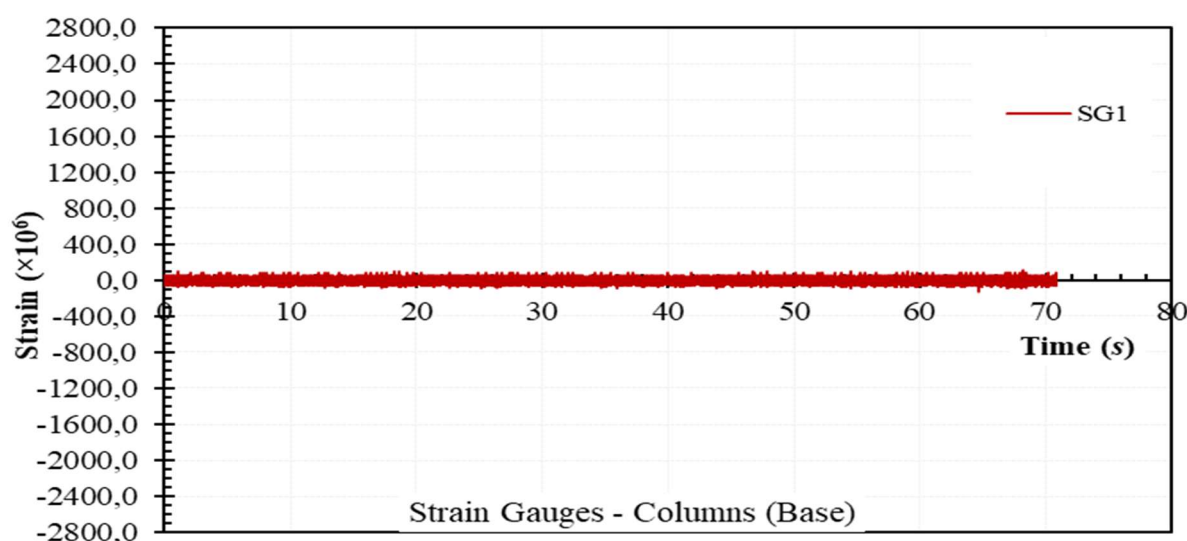
Figure 3.1.11 Characteristic results for phase A (white noise before 0,1g earthquake): (a) Diagram of displacement Slab – Base

Figure 3.1.11 shows slab – base displacement. More specifically, the maximum drift detected is 0,07 ‰ while the minimum is -0,07 ‰. The residual drift is -0,02 mm.

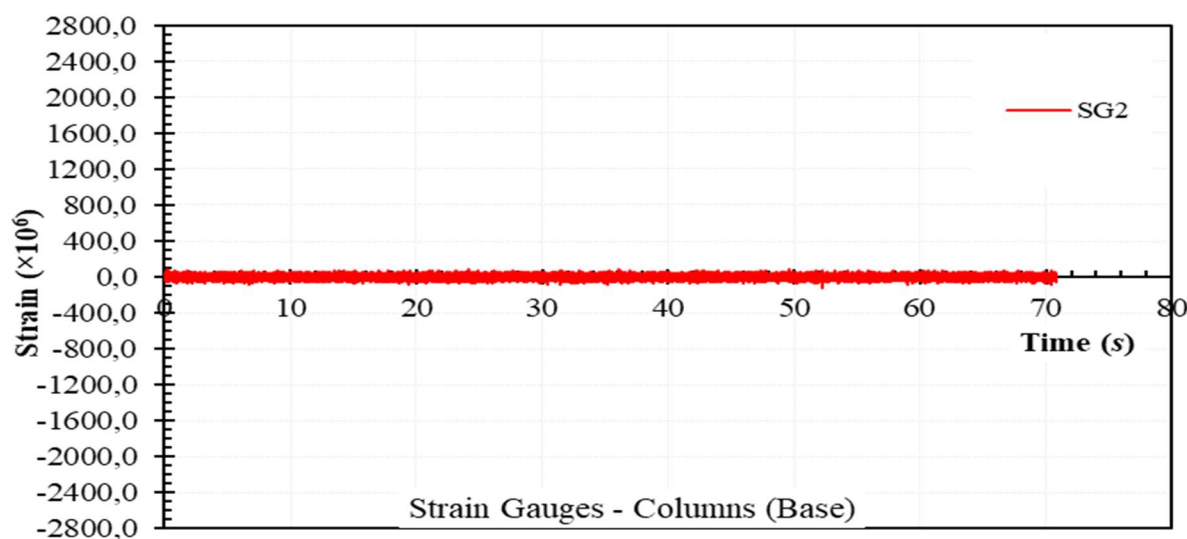
Maximum drift (‰): 0,07 ($0,086\text{mm}/1,225\text{m} = 0,07\text{‰}$)

Minimum drift (‰): -0,07

Residual drift: -0,02 mm



(a)



(b)

Figure 3.1.12 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge SG1 and (b) strain gauge SG2

Strain gauges detect strain on the surface of the steel reinforcement. The strain gauges shown in the figures 3.1.12, 3.1.13, 3.1.14 and 3.1.19 are located on the longitudinal reinforcement, at the bottom of the column. More specifically, strain gauge SG1 has maximum strain 106,81 μ strain and minimum strain -122,07 μ strain. The residual strain is 0 μ strain. Strain gauge SG2 has maximum strain 91,56 μ strain and minimum -91,56 μ strain. The residual strain is -30,52 μ strain. Strain gauge SG3 has 91,56 μ strain and -91,56 μ strain maximum and minimum strain respectively. The residual strain is -15,26 μ strain. Strain gauge SG4 as we can see in figure 3.1.13 has maximum 106,81 μ strain and minimum -91,56 μ strain strain. The residual strain is -30,52 μ strain. Figure 3.1.19 shows strain gauges SG5 and SG6. Strain gauge 5 has 279,14 μ strain and -221,24 μ strain maximum and minimum strain respectively. Strain gauge SG5 presents 39,87 μ strain residual strain. Strain gauge SG6 has 65,29 μ strain maximum strain, -83,23 μ strain minimum strain and -0,82 μ strain residual. Finally in figure 3.1.14 we see strain gauge SG7 and SG8. Strain gauge SG7 and SG8 have the same maximum strain 91,56 μ strain. Strain gauge SG7 has -106,81 μ strain minimum deformation and 8 has -91,56 μ strain. The residual strain for strain gauge SG7 and SG8 is 15,26, 30,52 respectively.

Sg 1

Max: 106,81 μ strain

Min: -122,07 μ strain

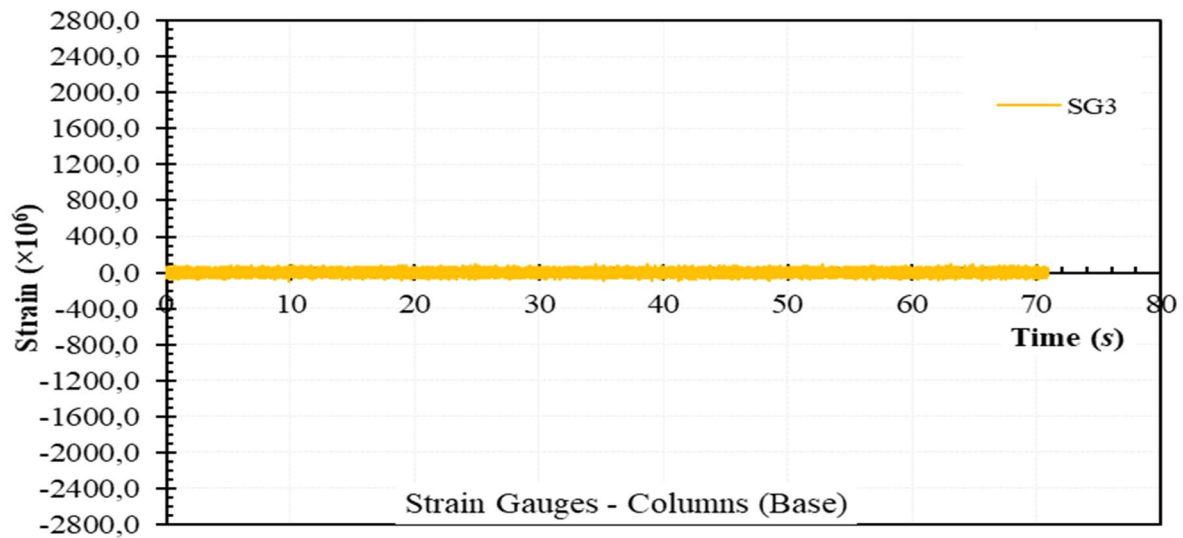
Residual: 0 μ strain

Sg 2

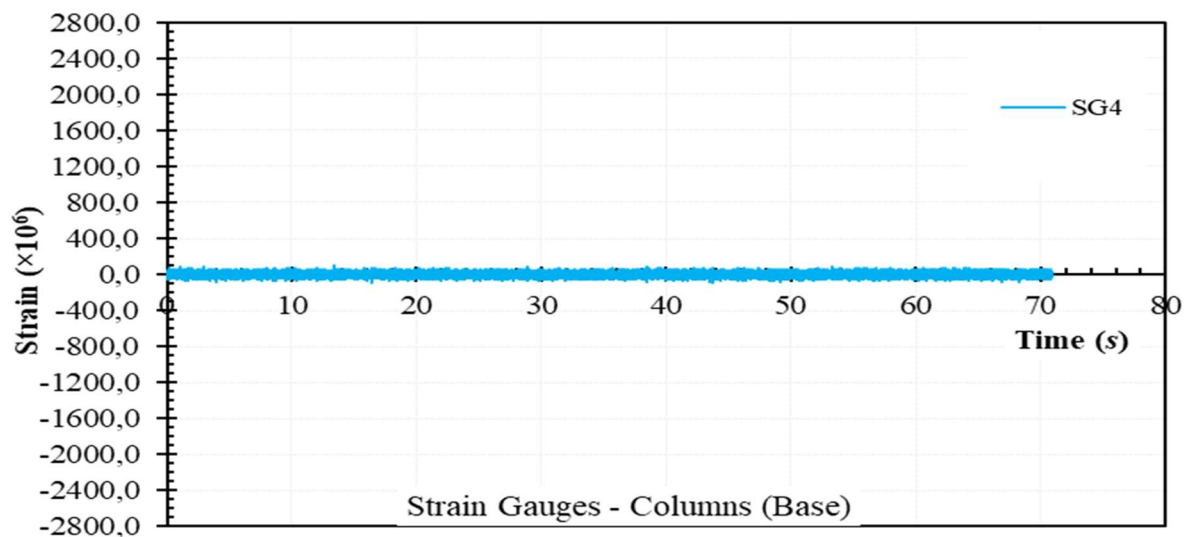
Max: 91,56 μ strain

Min: -91,56 μ strain

Residual: -30,52 μ strain



(a)



(b)

Figure 3.1.13 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 3 and (b) strain gauge 4

Sg 3

Max: 91,56 μ strain

Min: -91,56 μ strain

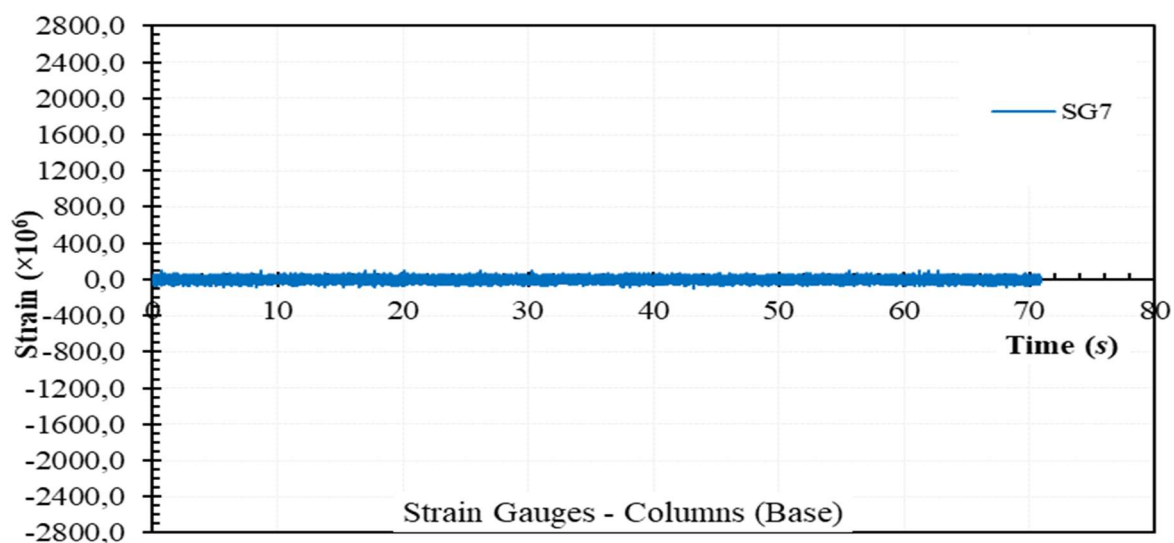
Residual: -15,26 μ strain

Sg 4

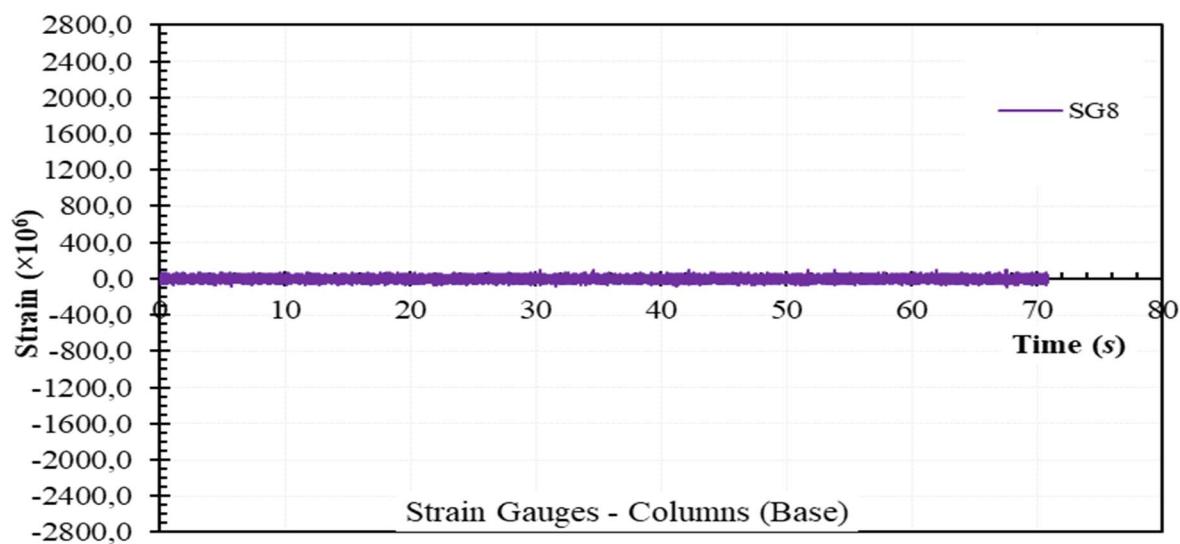
Max: 106,81 μ strain

Min: -91,56 μ strain

Residual: -30,52 μ strain



(a)



(b)

Figure 3.1.14 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 7 and (b) strain gauge 8

Sg 7

Max: 91,56 μ strain

Min: -106,81 μ strain

Residual: 15,26 μ strain

Sg 8

Max: 91,56 μ strain

Min: -91,56 μ strain

Residual: 30,52 μ strain

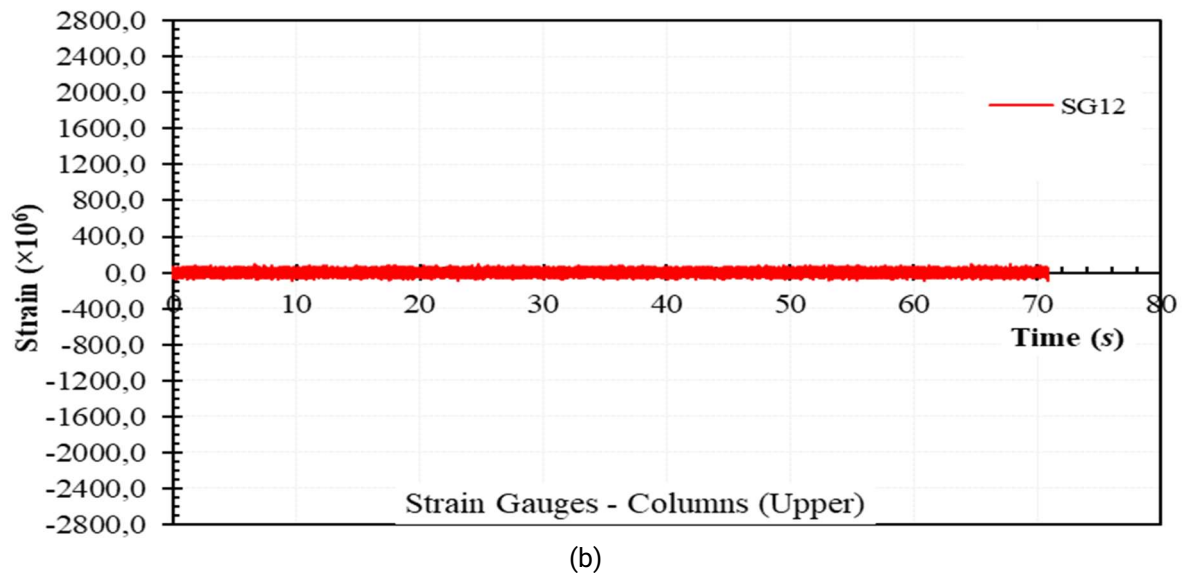
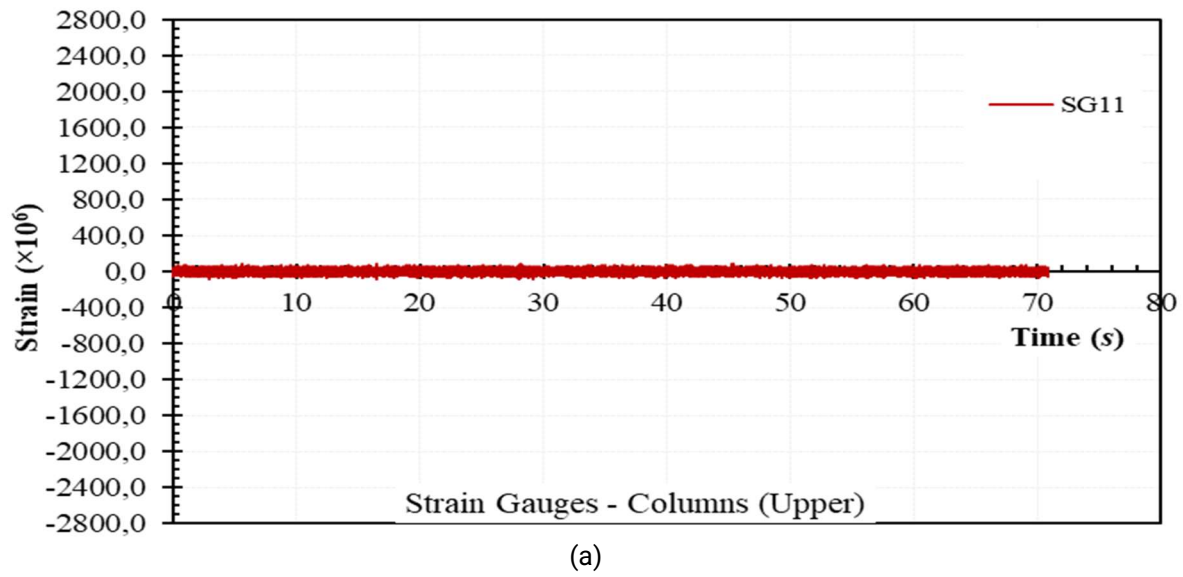


Figure 3.1.15 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12

The strain gauges shown in the figures 3.1.15, 3.1.16, 3.1.17 and 3.1.20 are located in the longitudinal reinforcement, on the upper side. More specifically, strain gauge SG9 has 70,80 μ strain maximum strain, -96,83 μ strain minimum strain and 22,79 residual. Strain gauge SG10 has 209,05 μ strain maximum strain, -187,74 μ strain minimum strain and 61,23 μ strain residual. Strain gauge SG11 and SG12 have the same maximum 91,56 μ strain and minimum -91,56 μ strain deformation. The residual strain is 15,26 for strain gauge SG11. Strain gauge SG12 and 15 don't present residual. Strain gauge SG13 has maximum strain 91,56 μ strain, minimum -106,81 μ strain and -15,26 μ strain residual. Strain gauge SG14 has maximum strain 91,56 μ strain and minimum strain -91,56 μ strain. The residual value is 0 μ strain. Finally strain gauges SG15 has maximum strain 91,56 μ strain and minimum strain -91,56 μ strain. Strain gauge SG16 has maximum strain 91,56 μ strain, minimum strain -106,81 μ strain and residual strain 15,26 μ strain.

Sg 11

Max: 91,56 μ strain

Min: -91,56 μ strain

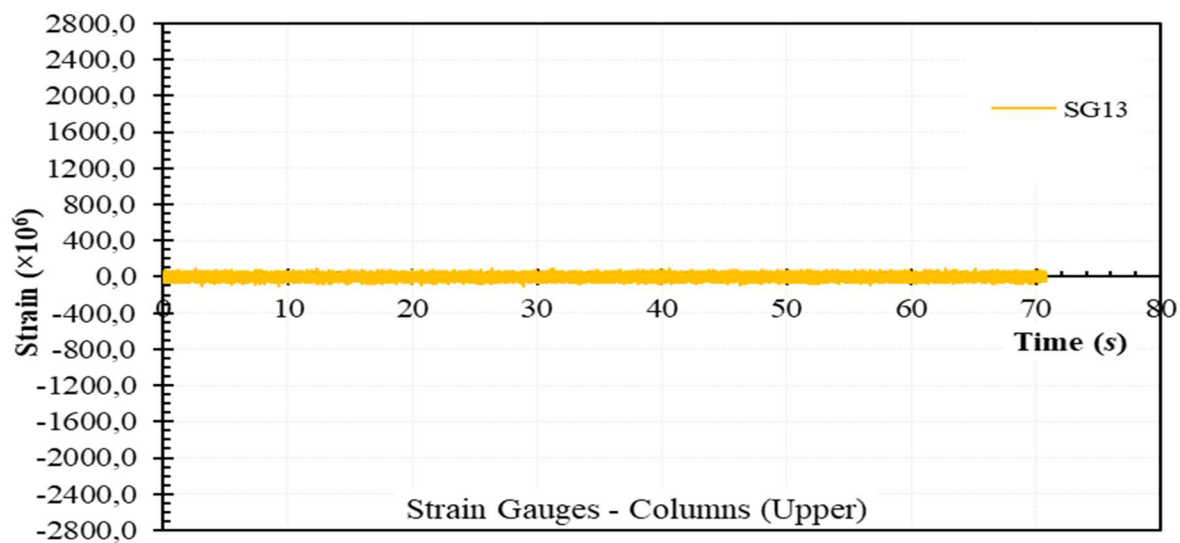
Residual: 15,26 μ strain

Sg 12

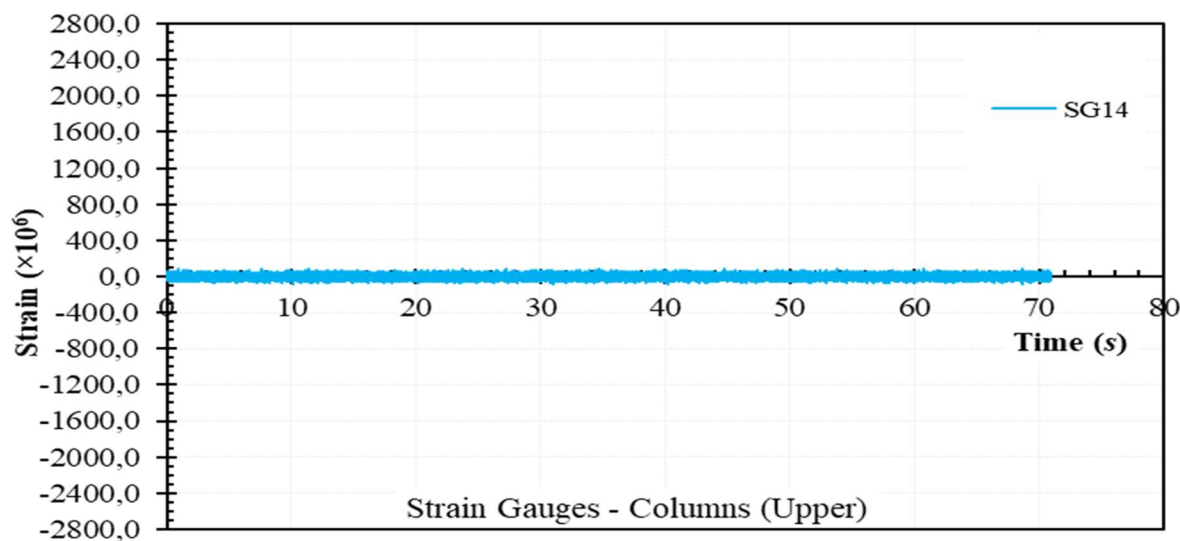
Max: 91,56 μ strain

Min: -91,56 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.1.16 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 13 and (b) strain gauge 14

Sg 14

Max: 91,56 μ strain

Min: -91,56 μ strain

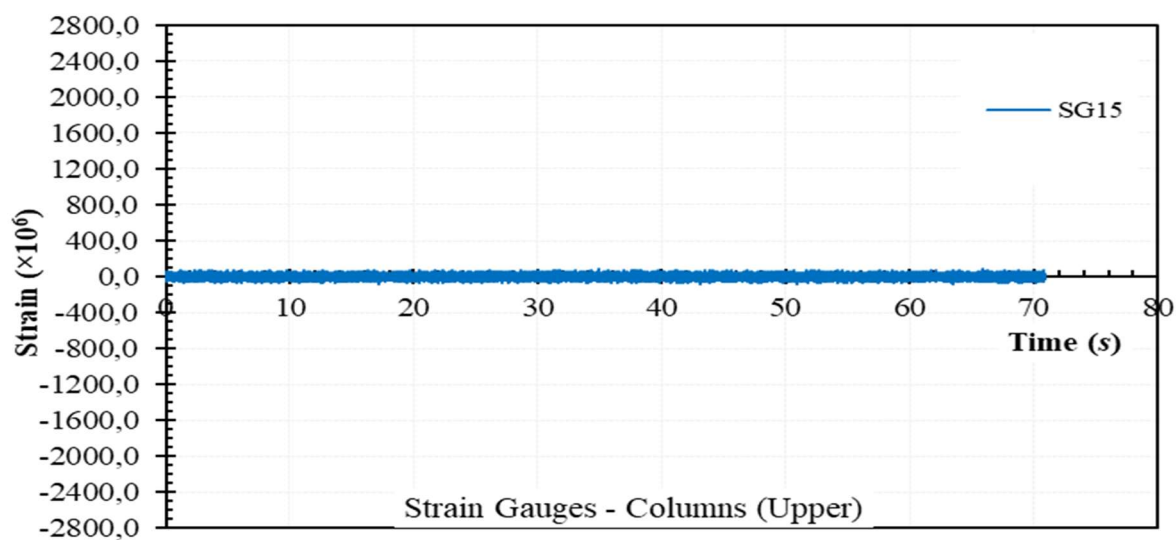
Residual: 0 μ strain

Sg 13

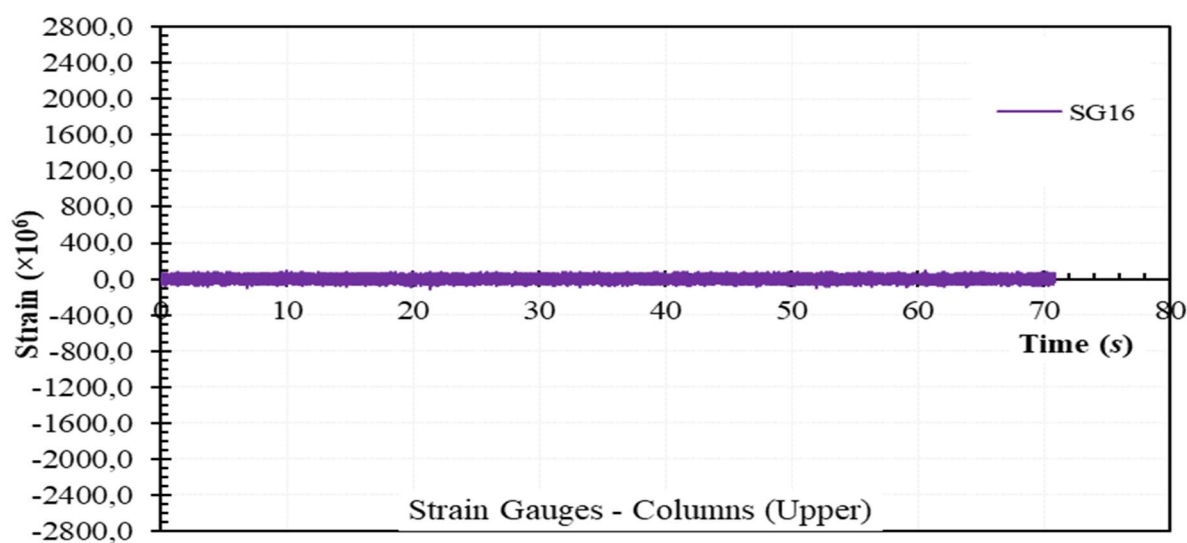
Max: 91,56 μ strain

Min: -106,81 μ strain

Residual: -15,26 μ strain



(a)



(b)

Figure 3.1.17 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 15 and (b) strain gauge 16

Sg 15

Max: 91,56 μ strain

Min: -91,56 μ strain

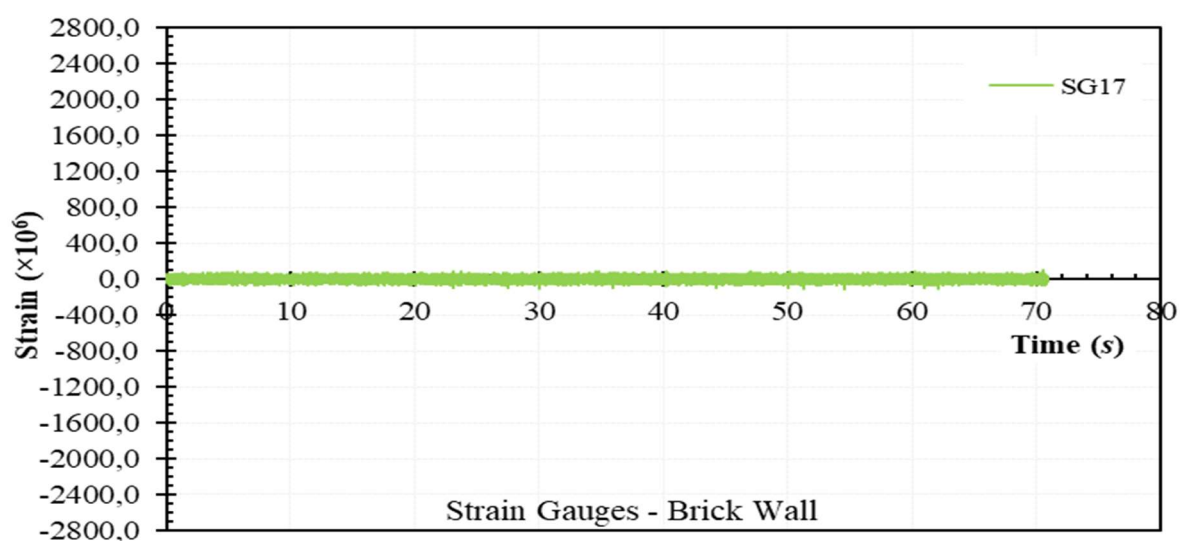
Residual: 0 μ strain

Sg 16

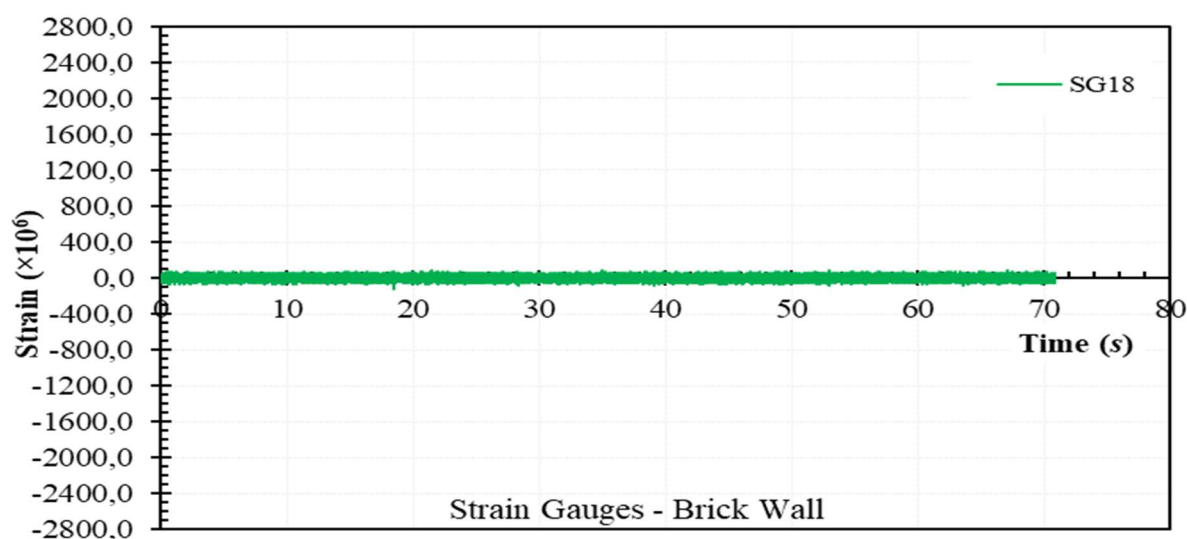
Max: 91,56 μ strain

Min: -106,81 μ strain

Residual: 15,26 μ strain



(a)



(b)

Figure 3.1.18 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 17 and (b) strain gauge 18

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauge SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge 17 and strain gauge 18 have the same 91,56 μ strain maximum strain. Strain gauge 17 has minimum deformation -91,56 μ strain and strain gauge 18 -106,81 μ strain. Finally strain gauge 17 presents 15,26 μ strain residual. Strain gauge 18 doesn't present residual.

Sg 17

Max: 91,56 μ strain

Min: -91,56 μ strain

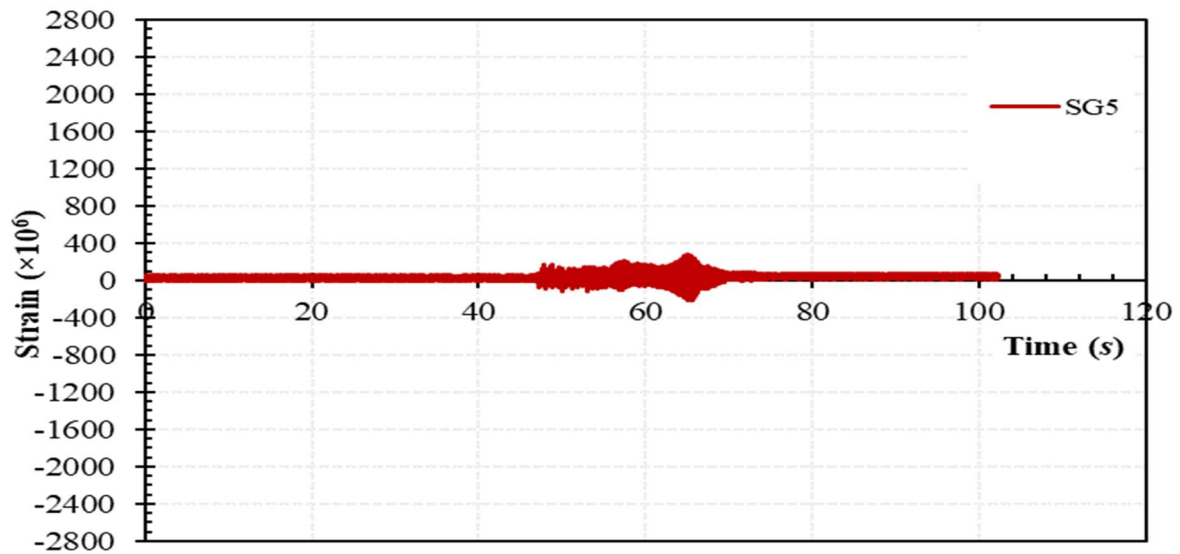
Residual: 15,26 μ strain

Sg 18

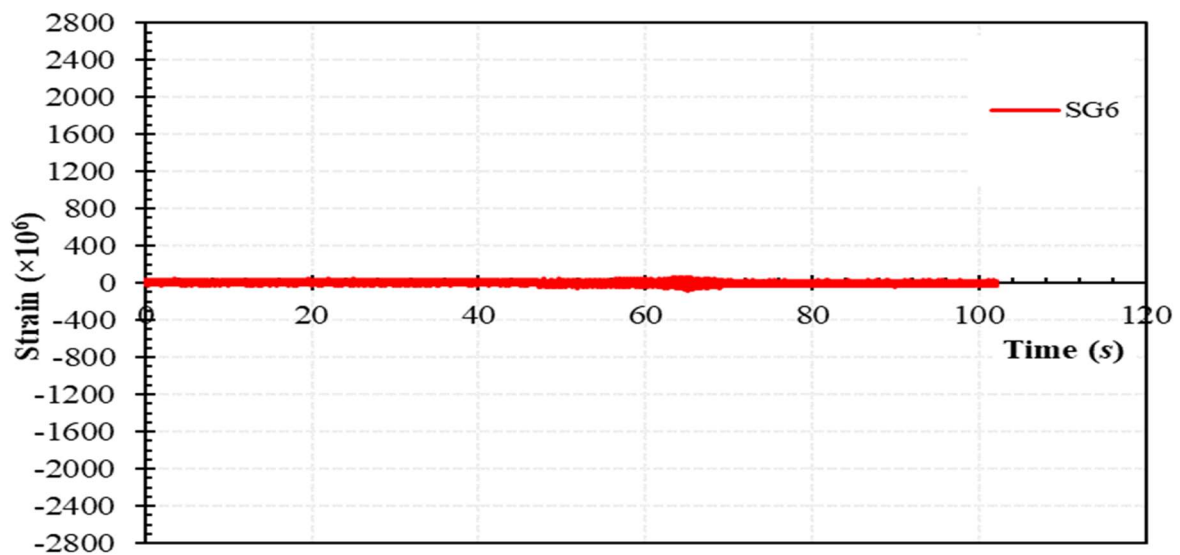
Max: 91,56 μ strain

Min: -106,81 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.1.19 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 5 and (b) strain gauge 6

Sg 5

Max: 279,14 μ strain

Min: -221,24 μ strain

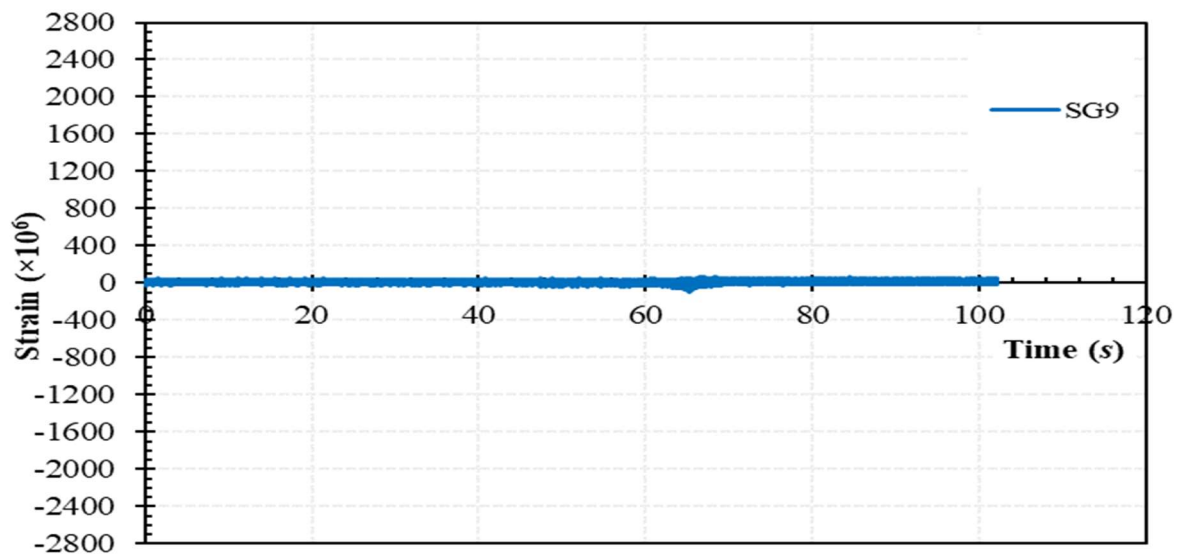
Residual: 39,87 μ strain

Sg 6

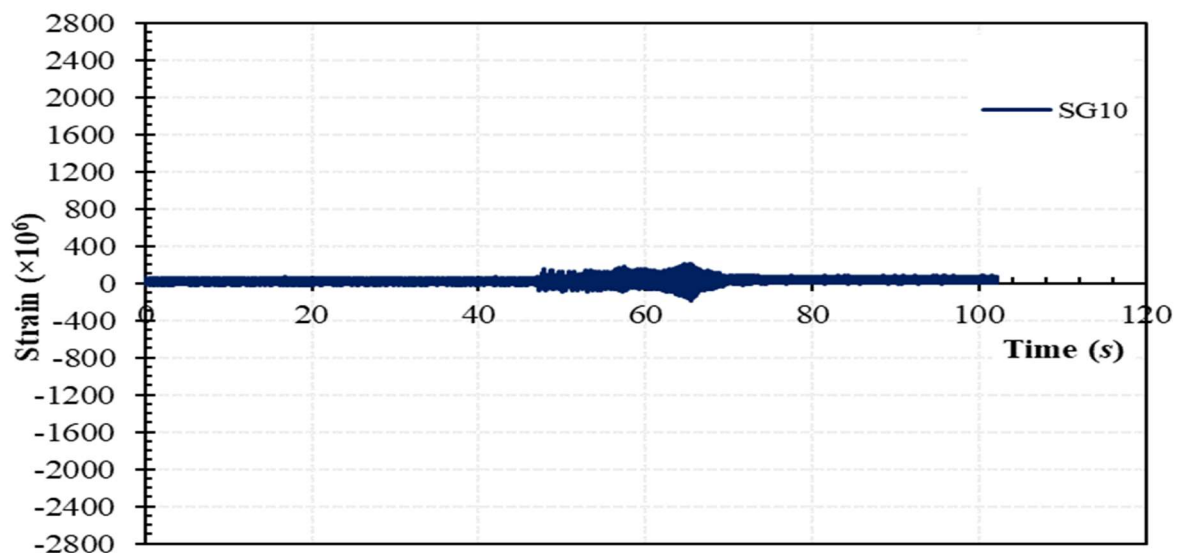
Max: 65,29 μ strain

Min: -83,23 μ strain

Residual: -0,82 μ strain



(a)



(b)

Figure 3.1.20 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 9 and (b) strain gauge 10

Sg 9

Max: 70,80 μ strain

Min: -96,83 μ strain

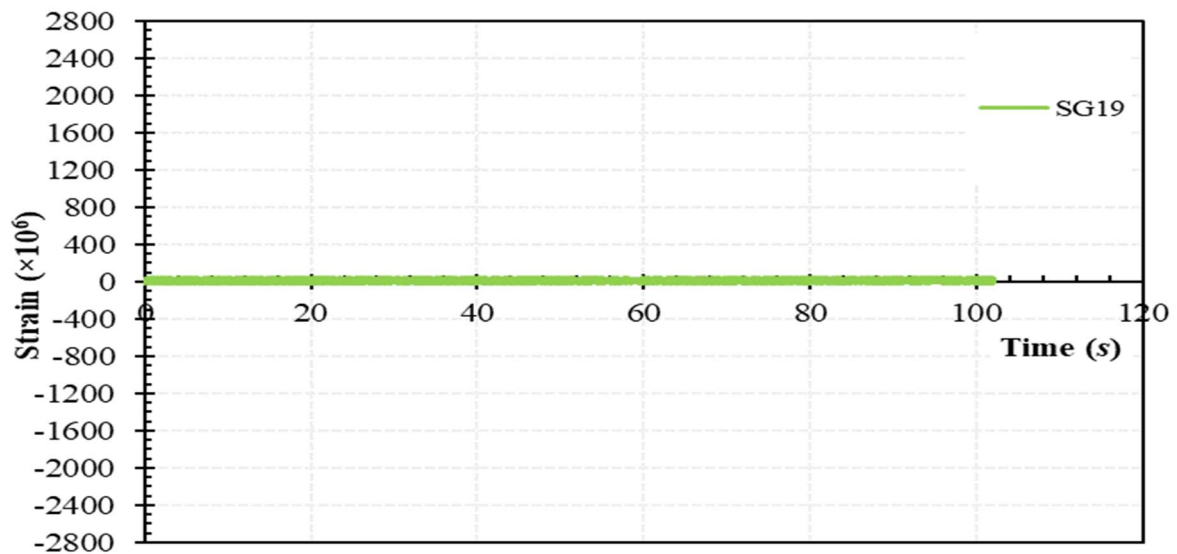
Residual: 22,79 μ strain

Sg 10

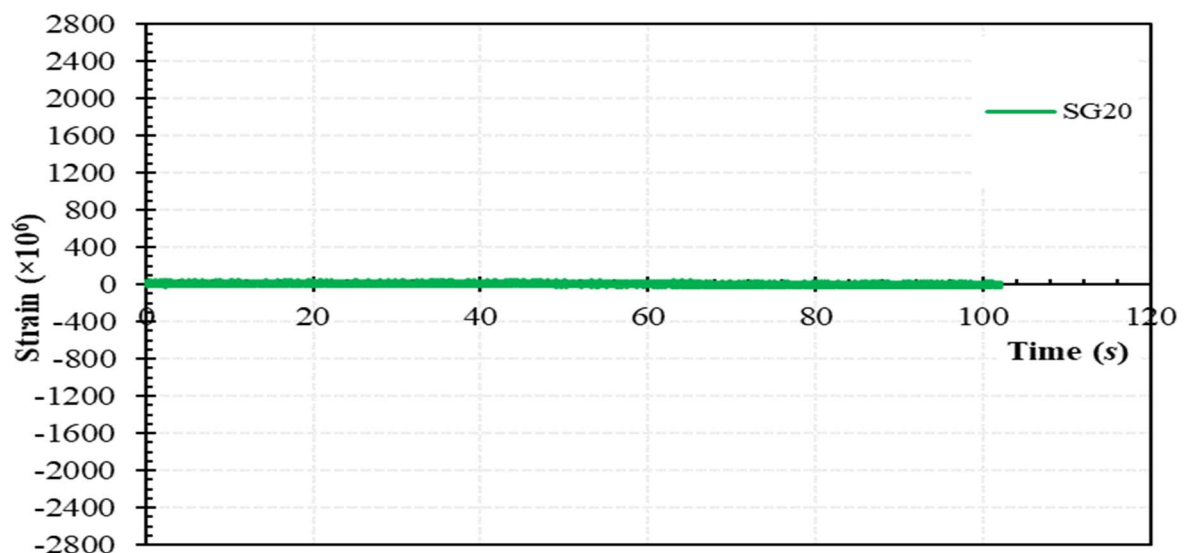
Max: 209,05 μ strain

Min: -187,74 μ strain

Residual: 61,23 μ strain



(a)



(b)

Figure 3.1.21 Characteristic results for phase A (white noise before 0,1g earthquake) (a) strain gauge 19 and (b) strain gauge 20

Strain gauge SG19 is located on the centre of partial masonry 2 along direction x. Strain gauges 20 is located on the centre of partial masonry 2 along direction x. More specifically strain gauge SG19 has maximum $0,81 \mu$ strain and minimum $-3,24 \mu$ strain. Strain gauge 20 has maximum strain $5,69 \mu$ strain and minimum $-17,07 \mu$ strain. The residual strain for strain gauge SG20 is $-9,76 \mu$ strain. Strain gauge SG19 doesn't present residual.

Sg 19

Max: $51,94 \mu$ strain

Min: $-27,59 \mu$ strain

Residual: $22,72 \mu$ strain

Sg 20

Max: 51,25 μ strain

Min: -37,42 μ strain

Residual: 21,97 μ strain

3.2) Earthquake 0,1g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for EQ0,1g. The max acceleration at the slab level on the accelerometer acc4 is 0,14g. The max acceleration at the foundation level on the accelerometer acc10 is 0,11g.

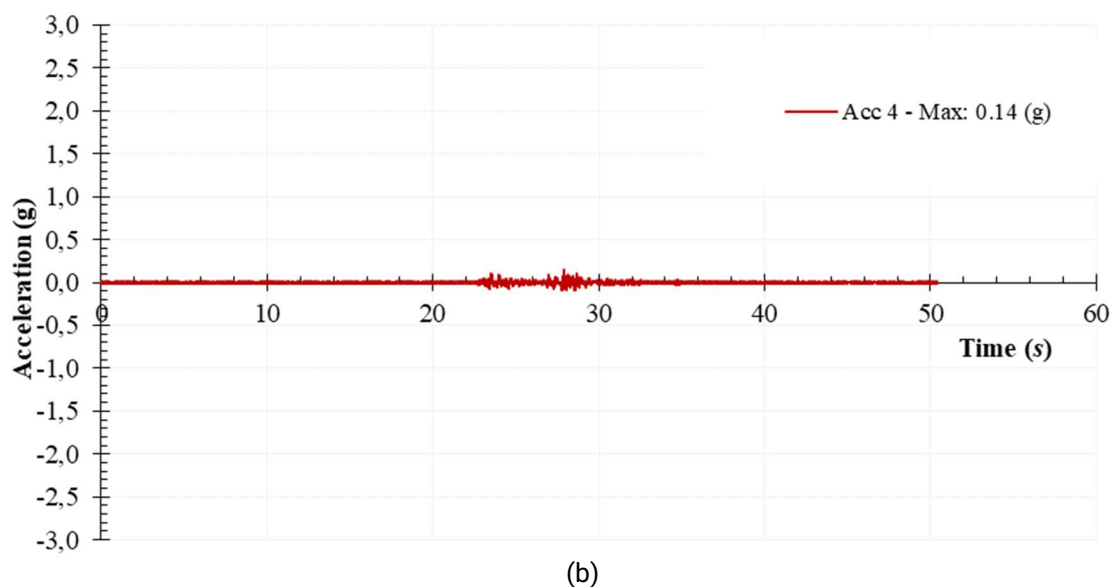
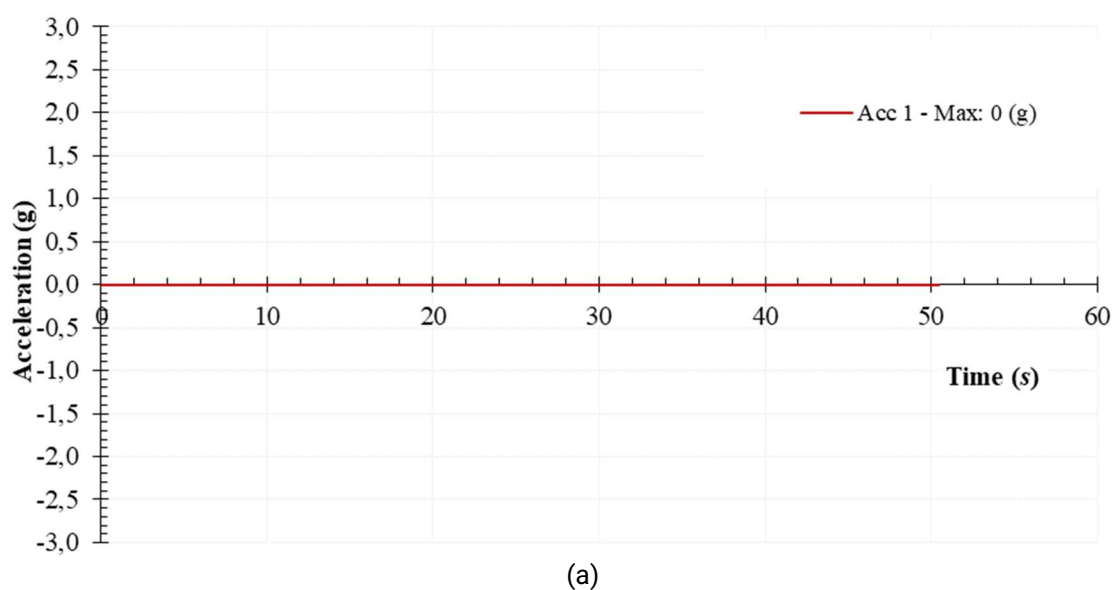
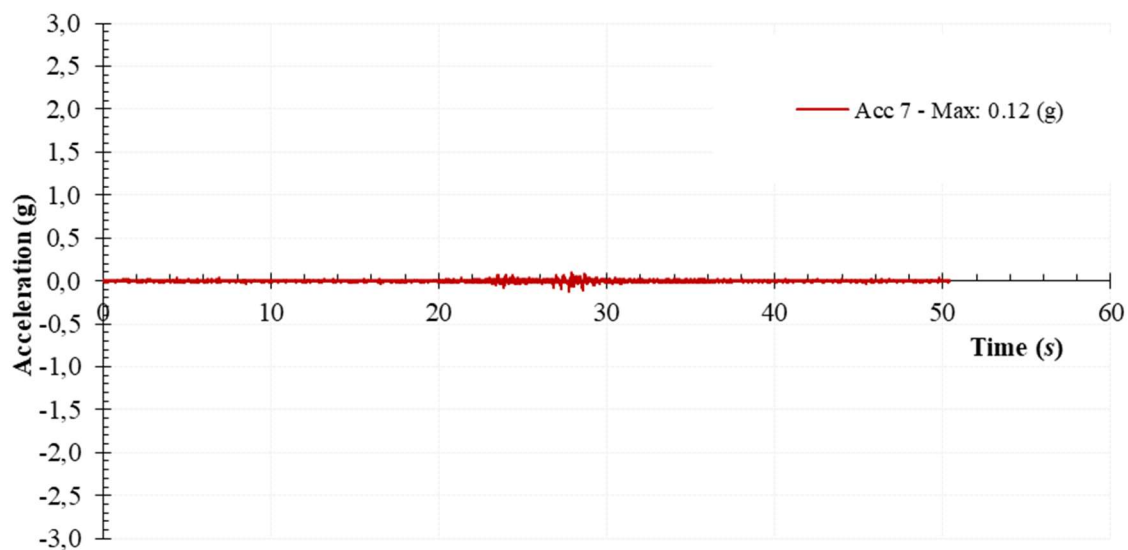
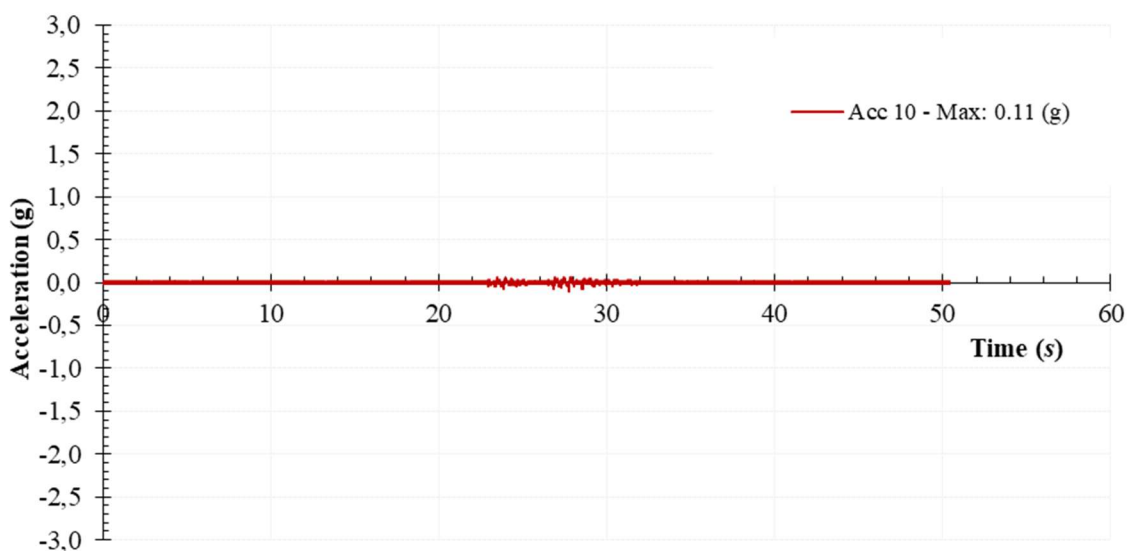


Figure 3.2.1 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 1 (b)

Accelerometer 4

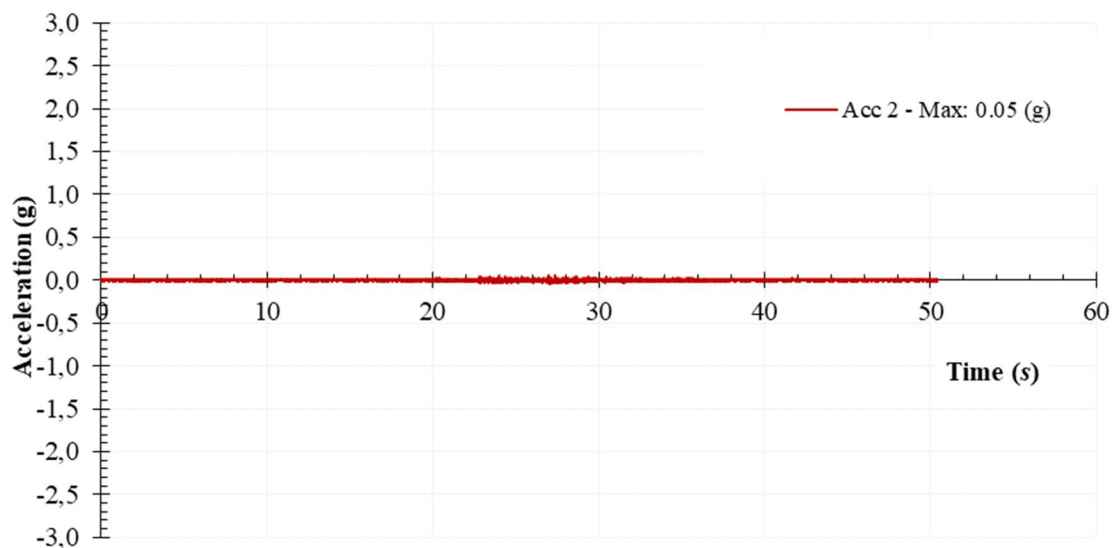


(a)

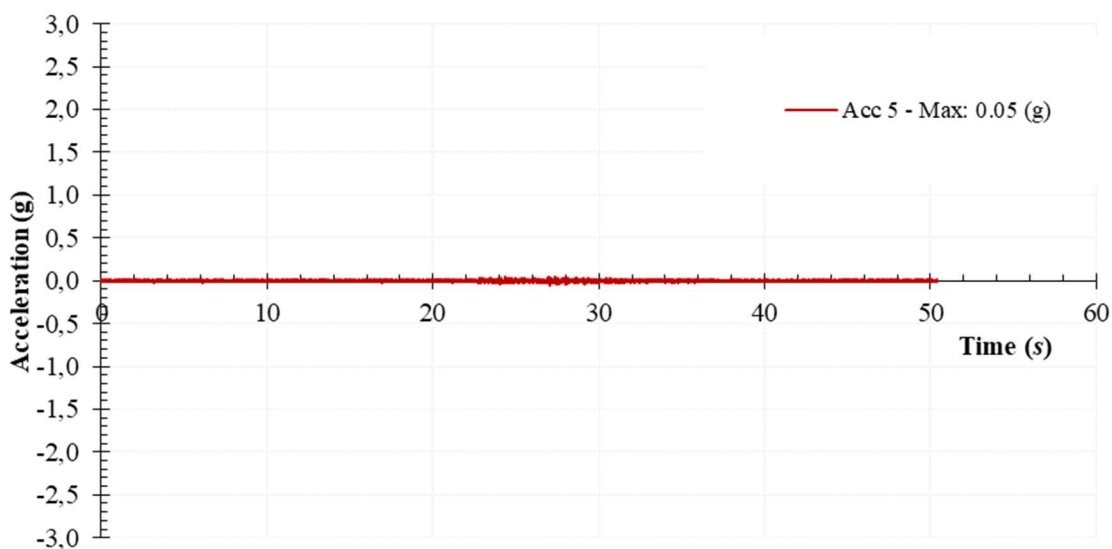


(b)

Figure 3.2.2 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

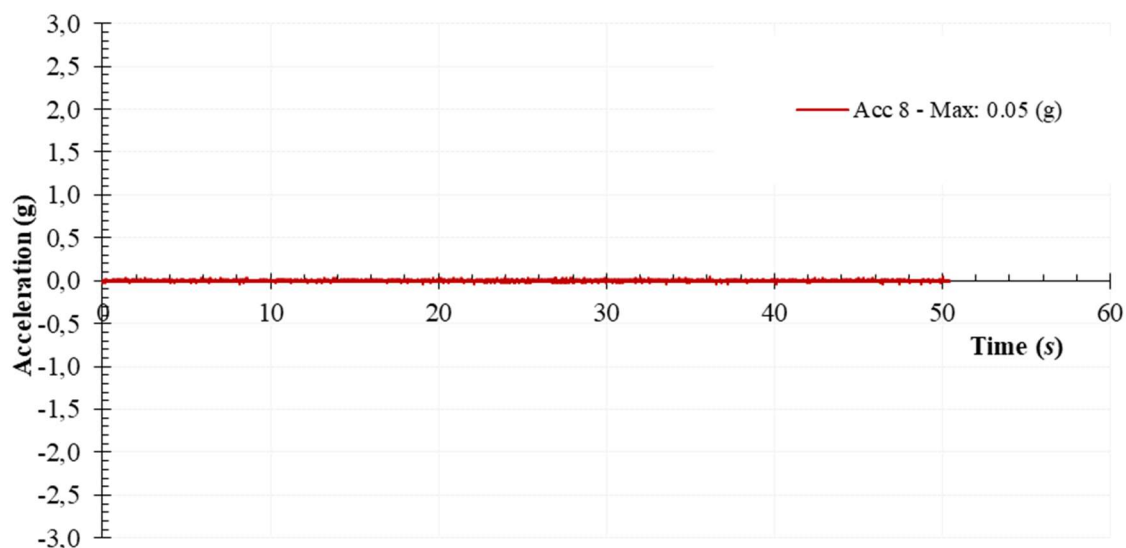


(a)

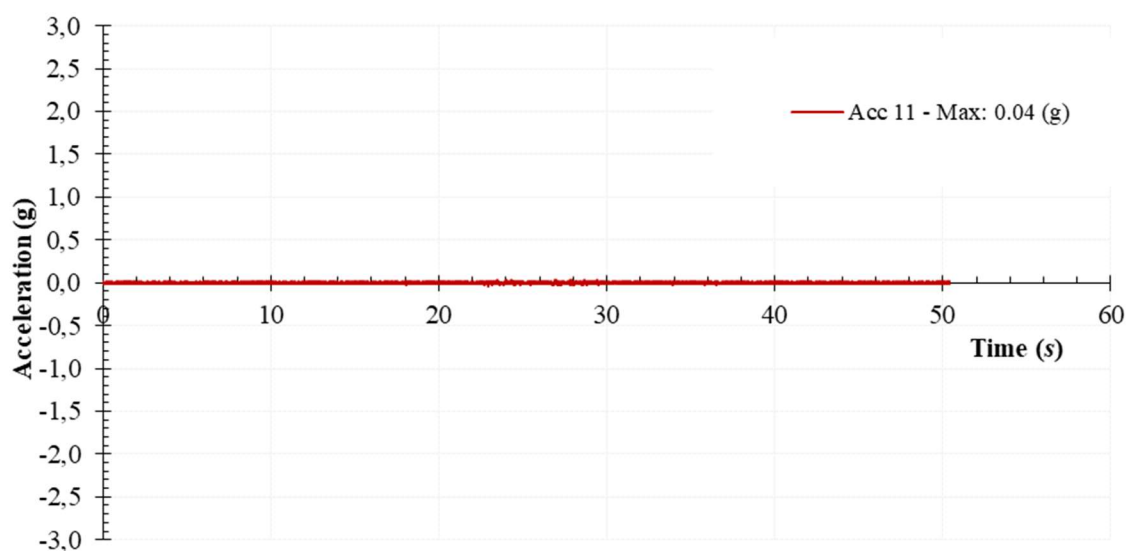


(b)

Figure 3.2.3 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

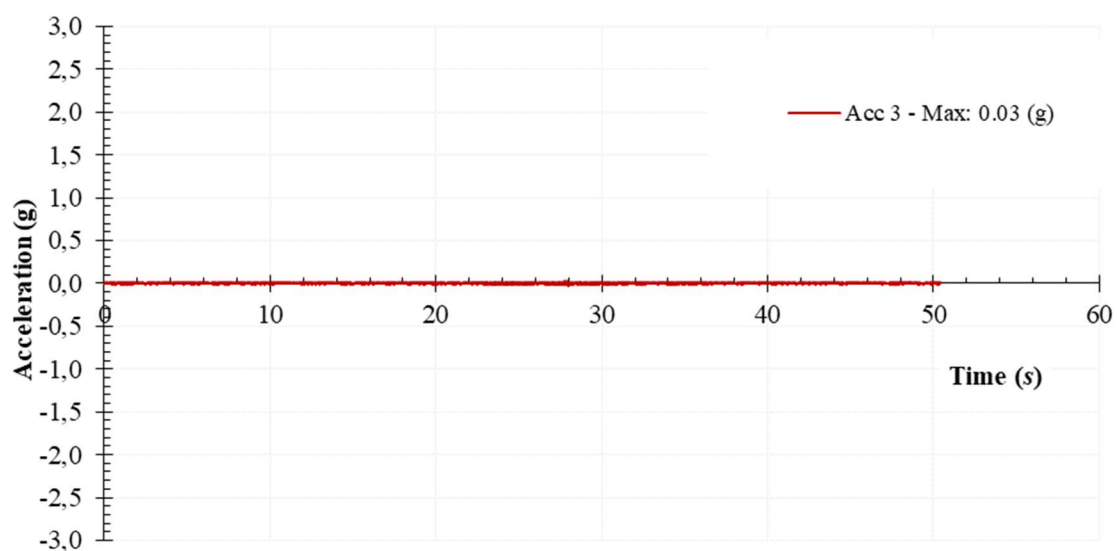


(a)

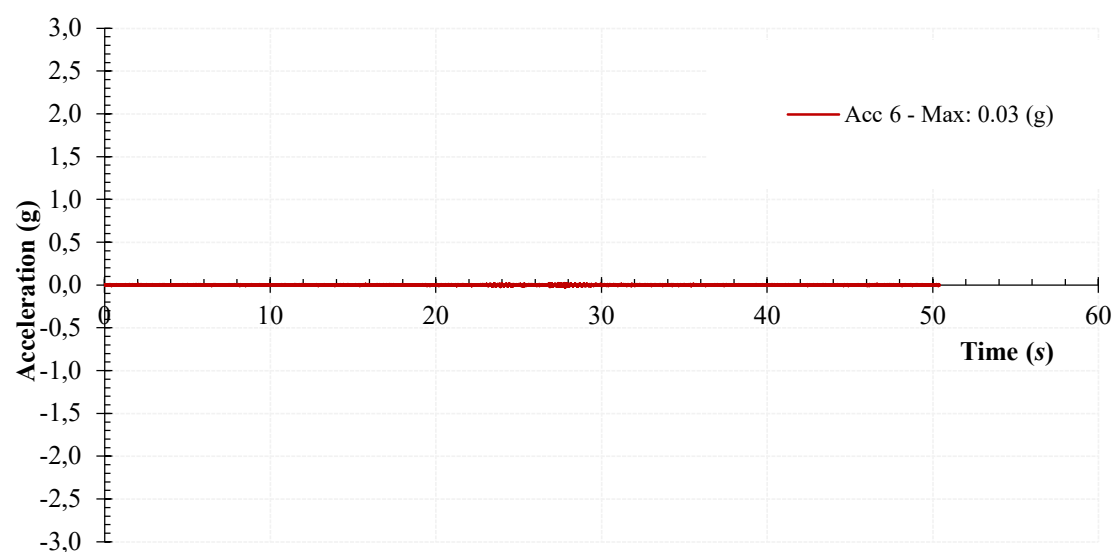


(b)

Figure 3.2.4 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 8 (b) Accelerometer 11

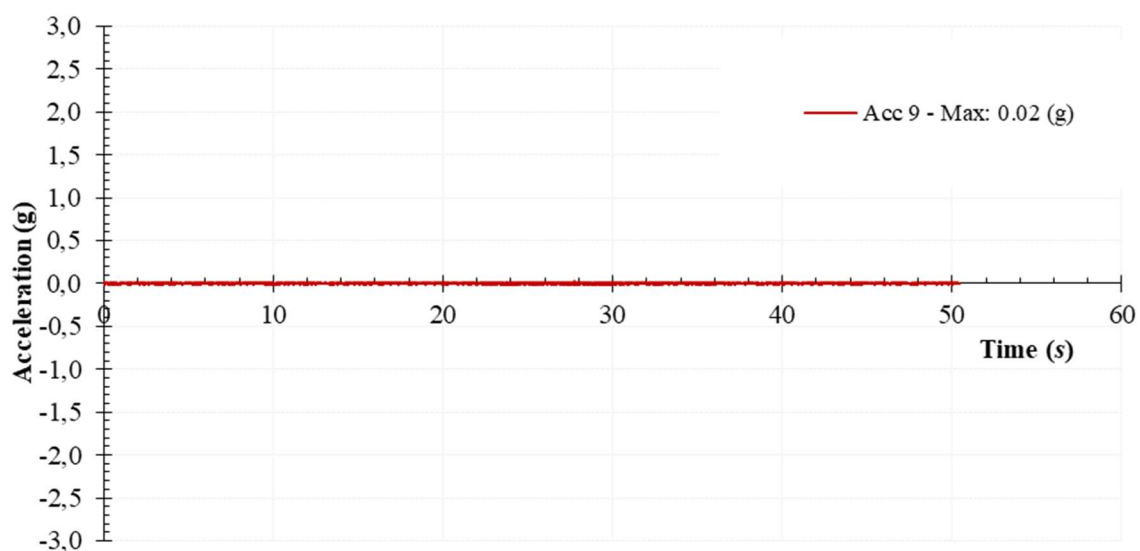


(a)

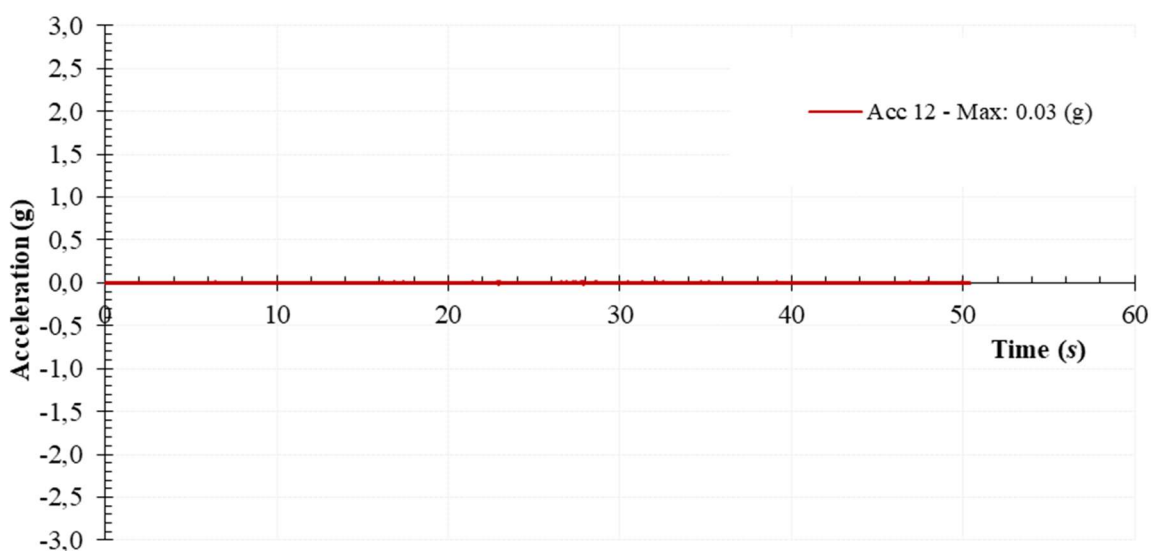


(b)

Figure 3.2.5 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 3 (b) Accelerometer 6

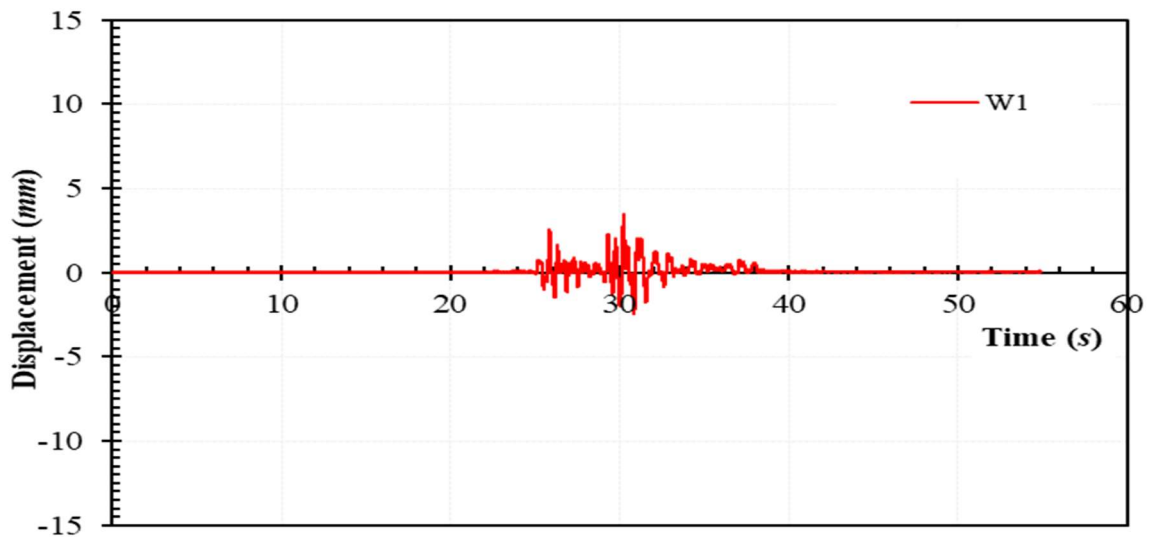


(a)

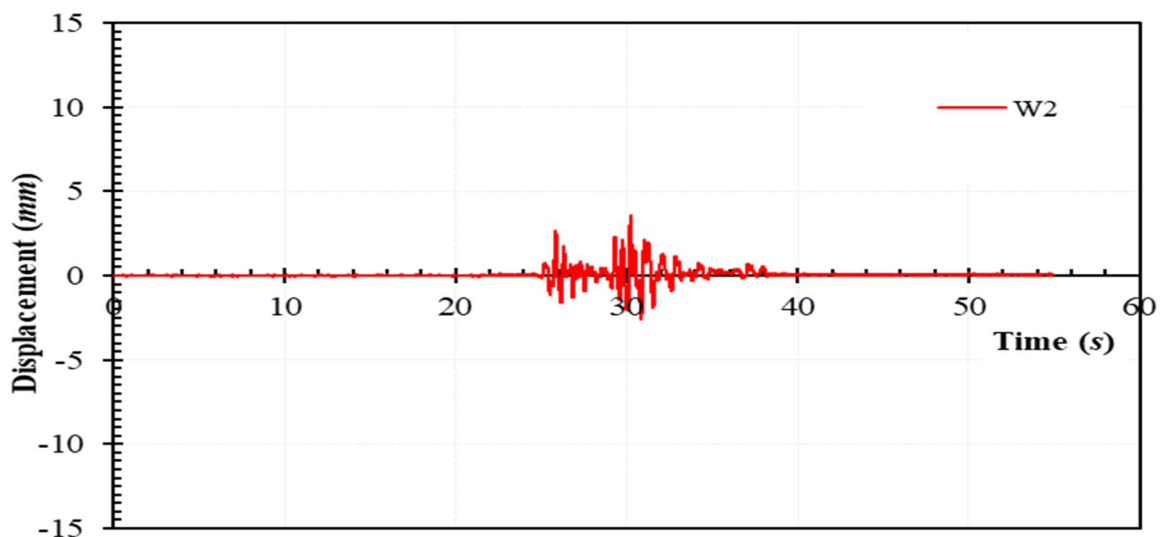


(b)

Figure 3.2.6 Characteristic results for phase A (0,1g earthquake): (a) Accelerometer 9 (b) Accelerometer 12



(a)



(b)

Figure 3.2.7 Characteristic results for phase A (0,1g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2

Figure 3.2.7 shows draw wire sensors W1 and W2. More specifically, draw wire sensor W1 is located on the slab, on the left side and draw wire sensor W2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor W1 is 3,45 mm while the minimum is -2,47 mm. The maximum movement detected by draw wire sensor W2 is 3,55 mm while the minimum is -2,61 mm.

W1

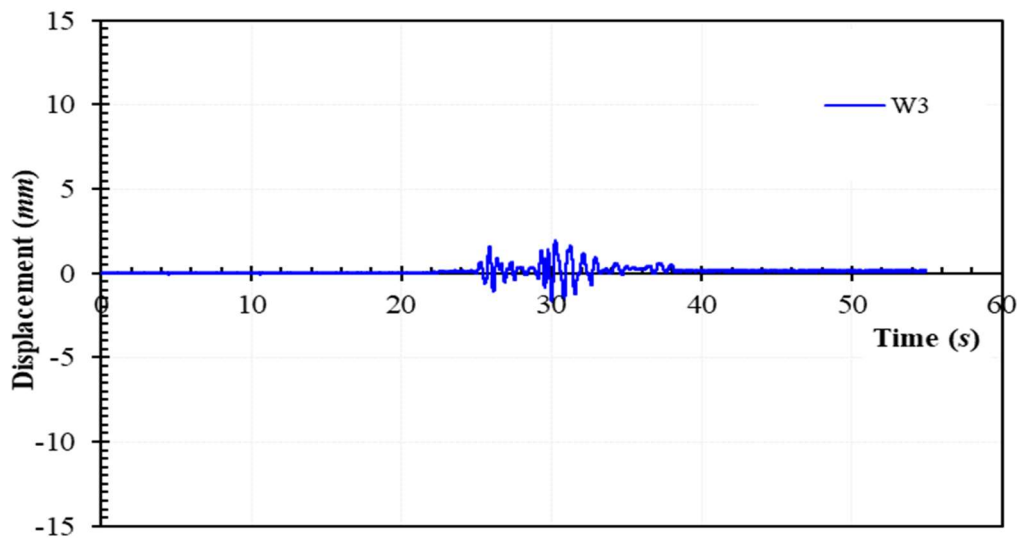
Max: 3,45 mm

Min: -2,47 mm

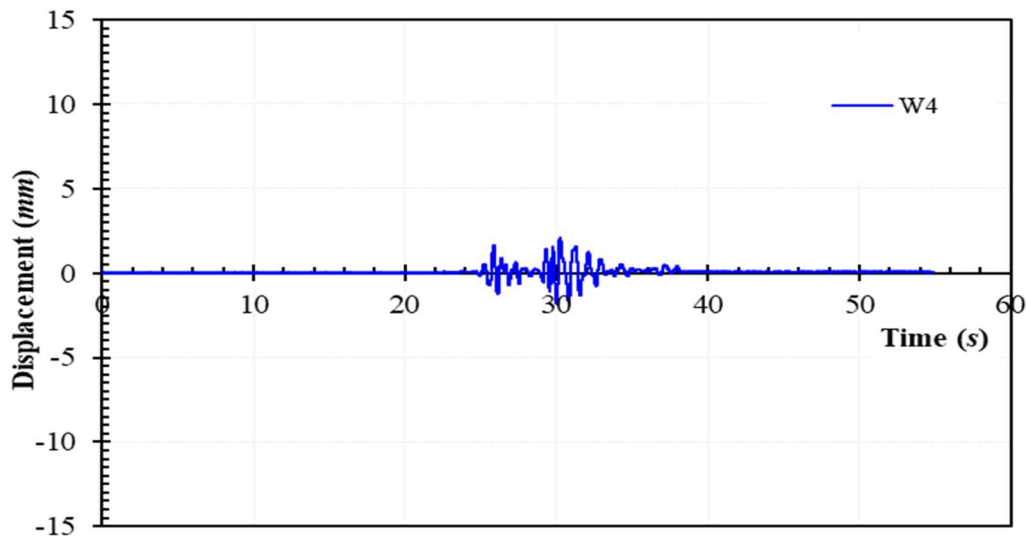
W2

Max: 3,55 mm

Min: -2,61 mm



(a)



(b)

Figure 3.2.8 Characteristic results for phase A (0,1g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor 4

Figure 3.2.8 shows draw wire sensors W3 and W4. More specifically, draw wire sensor W3 is located on the foundation, on the left side and draw wire sensor W4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor W3 is 1,98 mm while the minimum is -1,71 mm. The maximum movement detected by draw wire sensor W4 is 2,13 mm while the minimum is -1,85 mm.

W3

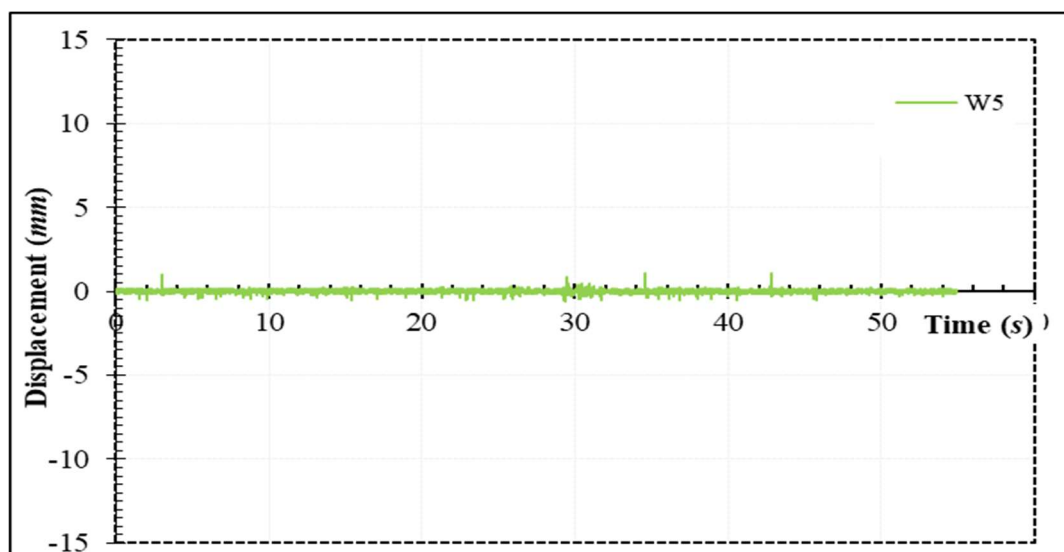
Max: 1,98 mm

Min: -1,71 mm

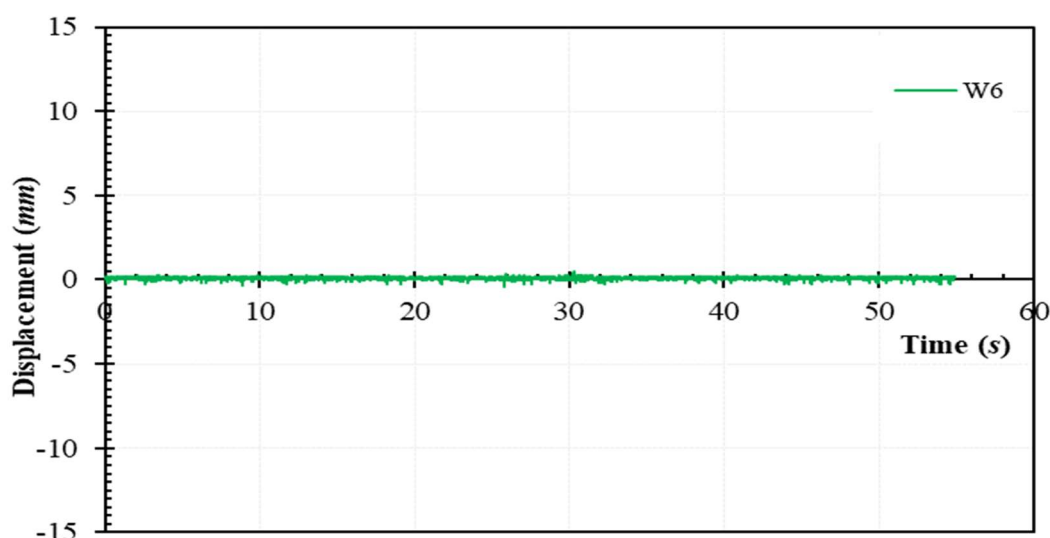
W4

Max: 2,13 mm

Min: -1,85 mm



(a)



(b)

Figure 3.2.9 Characteristic results for phase A (0,1g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6

Figure 3.2.9 shows draw wire sensors W5 and W6. More specifically, draw wire sensor W5 is located along the partial masonry infill diagonal and draw wire sensor W6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W5 is 1,09 mm while the minimum is -0,12 mm. The maximum movement detected by draw wire sensor W6 is 0,48 mm while the minimum is -0,39 mm.

W5

Max: 1,09 mm

Min: -0,12 mm

W6

Max: 0,48 mm

Min: -0,39 mm

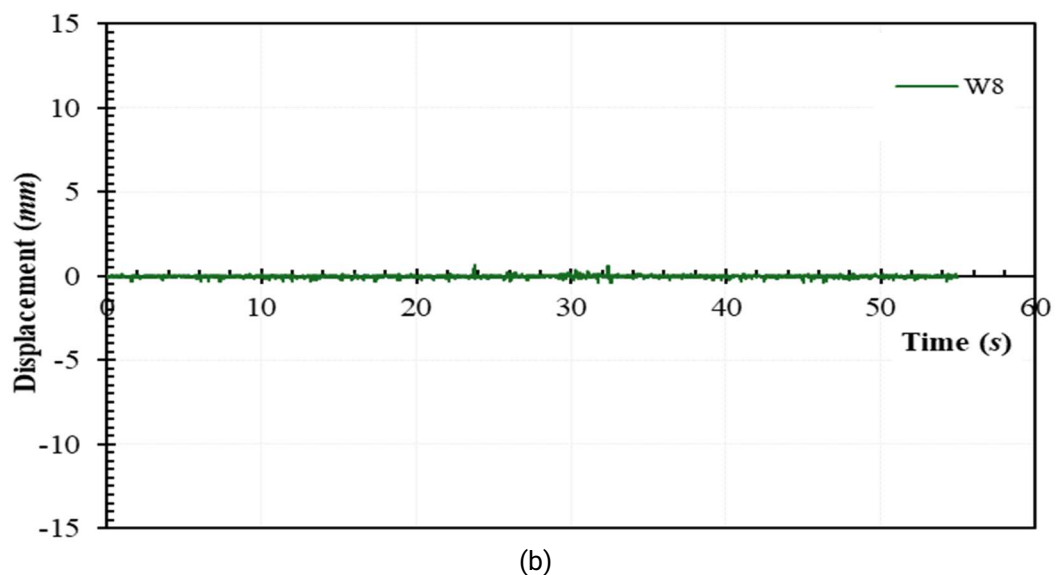
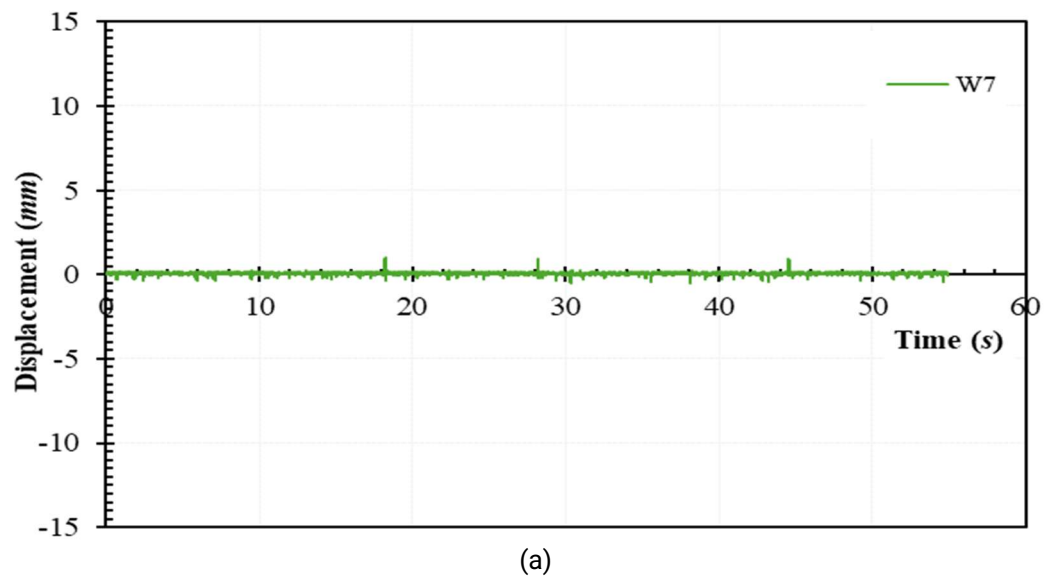


Figure 3.2.10 Characteristic results for phase A (0,1g earthquake): (a) Draw wire sensor 7 and (b) Draw wire sensor 8

Figure 3.2.10 shows draw wire sensors W7 and W8. More specifically, draw wire sensor W7 is located along the partial masonry infill diagonal and draw wire sensor W8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W7 is 1,01 mm while the minimum is -0,50 mm. The maximum movement detected by draw wire sensor W8 is 0,69 mm while the minimum is -0,40 mm.

W7

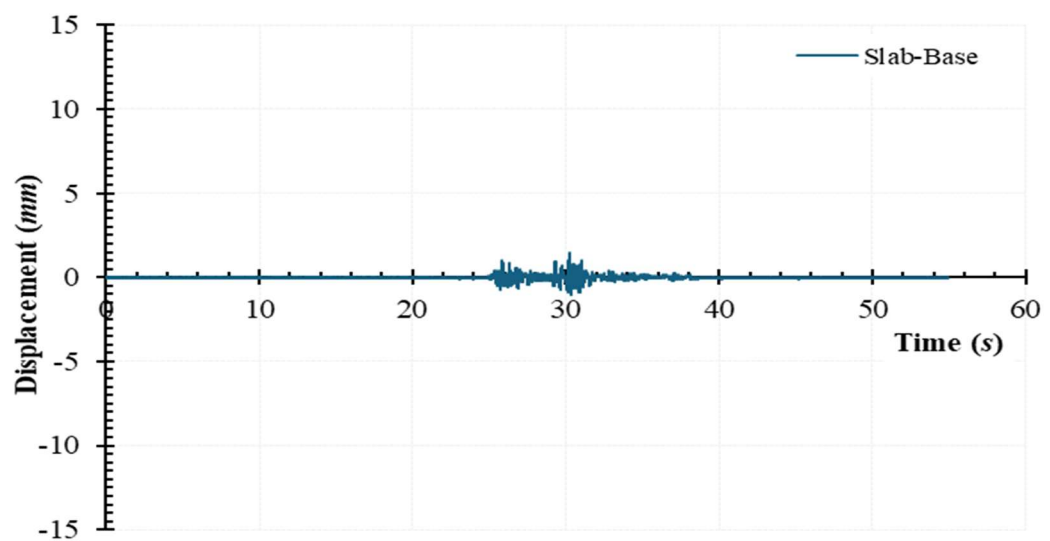
Max: 1,01 mm

Min: -0,50 mm

W8

Max: 0,69 mm

Min: -0,40 mm



(a)

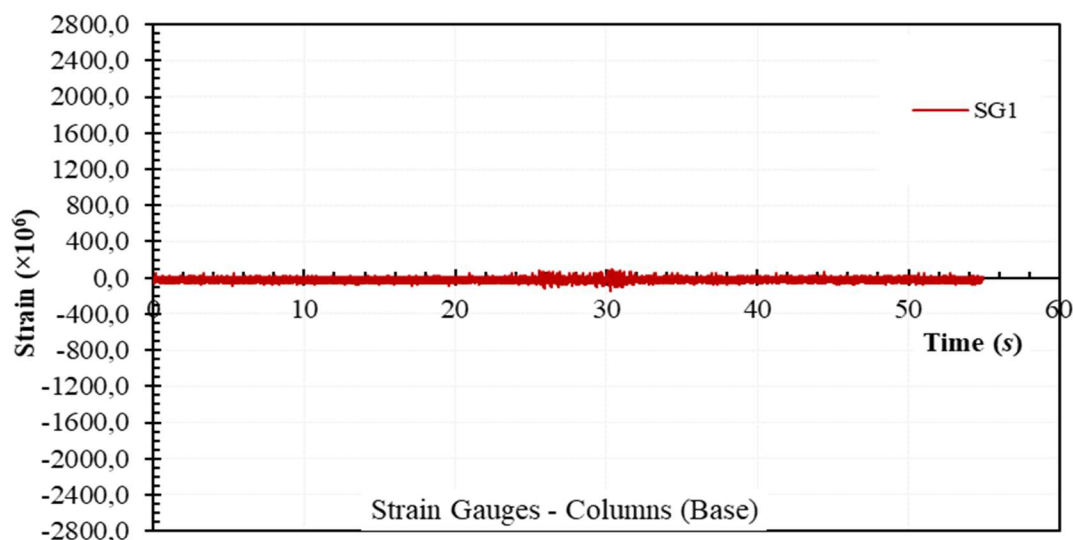
Figure 3.2.11 Characteristic results for phase A (0,1g earthquake): (a) Diagram of displacement Slab – Base

Figure 3.2.11 shows slab – base displacement. More specifically, the maximum drift detected is 1,20 ‰ while the minimum is -0,84 ‰. The residual drift is -0,02 mm.

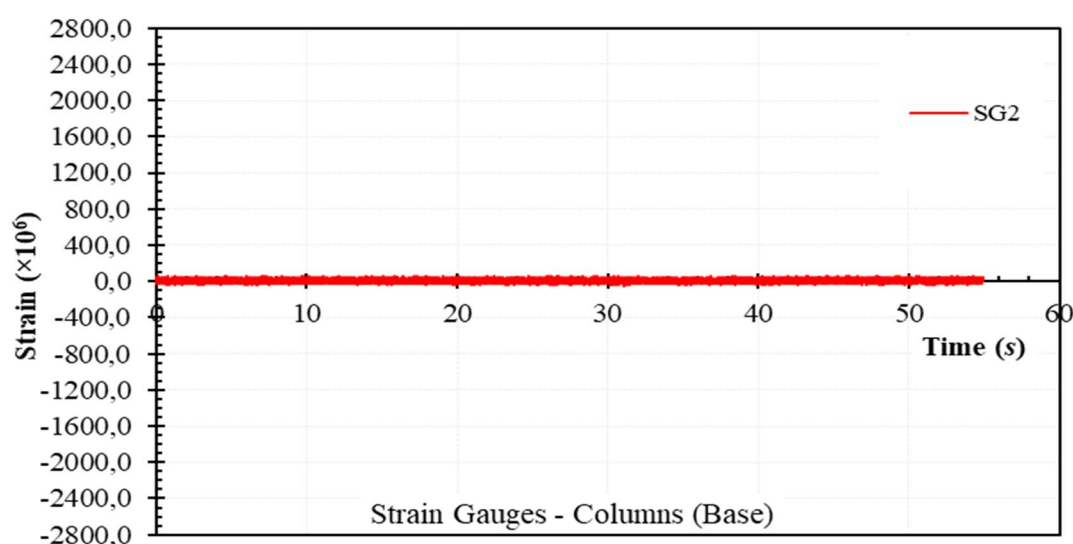
Maximum drift (‰): 1,20 ($1,47\text{m} / 1.225\text{m} = 1,20 \text{ ‰}$)

Minimum drift (‰): -0,84

Residual drift: -0,02 mm



(a)



(b)

Figure 3.2.12 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 1 and (b) strain gauge 2

Strain gauges detect strain. The strain gauges shown in the figures 3.2.12, 3.2.13, 3.2.14 and 3.2.19 are located in the longitudinal reinforcement, on the underside. More specifically, strain gauge SG1 has maximum strain $91,56\mu\text{strain}$ and minimum strain $-152,59\mu\text{strain}$. The residual strain is $15,26\mu\text{strain}$. Strain gauge SG2 has maximum deformation $61,04\mu\text{strain}$ and minimum $-61,04\mu\text{strain}$. The residual strain is $15,26\mu\text{strain}$. Strain gauge SG3 has $61,04\mu\text{strain}$ and $-76,30\mu\text{strain}$ maximum and minimum strain respectively. The residual strain is $-15,26\mu\text{strain}$. Strain gauge SG4 as we can see in figure 3.2.13 has maximum $122,07\mu\text{strain}$ and minimum $-106,81\mu\text{strain}$ deformation. The residual strain is $-15,26\mu\text{strain}$. Figure 3.2.19 shows strain gauges SG5 and SG6. Strain gauge 5 has $271,86\mu\text{strain}$ and $-167,60\mu\text{strain}$ maximum and minimum strain respectively. Strain gauge SG5 presents $11,39\mu\text{strain}$ residual strain. Strain gauge SG6 has $55,50\mu\text{strain}$ maximum strain, $-62,84\mu\text{strain}$ minimum strain and $-26,12\mu\text{strain}$ residual. Finally in figure 3.2.14 see strain gauge SG7 and SG8. Strain gauge SG7 has maximum strain $61,94\mu\text{strain}$ and SG8 has maximum strain $122,07\mu\text{strain}$. Strain gauge SG7 has -

76,30 μ strain minimum deformation and 8 has -152,59 μ strain. The residual strain for strain gauge SG7 and SG8 is 30,52, -15,26 respectively.

Sg 1

Max: 91,56 μ strain

Min: -152,59 μ strain

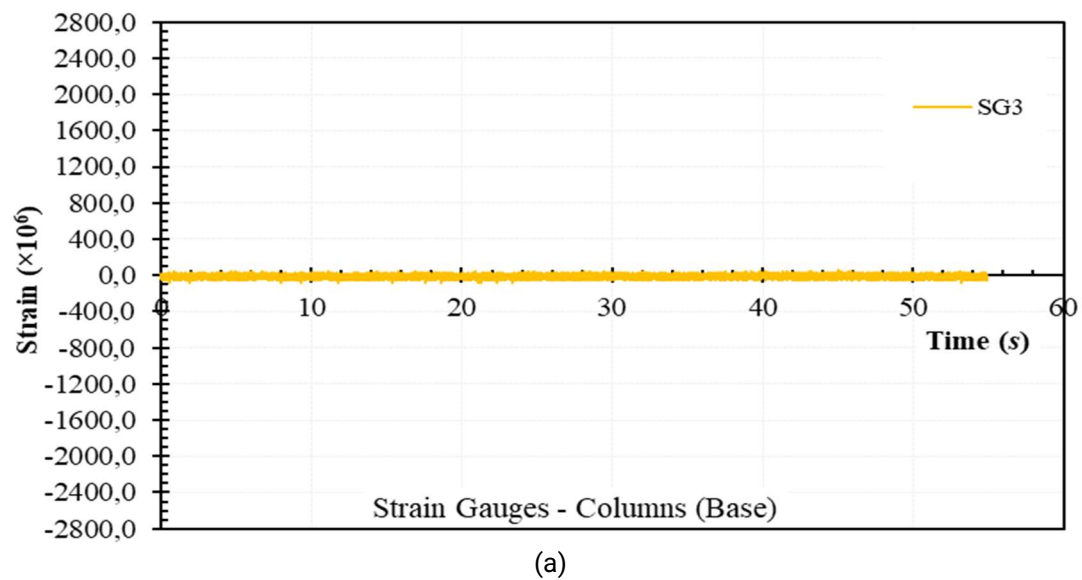
Residual: 15,26 μ strain

Sg2

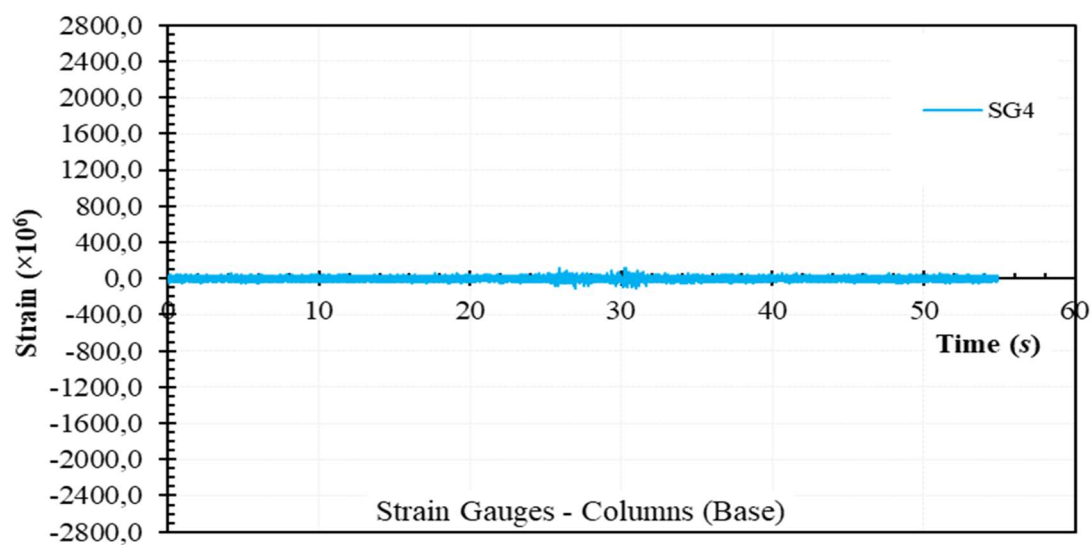
Max: 61,04 μ strain

Min: -61,04 μ strain

Residual: 15,26 μ strain



(a)



(b)

Figure 3.2.13 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 3 and (b) strain gauge 4

Sg 3

Max: 61,04 μ strain

Min: -76,30 μ strain

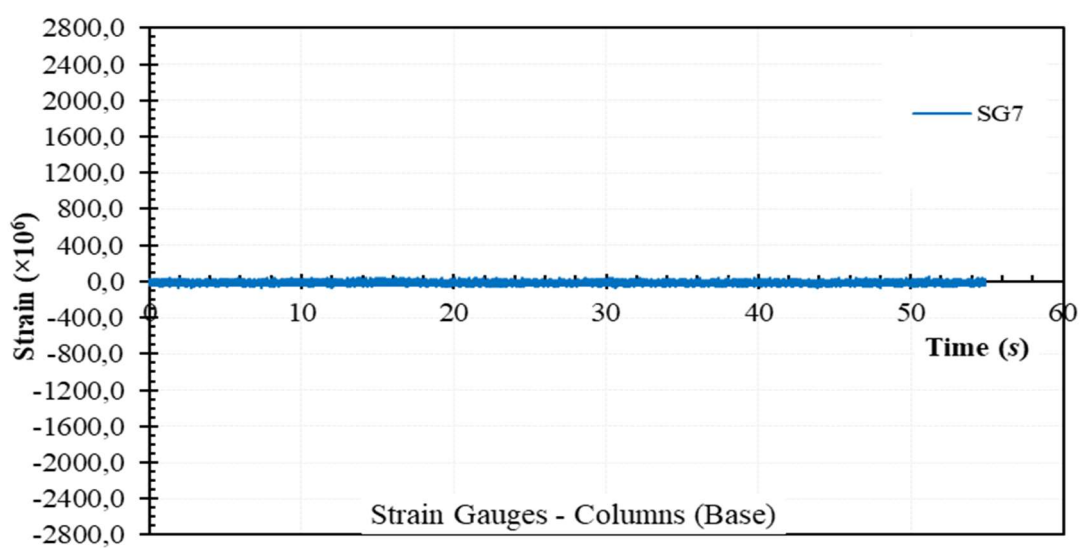
Residual: -15,26 μ strain

Sg 4

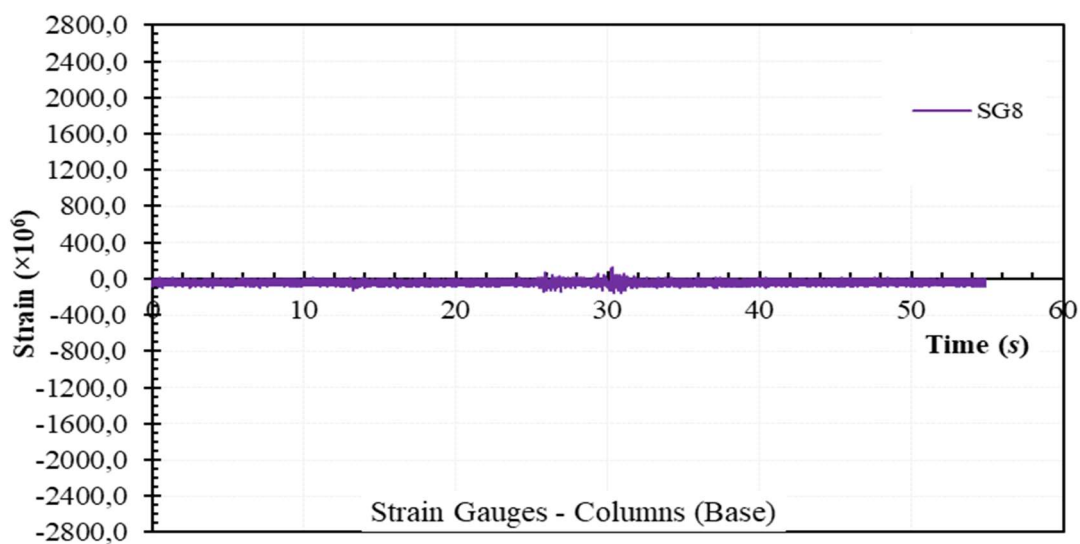
Max: 122,07 μ strain

Min: -106,81 μ strain

Residual: -15,26 μ strain



(a)



(b)

Figure 3.2.14 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 7 and (b) strain gauge 8

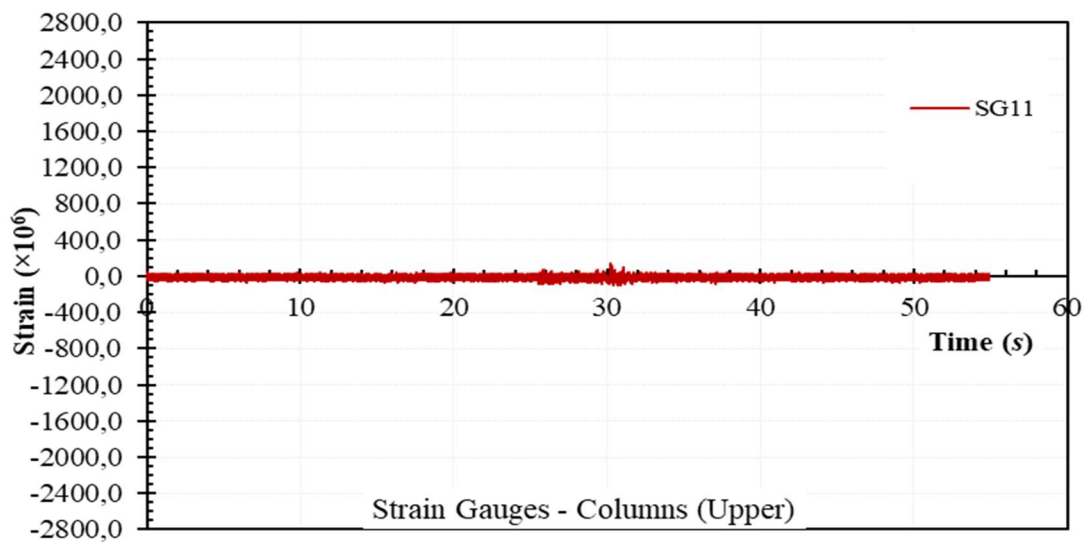
Sg 7

Max: 61,04 μ strain

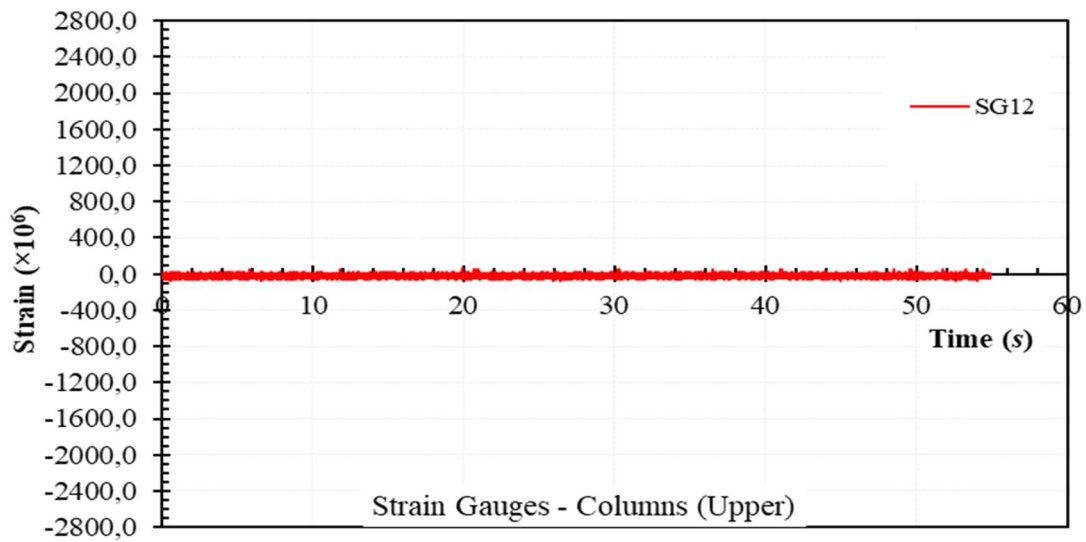
Min: -76,30 μstrain
Residual: 30,52 μstrain

Sg 8

Max: 122,07 μstrain
Min: -152,59 μstrain
Residual: -15,26 μstrain



(a)



(b)

Figure 3.2.15 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12

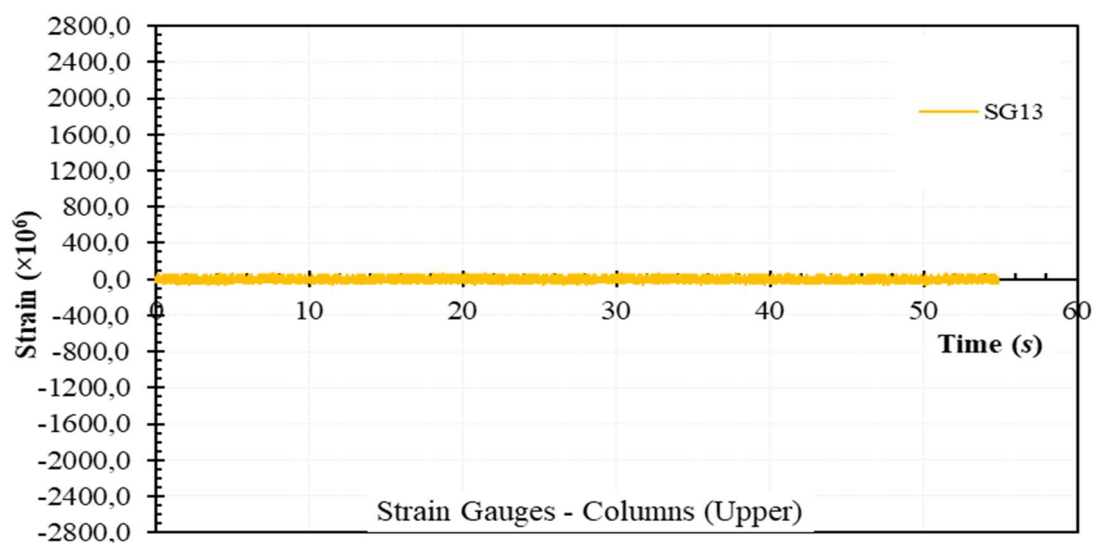
The strain gauges shown in the figures 3.2.15, 3.2.16, 3.1.17 and 3.2.20 are located in the longitudinal reinforcement, on the upper side. More specifically, strain gauge SG9 has 38,26 μstrain maximum strain, -133,47 μstrain minimum strain and -13,84 μstrain residual. Strain gauge SG10 has 191,94 μstrain maximum strain, -144,52 μstrain minimum strain and 4,9 μstrain residual. Strain gauge SG11 has maximum strain 137,33 μstrain and minimum -106,81 μstrain deformation. The residual strain

is -15,2 for strain gauge SG11. Strain gauge SG12 has maximum strain 61,04 μ strain and minimum strain -76,30 μ strain. The residual value is -30,52 μ strain. Strain gauge SG13 has maximum strain 61,04 μ strain and minimum strain -61,04 μ strain. The residual is 15,26 μ strain. Strain gauge SG14 has maximum strain 106,81 μ strain and minimum strain -122,07 μ strain. The residual is 15,26 μ strain. Finally strain gauges SG15 has maximum strain 122,07 μ strain and minimum strain -106,81 μ strain. The residual is -30,52 μ strain. Strain gauge SG16 has maximum strain 106,81 μ strain, minimum strain -106,81 μ strain and residual strain 0 μ strain.

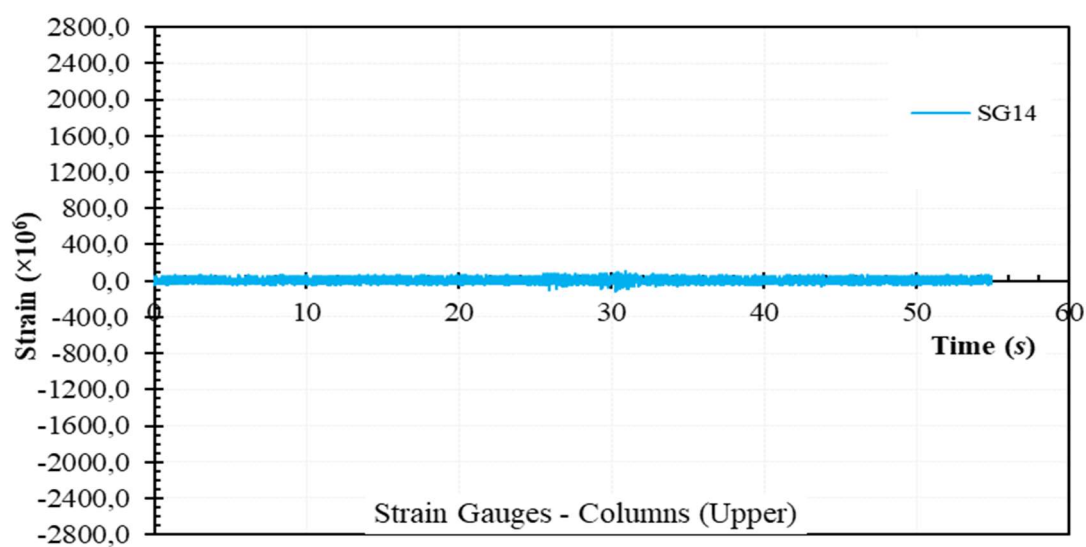
Sg 11Max: 137,33 μ strainMin: -106,81 μ strain

Residual: -15,26

Sg 12Max: 61,04 μ strainMin: -76,30 μ strainResidual: -30,52 μ strain



(a)



(b)

Figure 3.2.16 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 13 and (b) strain gauge 14

Sg 13

Max: 61,04 μ strain

Min: -61,04 μ strain

Residual: 15,26 μ strain

Sg 14

Max: 106,81 μ strain

Min: -122,07 μ strain

Residual: 15,26 μ strain

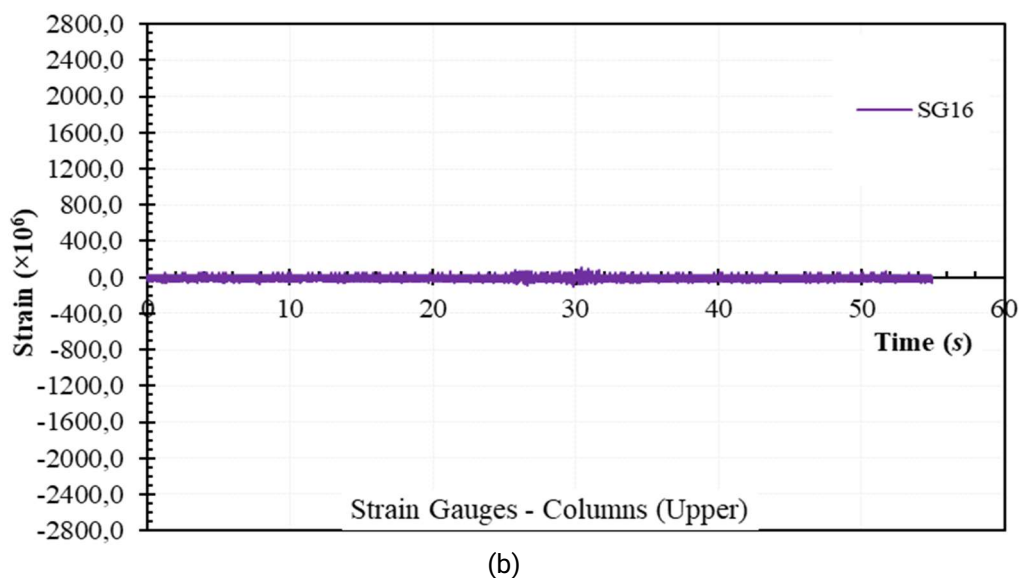
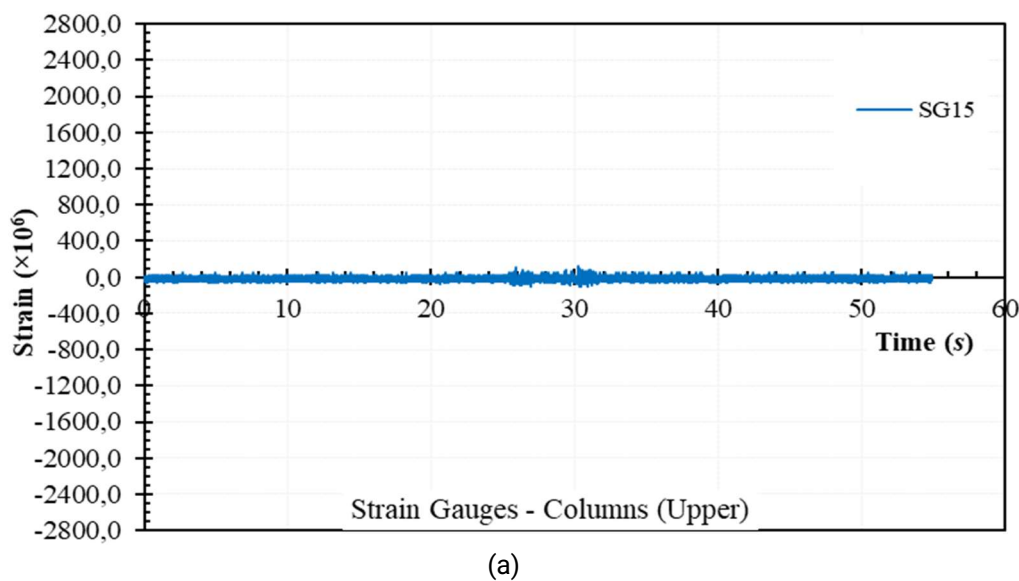


Figure 3.2.17 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 15 and (b) strain gauge 16

Sg 15

Max: 122,07 μ strain

Min: -106,81 μ strain

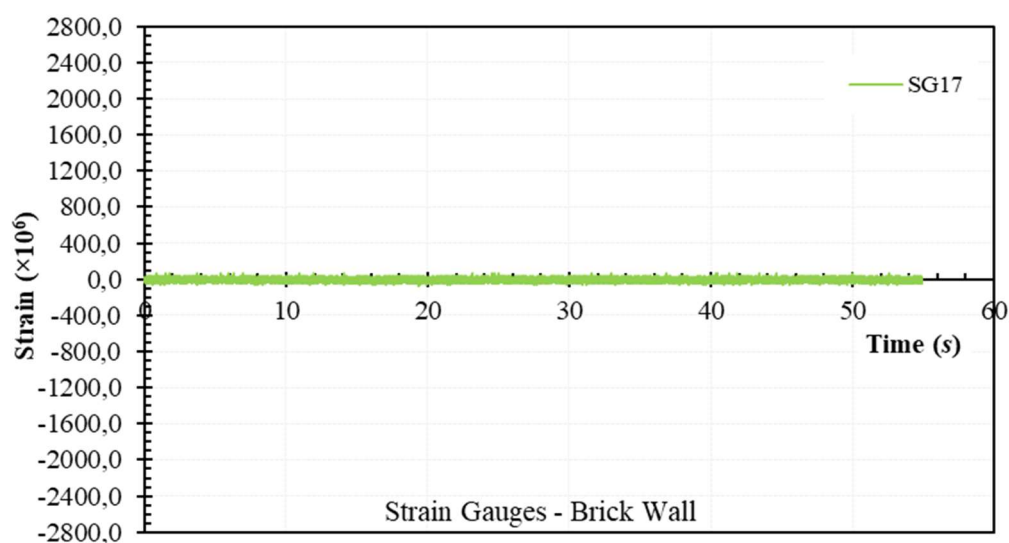
Residual: -30,52 μ strain

Sg 16

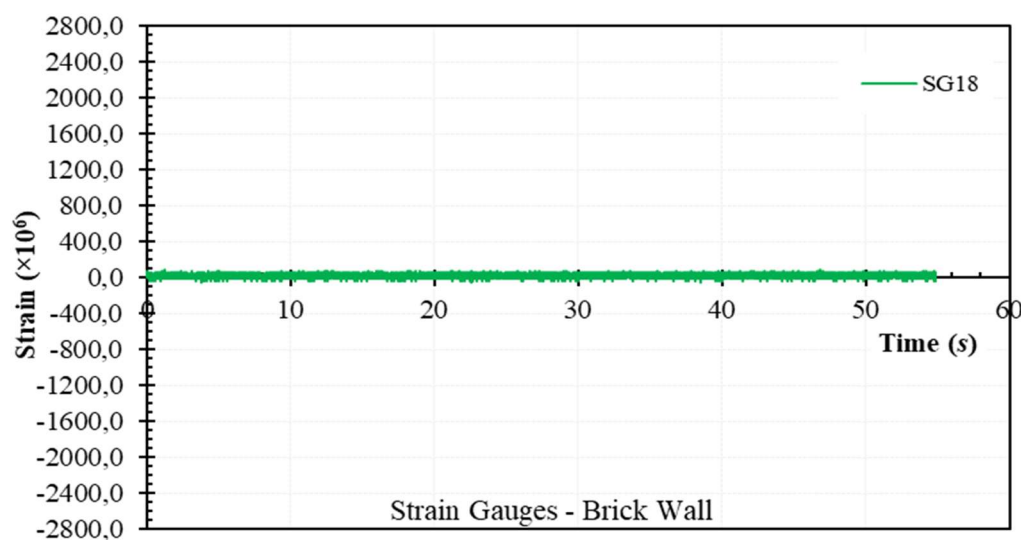
Max: 106,81 μ strain

Min: -106,81 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.2.18 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 17 and (b) strain gauge 18

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauges SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge SG17 and strain gauge 18 have the same 91,56 μ strain. Strain gauge SG17 has minimum deformation -76,30 μ strain and strain gauge 18 -45,78 μ strain. Finally strain gauge SG17 presents 0 μ strain residual. Strain gauge SG18 presents 30,52 μ strain residual.

Sg 17

Max: 91,56 μ strain

Min: -76,30 μ strain

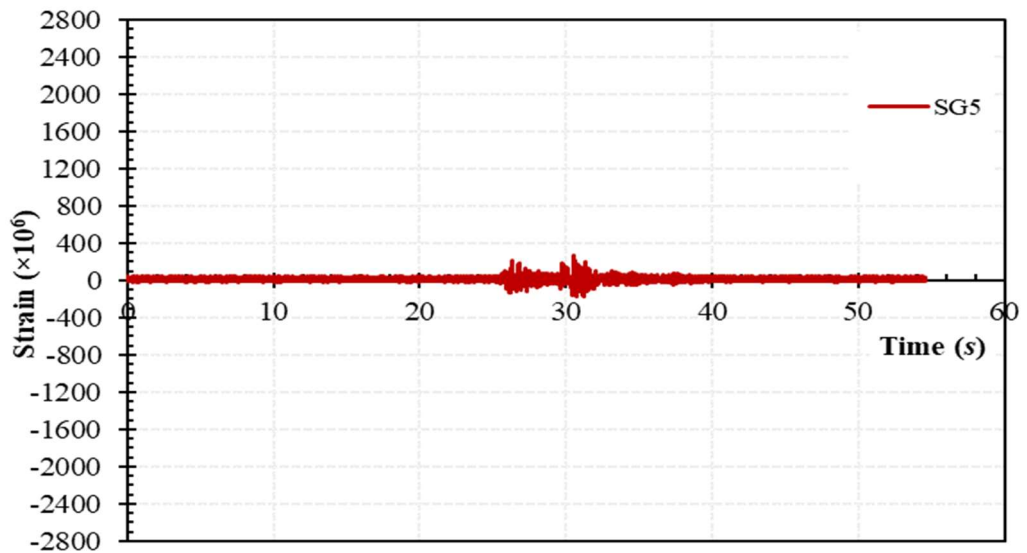
Residual: 0 μ strain

Sg 18

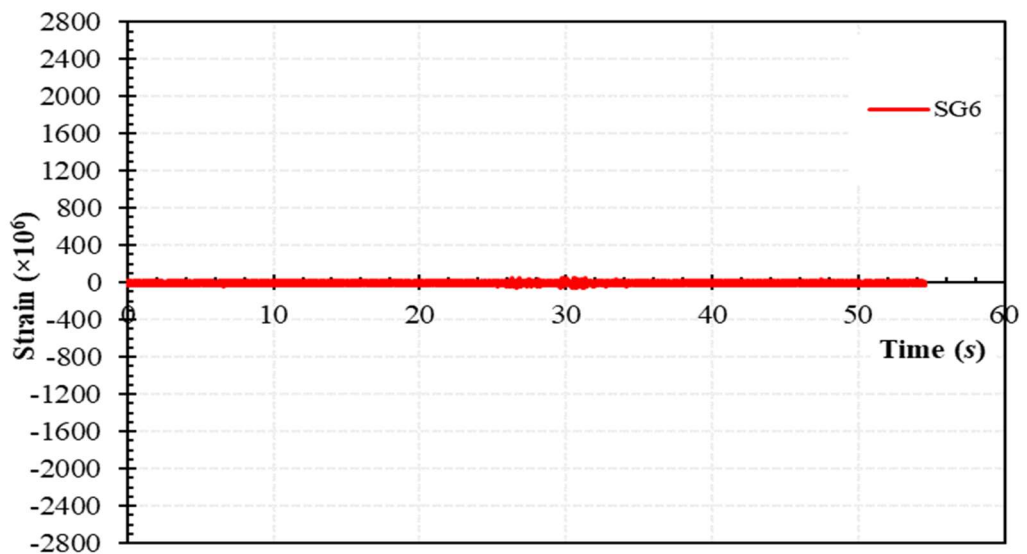
Max: 91,56 μ strain

Min: -45,78 μ strain

Residual: 30,52 μ strain



(a)



(b)

Figure 3.2.19 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 5 and (b) strain gauge 6

Sg 5

Max: 271,86 μ strain

Min: -167,60 μ strain

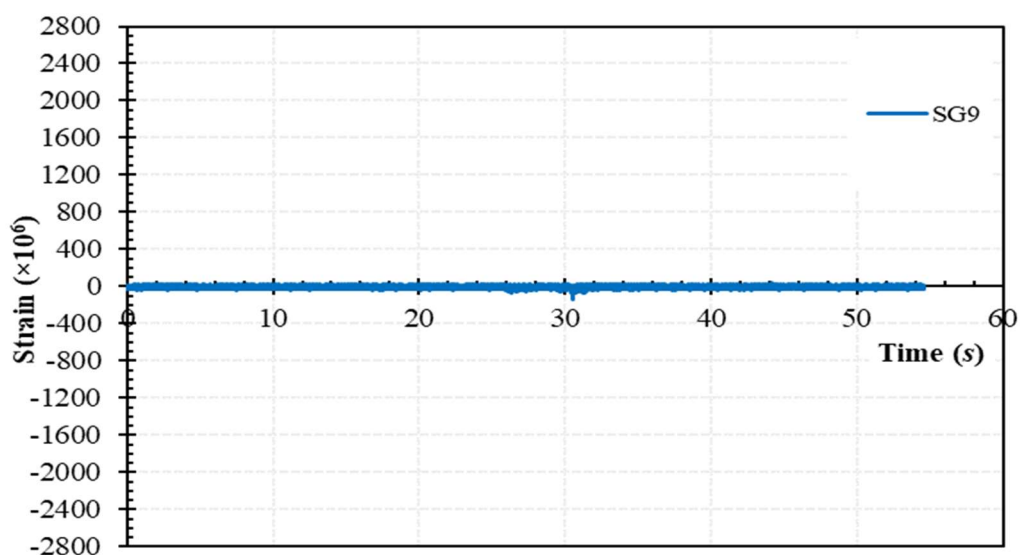
Residual: 11,39 μ strain

Sg 6

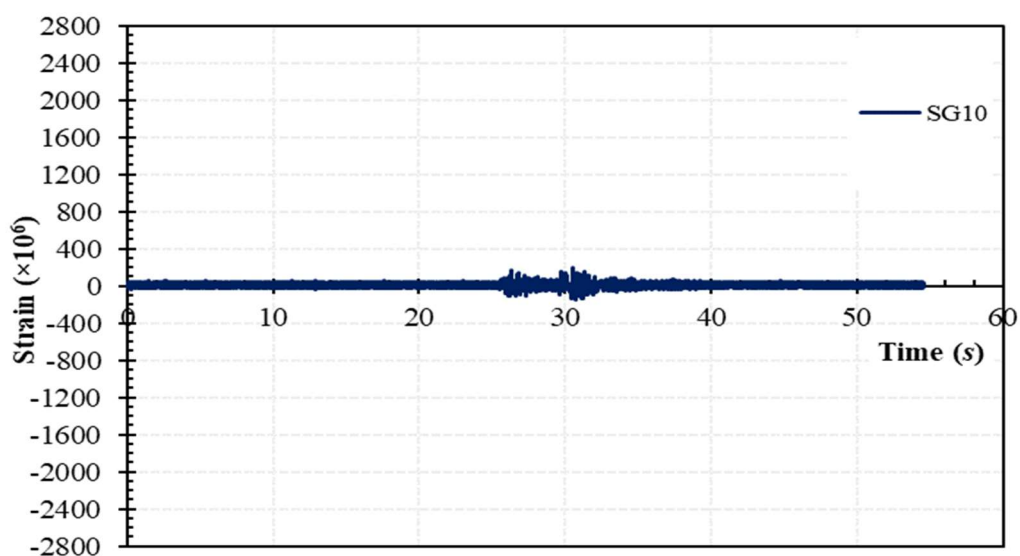
Max: 55,50 μ strain

Min: -62,84 μ strain

Residual: -26,12 μ strain



(a)



(b)

Figure 3.2.20 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 9 and (b) strain gauge 10

Sg 9

Max: 38,26 μ strain

Min: -133,47 μ strain

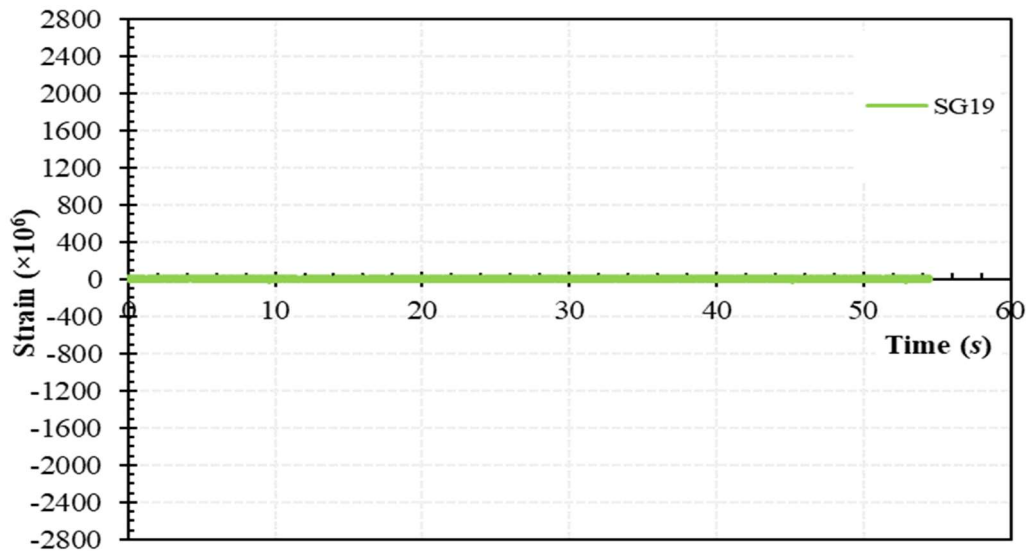
Residual: -13,84 μ strain

Sg 10

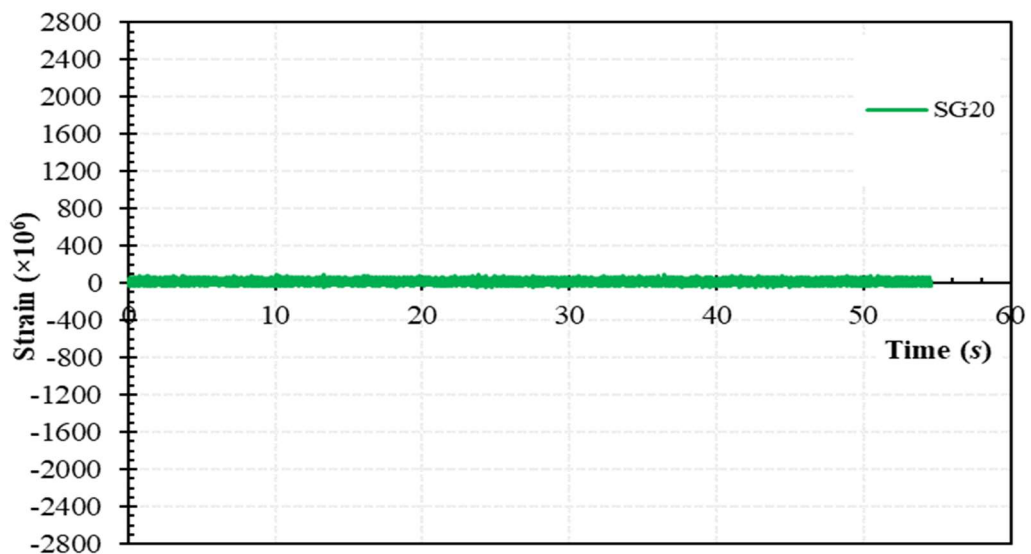
Max: 191,94 μ strain

Min: -144,52 μ strain

Residual: 4,90 μstrain



(a)



(b)

Figure 3.2.21 Characteristic results for phase A (0,1g earthquake) (a) strain gauge 19 and (b) strain gauge 20

Strain gauge 19 is located on the centre of partial masonry 2 along direction x. Strain gauges 20 is located on the centre of partial masonry 2 along direction x. More specifically strain gauge SG19 has maximum 38,96 μstrain and minimum -30,03 μstrain . Strain gauge SG20 has maximum strain 94,39 μstrain and minimum -51,25 μstrain . The residual strain for strain gauge SG19 is 7,31 μstrain and residual for strain gauge SG20 is 6,51 μstrain .

Sg 19

Max: 38,96 μstrain

Min: -30,03 μ strain

Residual: 7,31 μ strain

Sg 20

Max: 94,39 μ strain

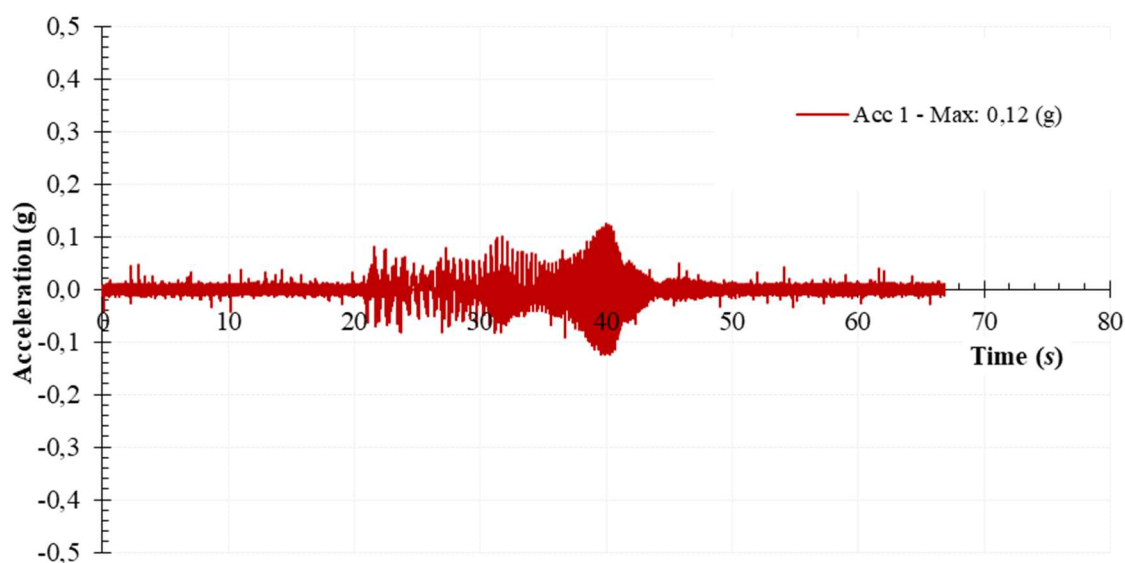
Min: -51,25 μ strain

Residual: 6,51 μ strain

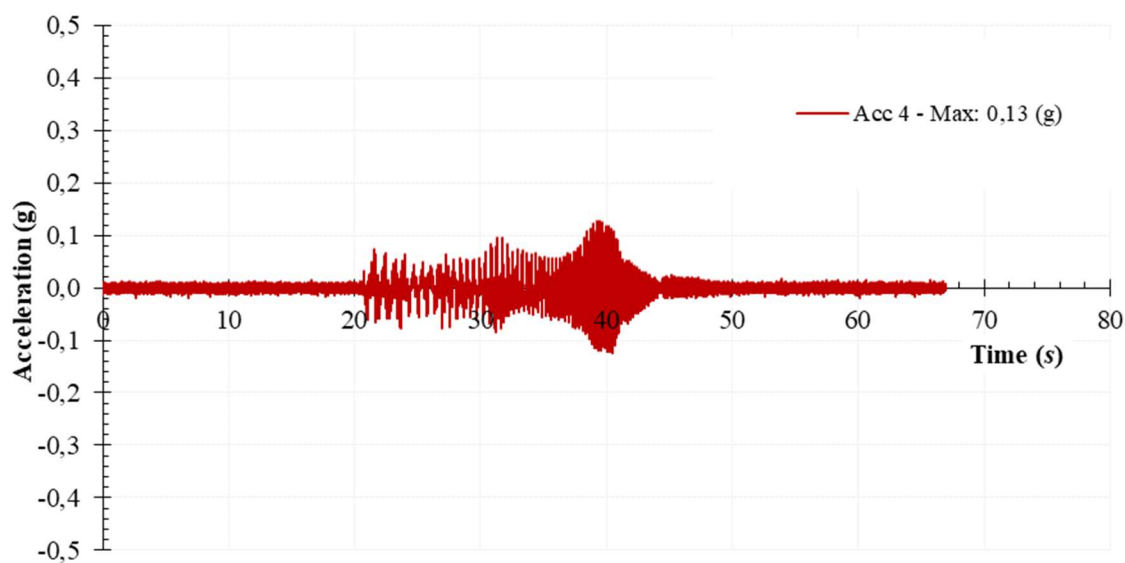
3.3) White noise before EQ0,2g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for white noise before EQ0,2g. The max acceleration at the slab level on the accelerometer acc 1 and acc4 is 0,12g and 0,13g respectively. The max acceleration at the foundation level on the accelerometer acc10 is 0,11g.

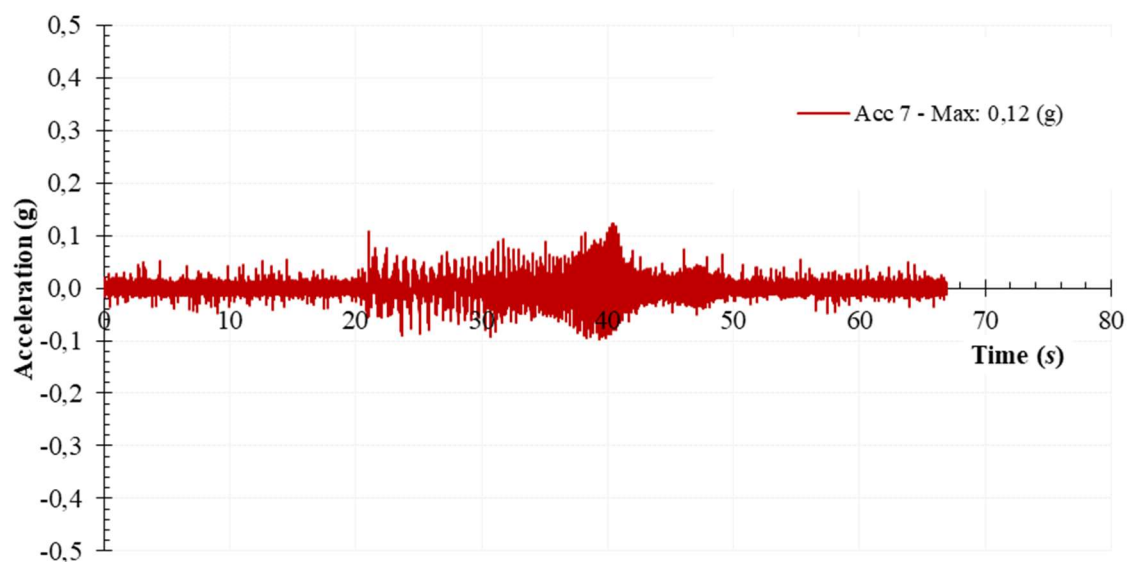


(a)

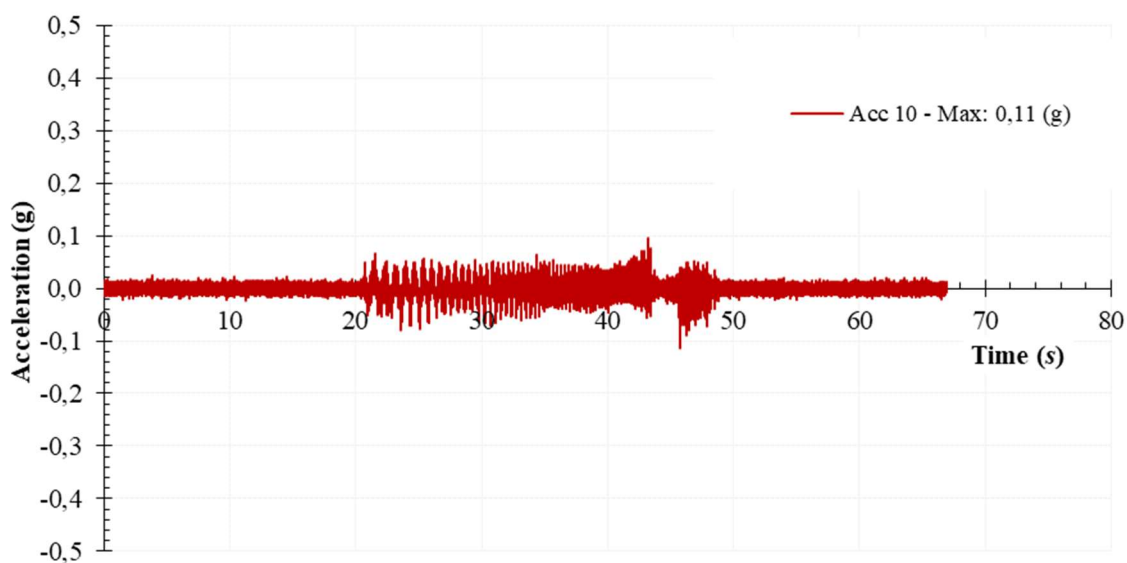


(b)

Figure 3.3.1 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 1 (b) Accelerometer 4

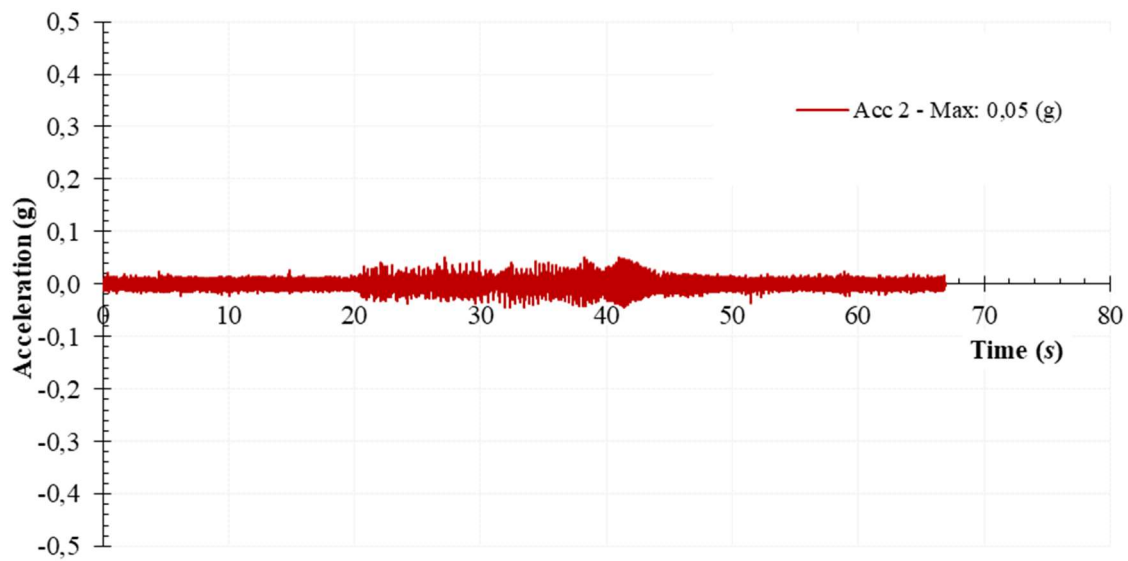


(a)

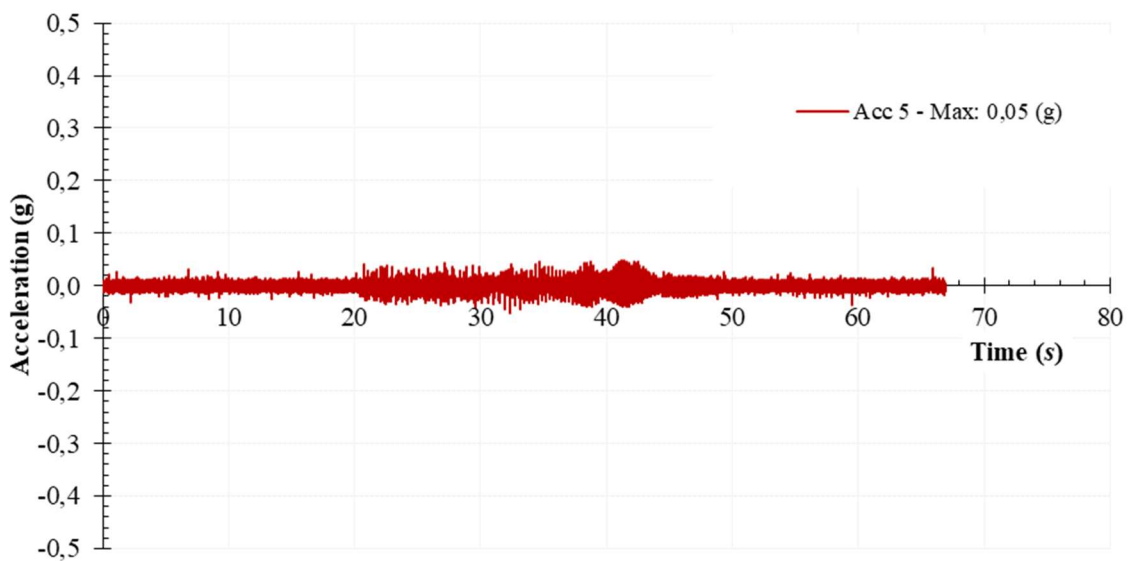


(b)

Figure 3.3.2 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

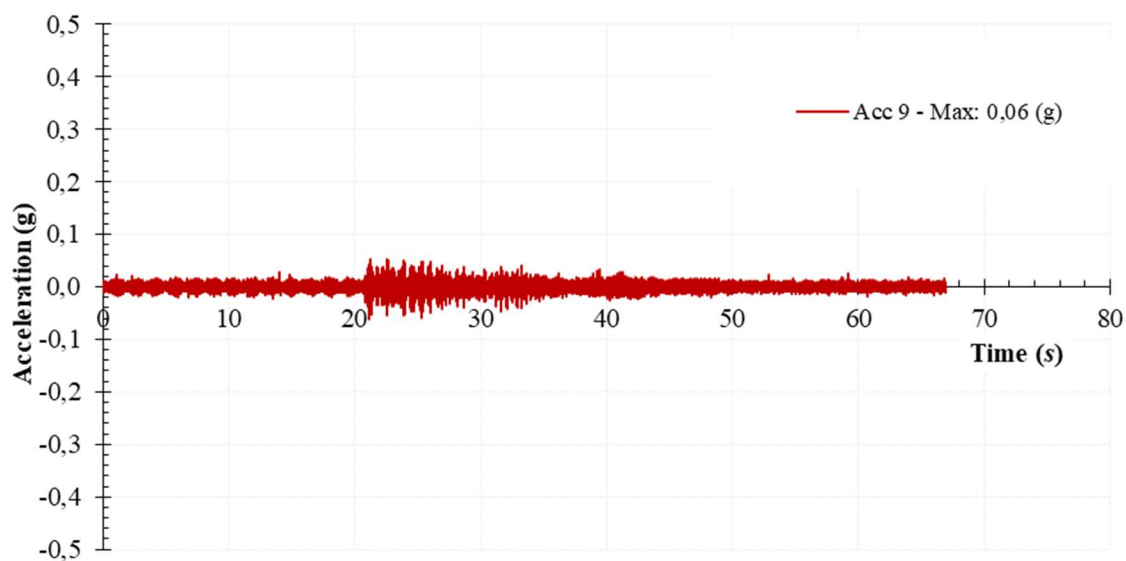


(a)

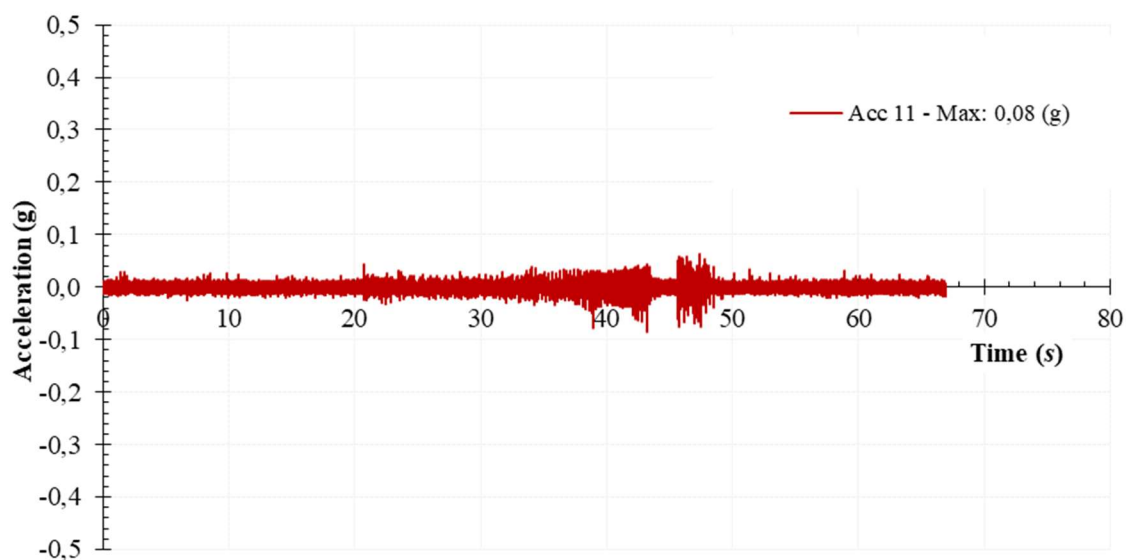


(b)

Figure 3.3.3 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

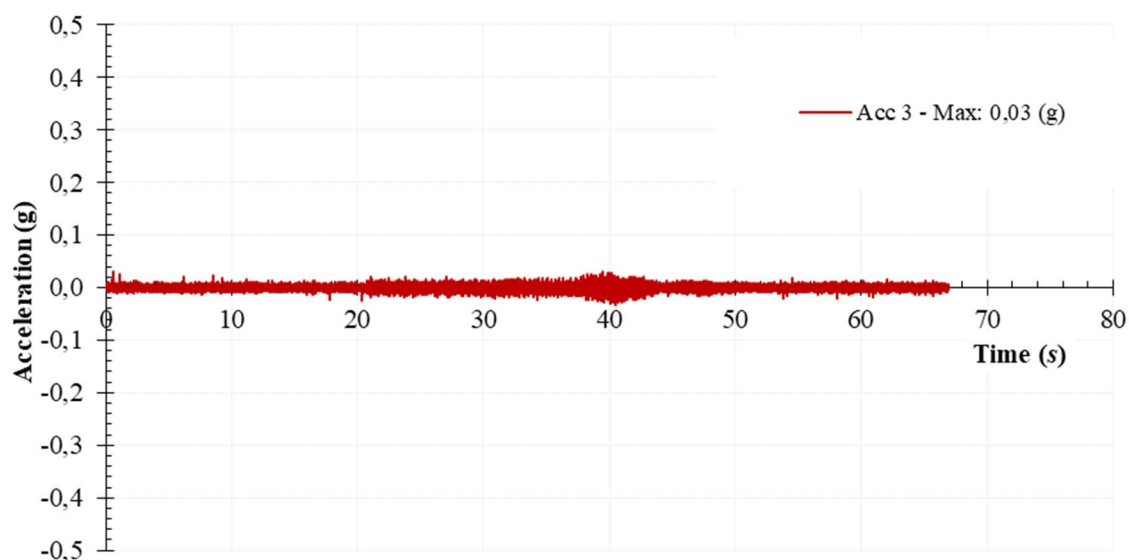


(a)

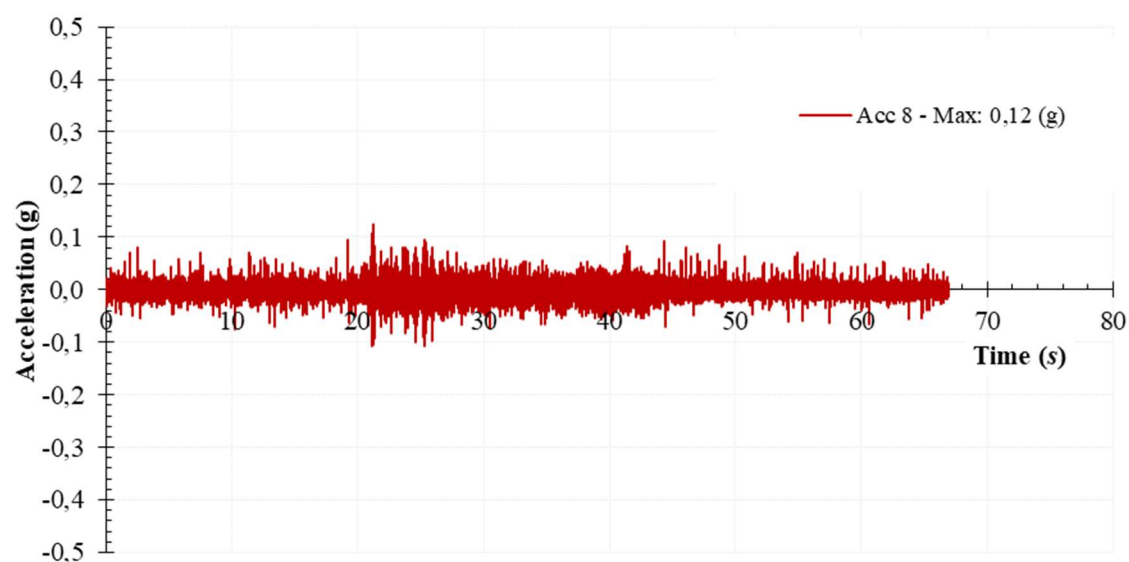


(b)

Figure 3.3.4 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 9 (b) Accelerometer 11

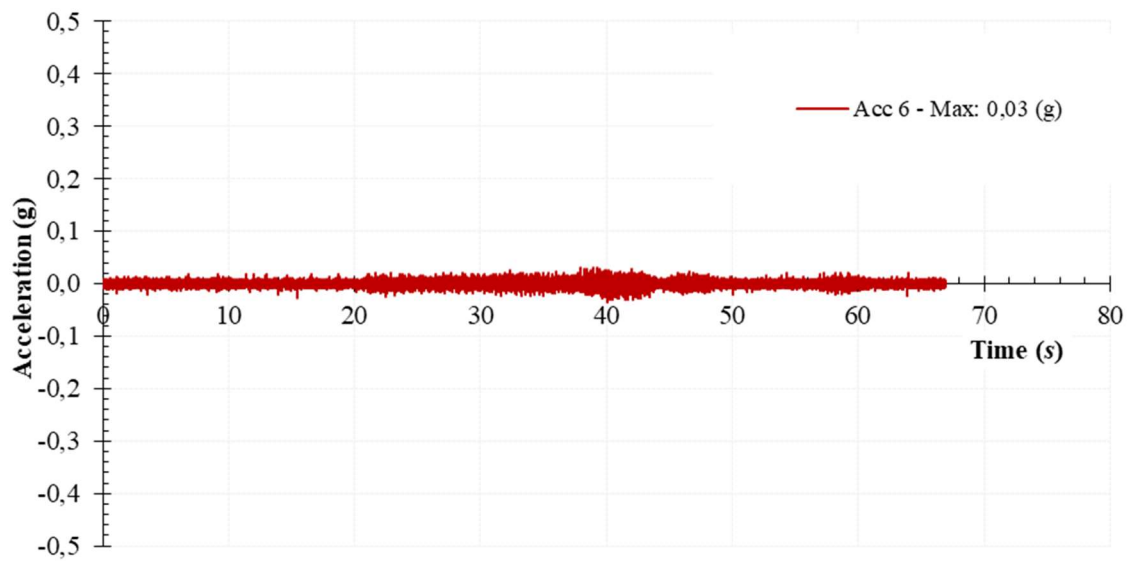


(a)

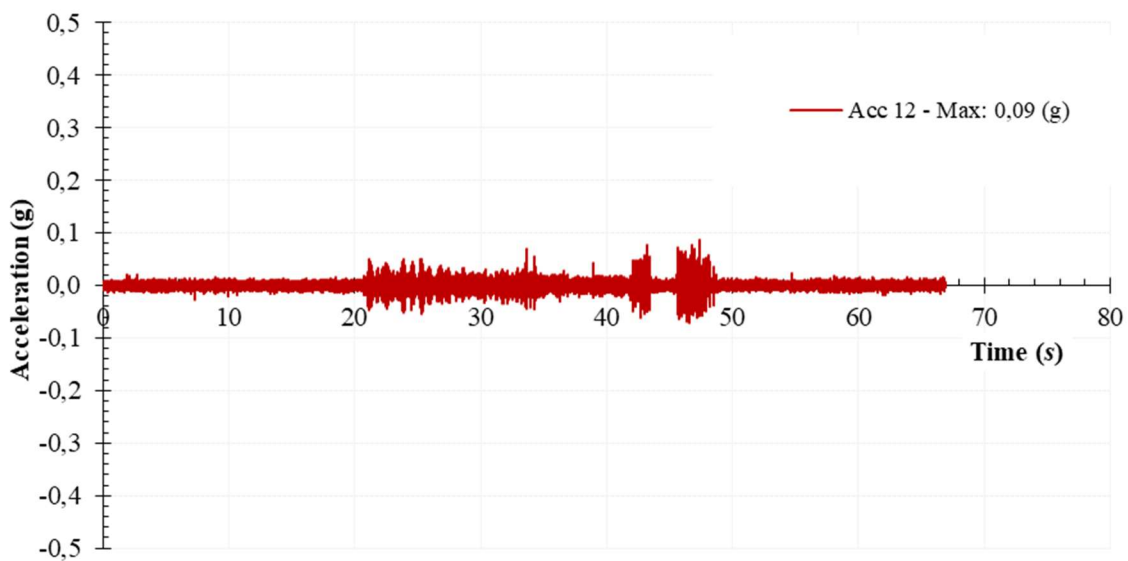


(b)

Figure 3.3.5 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 3 (b) Accelerometer 8

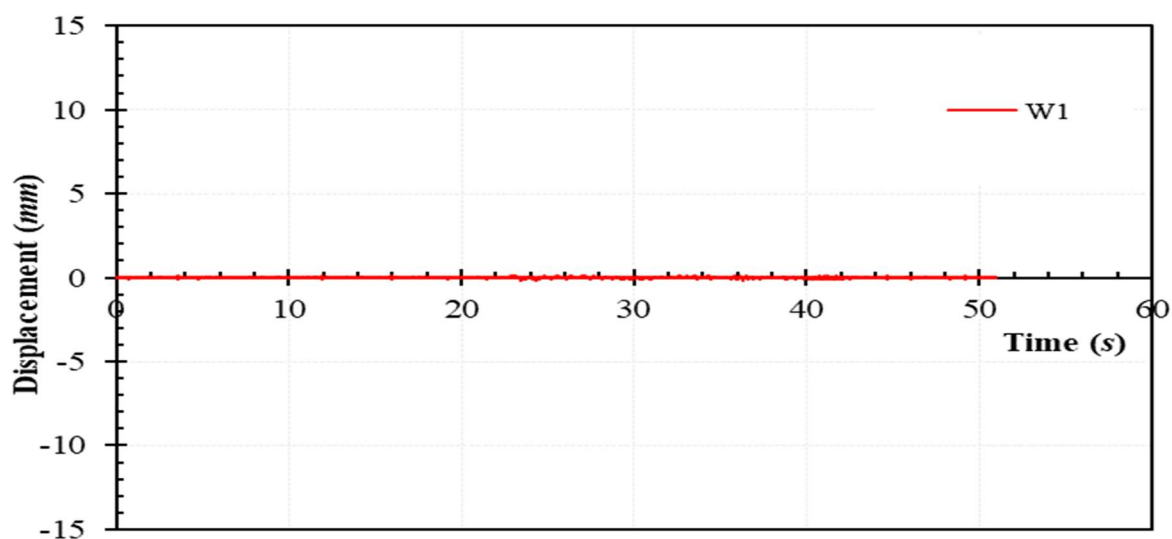


(a)

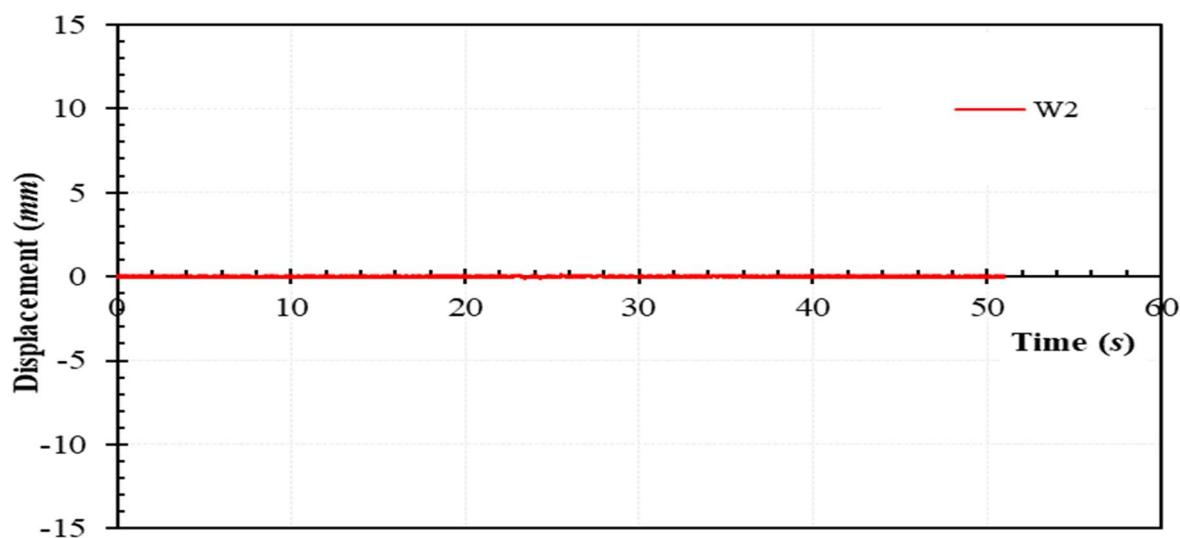


(b)

Figure 3.3.6 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Accelerometer 6 (b) Accelerometer 12



(a)



(b)

Figure 3.3.7 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2

Figure 3.3.7 shows draw wire sensors W1 and W2. More specifically, draw wire sensor W1 is located on the slab, on the left side and draw wire sensor W2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor W1 is 0,15 mm while the minimum is -0,17 mm. The maximum movement detected by draw wire sensor W2 is 0,13 mm while the minimum is -0,12 mm.

W1

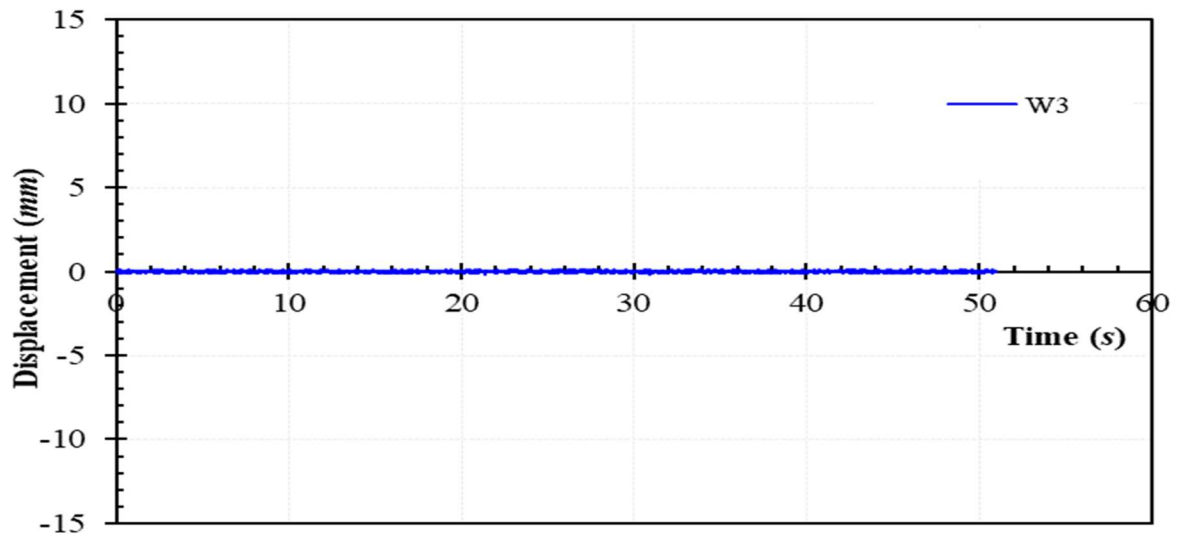
Max: 0,15 mm

Min: -0,17 mm

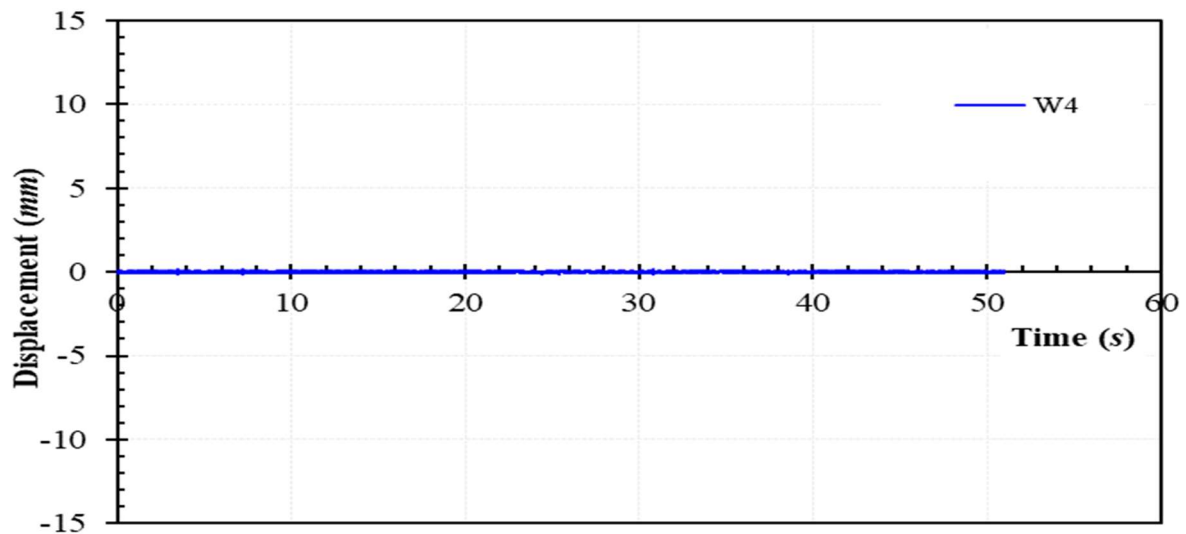
W2

Max: 0,13 mm

Min: -0,12 mm



(a)



(b)

Figure 3.3.8 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor

Figure 3.3.8 shows draw wire sensors W3 and W4. More specifically, draw wire sensor W3 is located on the foundation, on the left side and draw wire sensor W4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor W3 is 0,15 mm while the minimum is -0,16 mm. The maximum movement detected by draw wire sensor W2 is 0,18 mm while the minimum is -0,16 mm.

W 3

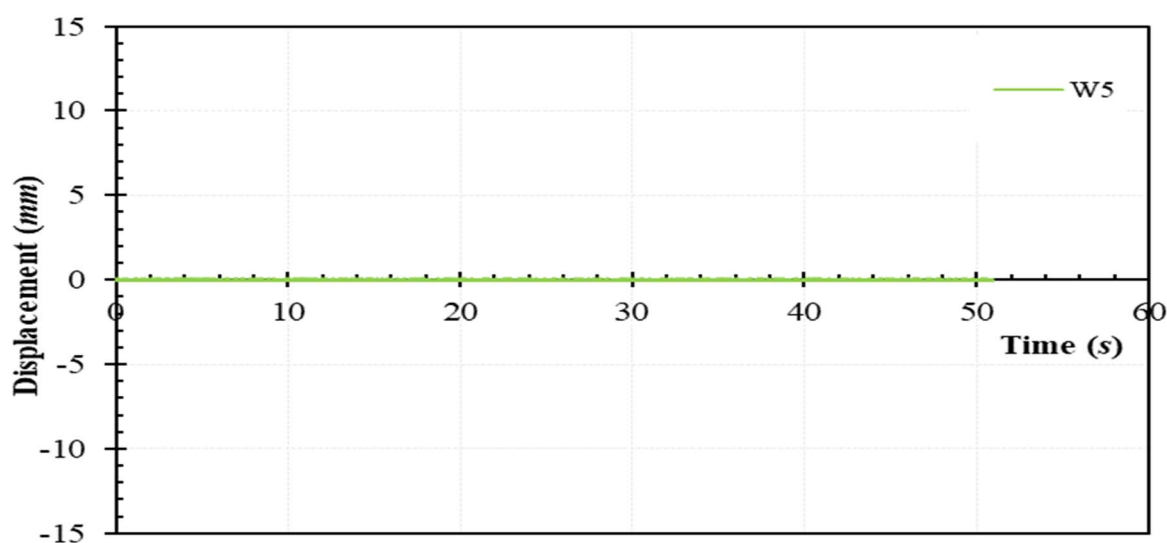
Max: 0,15 mm

Min: -0,16 mm

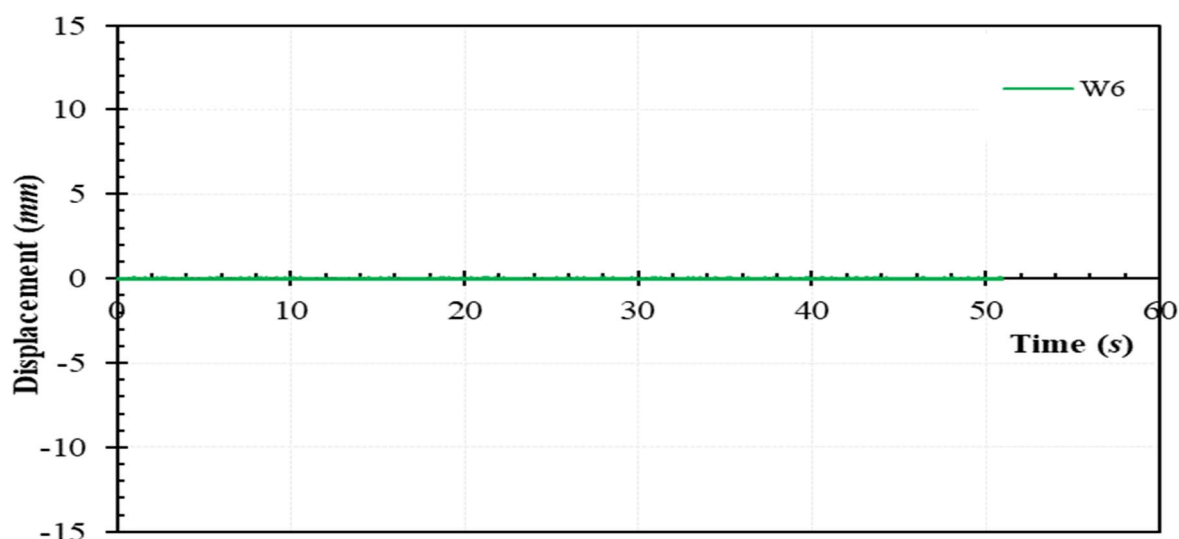
W 4

Max: 0,18 mm

Min: -0,16 mm



(a)



(b)

Figure 3.3.9 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6

Figure 3.3.9 shows draw wire sensors W5 and W6. More specifically, draw wire sensor WW5 is located along the partial masonry infill diagonal and draw wire sensor W6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W5 is 0,09 mm while the minimum is -0,08 mm. The maximum movement detected by draw wire sensor W6 is 0,07 mm while the minimum is -0,07 mm.

W 5

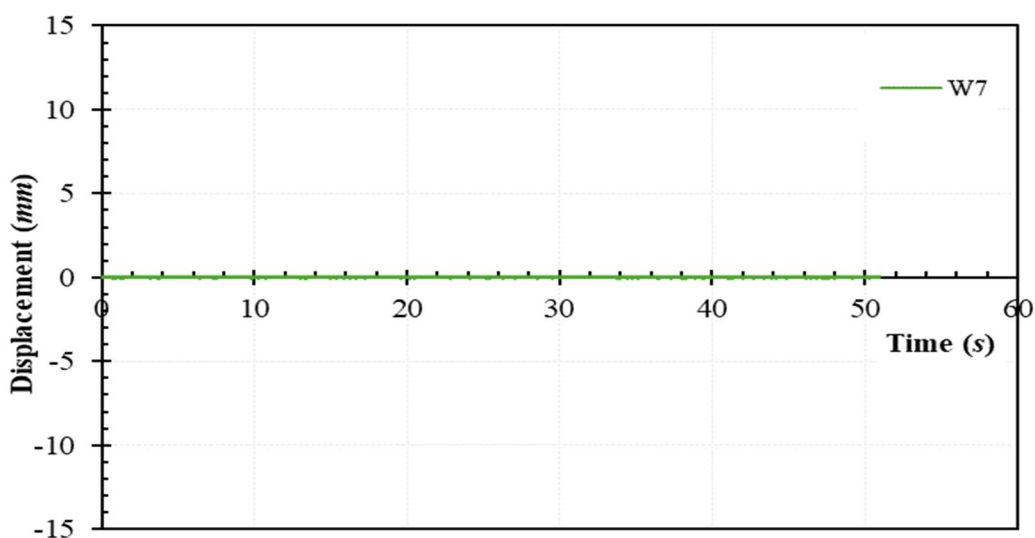
Max: 0,09 mm

Min: -0,08 mm

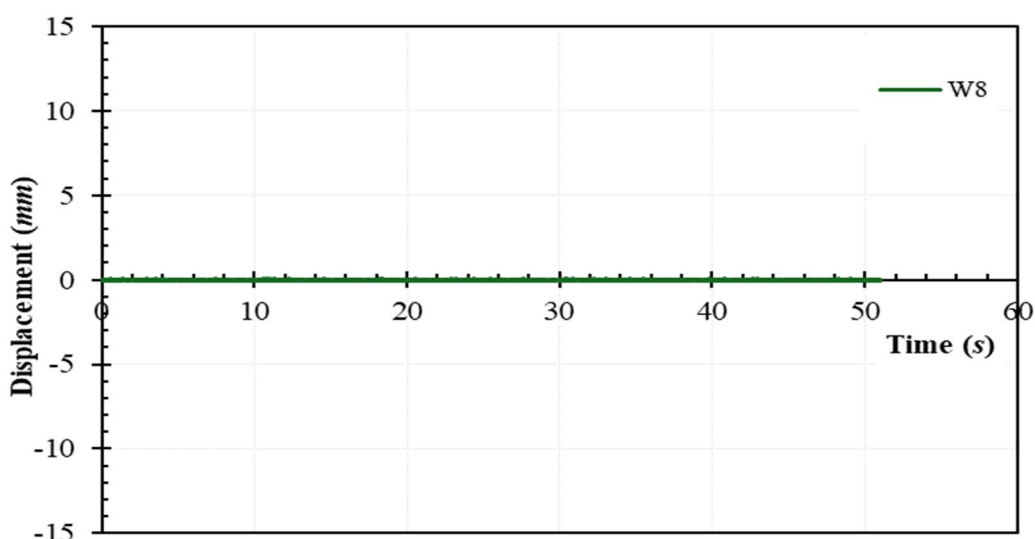
W 6

Max: 0,07 mm

Min: -0,07 mm



(a)



(b)

Figure 3.3.10 Characteristic results for phase A (white noise before 0,2g earthquake) : (a) Draw wire sensor 7 and (b) Draw wire sensor 8

Figure 3.3.10 shows draw wire sensors W7 and W8. More specifically, draw wire sensor W7 is located along the partial masonry infill diagonal and draw wire sensor W8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W7 is 0,07 mm while the minimum is -0,08 mm. The maximum movement detected by draw wire sensor W8 is 0,07 mm while the minimum is -0,06 mm.

W 7

Max: 0,07 mm

Min: -0,08 mm

W 8

Max: 0,07 mm

Min: -0,06 mm

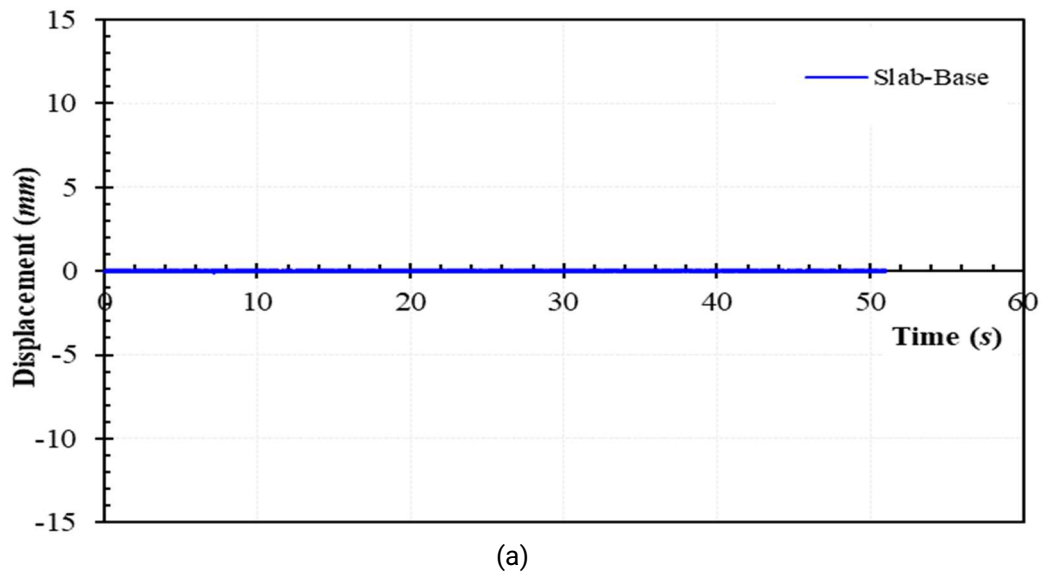


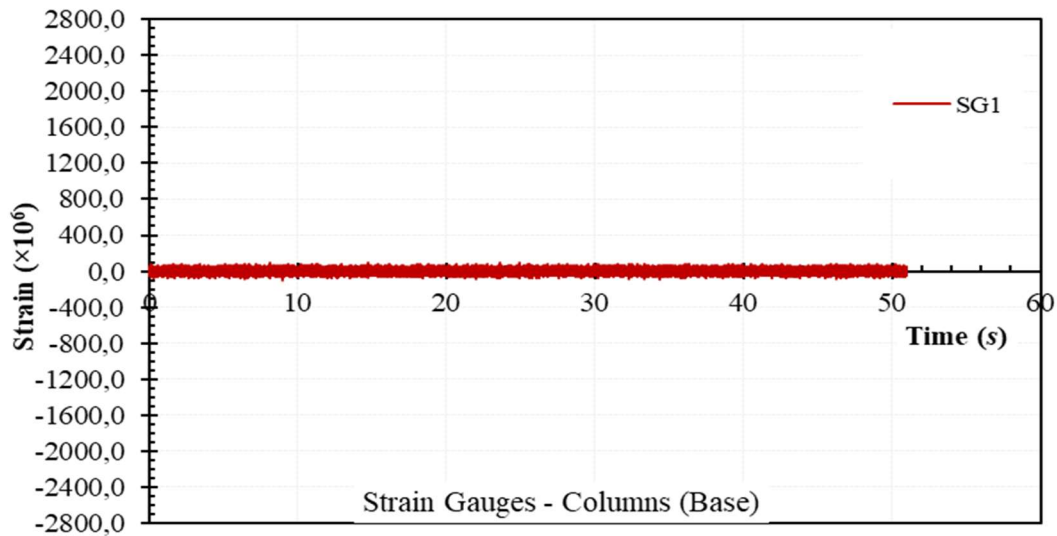
Figure 3.3.11 Characteristic results for phase A (white noise before 0,2g earthquake): (a) Diagram of displacement Slab – Base

Figure 3.3.11 shows slab – base displacement. More specifically, the maximum drift detected is 0,08 ‰ while the minimum is -0,09 ‰. The residual drift is -0,02 mm.

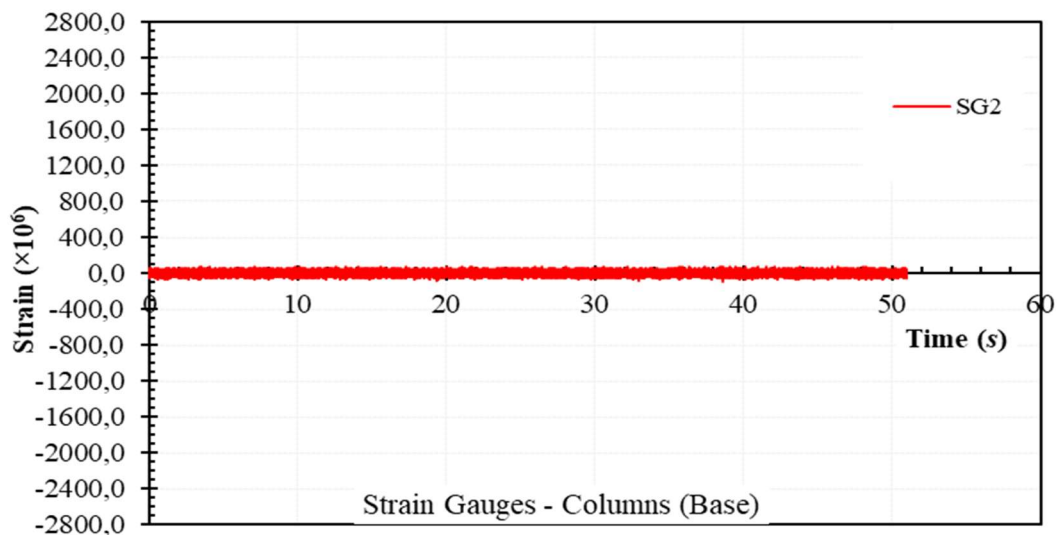
Maximum drift (‰): 0,08 ($0,098 \text{ m} / 1,225 \text{ m} = 0,08 \text{ ‰}$)

Minimum drift (‰): -0,09

Residual drift: -0,02 mm



(a)



(b)

Figure 3.3.12 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 1 and (b) strain gauge 2

Strain gauges detect strain. The strain gauges shown in the figures 3.3.12, 3.3.13, 3.3.14 and 3.3.19 are located in the longitudinal reinforcement, on the underside. More specifically, strain gauge SG1 has maximum strain $91,56\mu\text{strain}$ and minimum strain $-91,56\mu\text{strain}$. The residual strain is $0\mu\text{strain}$. Strain gauge SG2 has maximum deformation $76,30\mu\text{strain}$ and minimum $-91,56\mu\text{strain}$. The residual strain is $15,26\mu\text{strain}$. Strain gauge SG3 has $91,56\mu\text{strain}$ and $-91,56\mu\text{strain}$ maximum and minimum strain respectively. The residual strain is $-30,52\mu\text{strain}$. Strain gauge SG4 as we can see in figure 3.2.13 has maximum $122,07\mu\text{strain}$ and minimum $-106,81\mu\text{strain}$ deformation. The residual strain is $-30,52\mu\text{strain}$. Figure 3.2.19 shows strain gauges SG5 and SG6. Strain gauge 5 has $170,78\mu\text{strain}$ and $-166,68\mu\text{strain}$ maximum and minimum strain respectively. Strain gauge SG5 presents $16,26\mu\text{strain}$ residual strain. Strain gauge 6 has $28,53\mu\text{strain}$ maximum strain, $-50,54\mu\text{strain}$ minimum strain and $-6,52\mu\text{strain}$ residual. Finally in figure 3.2.14 see strain gauge SG7 and SG8. Strain gauge SG7 has maximum strain $91,56\mu\text{strain}$ and SG8 has maximum strain $91,56\mu\text{strain}$. Strain gauge SG7 has $-91,56\mu\text{strain}$ minimum

deformation and SG8 has $-91,56 \mu\text{strain}$. The residual strain for strain gauge SG7 and SG8 is 0, $-15,26$ respectively.

Sg 1

Max: $91,56 \mu\text{strain}$

Min: $-91,56 \mu\text{strain}$

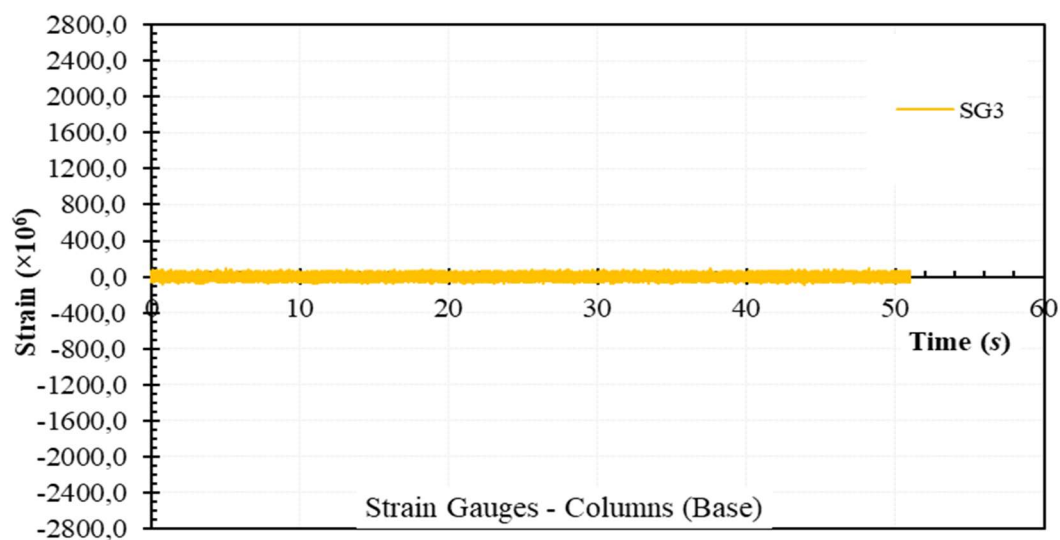
Residual: $0 \mu\text{strain}$

Sg 2

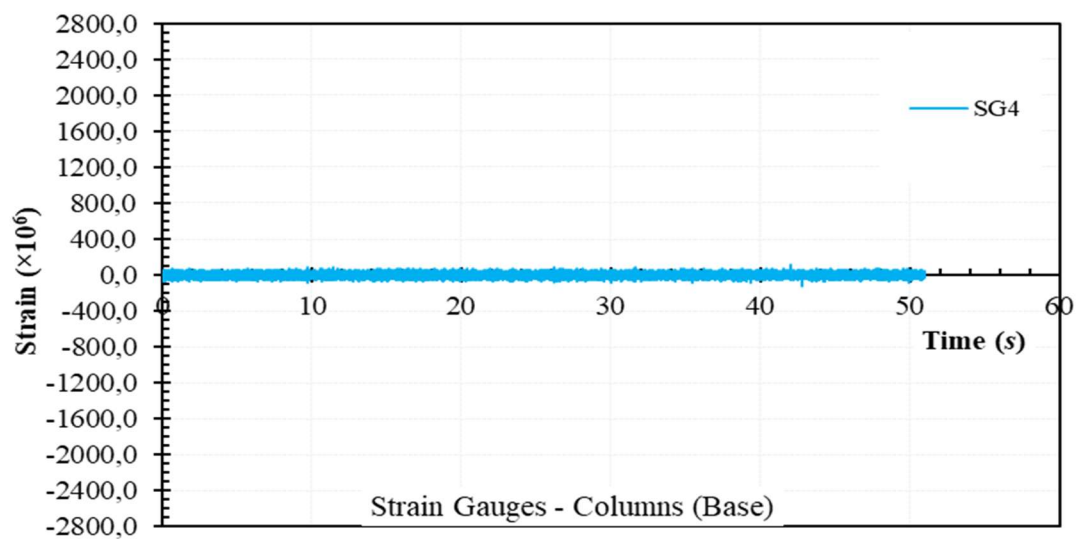
Max: $76,30 \mu\text{strain}$

Min: $-91,56 \mu\text{strain}$

Residual: $15,26 \mu\text{strain}$



(a)



(b)

Figure 3.3.13 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 3 and (b) strain gauge 4

Sg 3

Max: 91,56 μ strain

Min: -91,56 μ strain

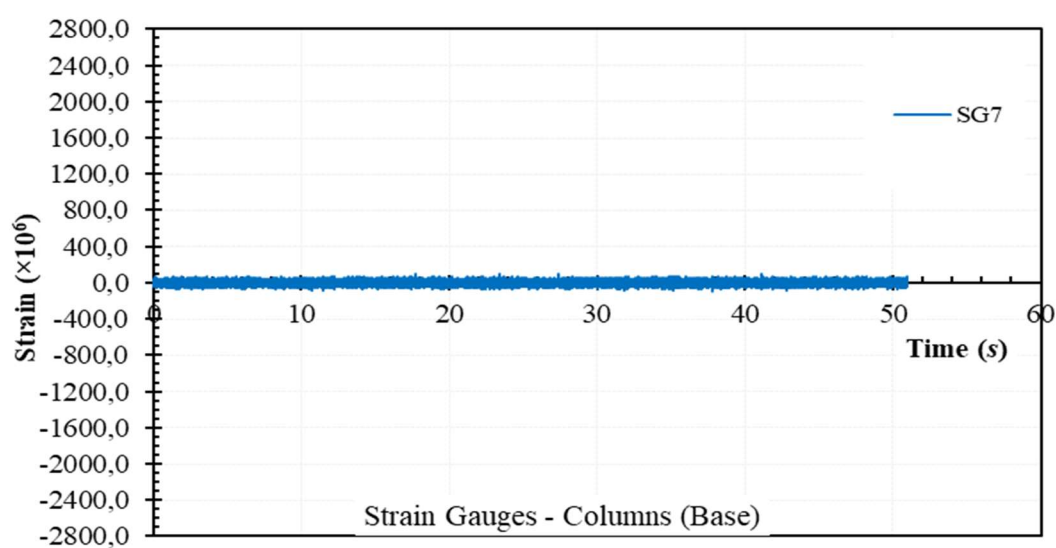
Residual: -30,52 μ strain

Sg 4

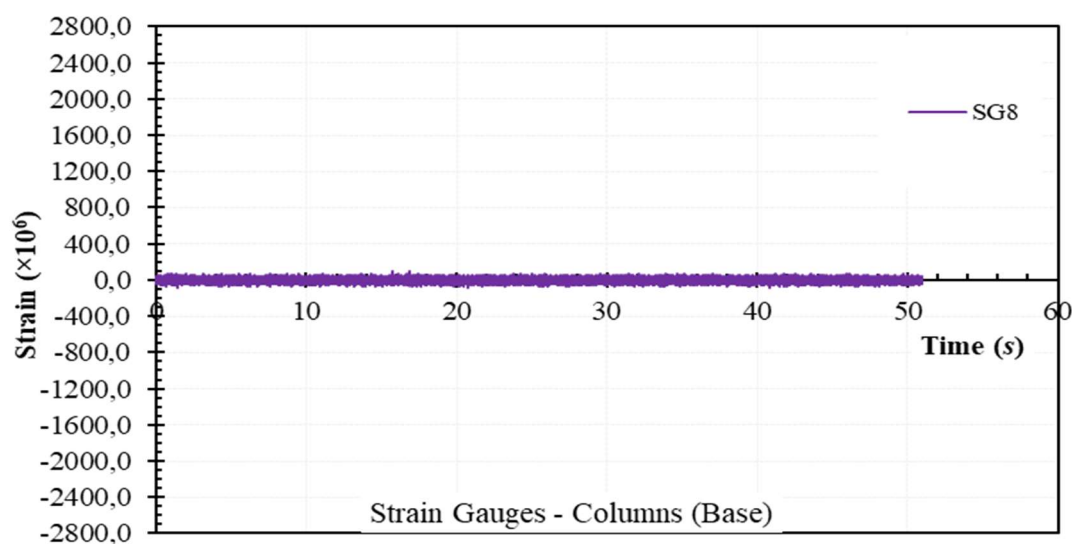
Max: 122,07 μ strain

Min: -106,81 μ strain

Residual: -30,52 μ strain



(a)



(b)

Figure 3.3.14 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 7 and (b) strain gauge 8

Sg 7

Max: 91,56 μ strain

Min: -91,56 μ strain

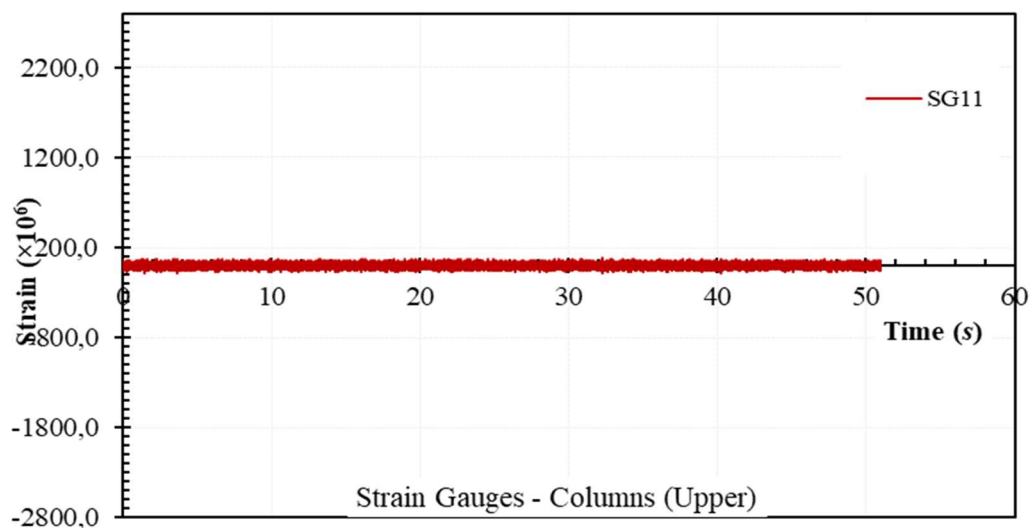
Residual: 0 μ strain

Sg 8

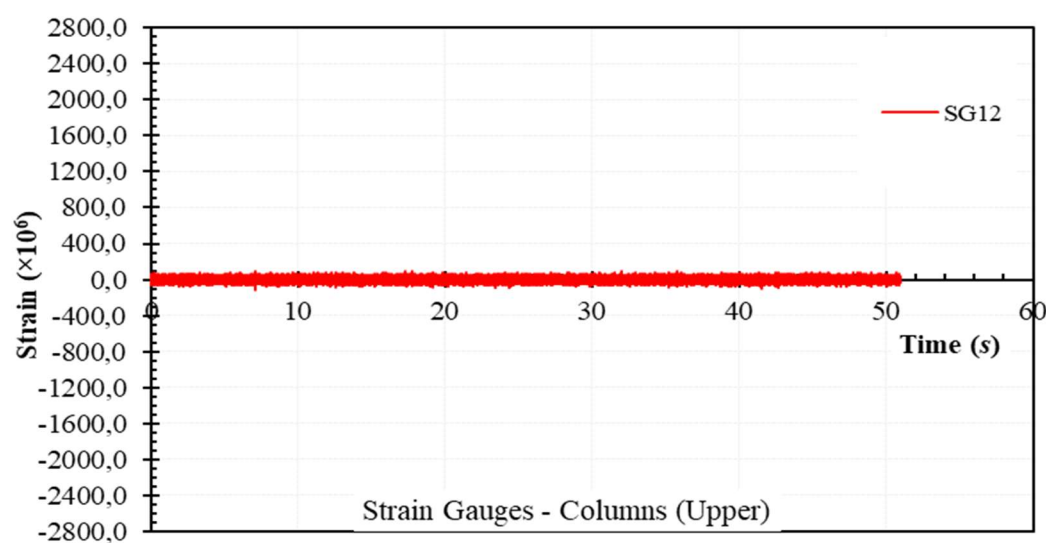
Max: 91,56 μ strain

Min: -91,56 μ strain

Residual: -15,26 μ strain



(a)



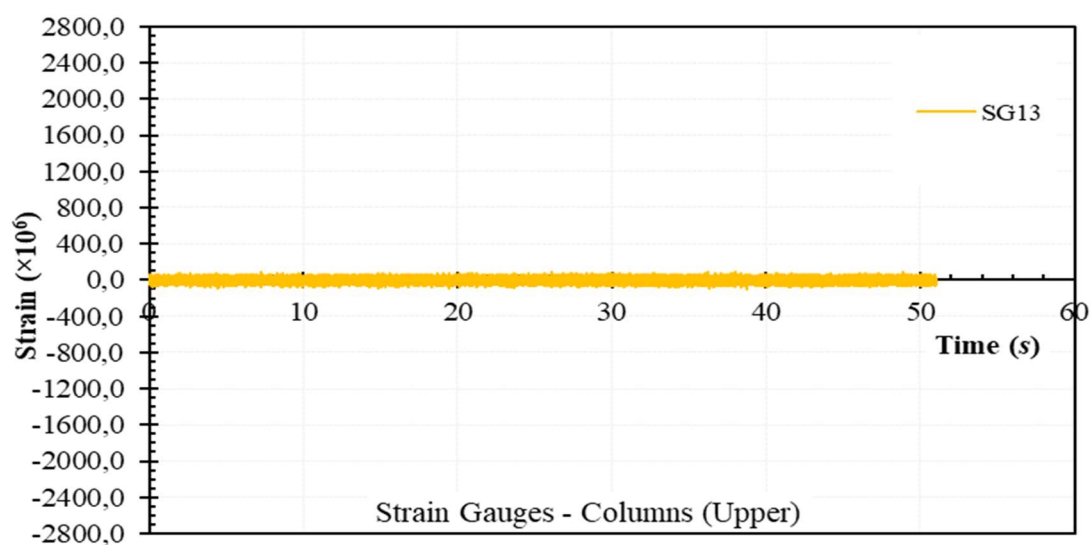
(b)

Figure 3.3.15 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 11 and (b) strain gauge 12

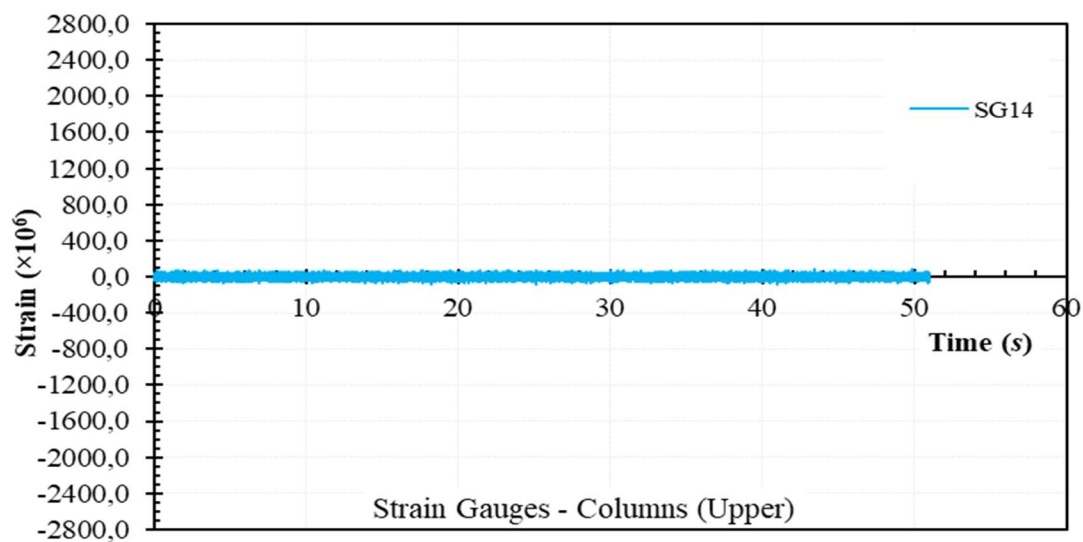
The strain gauges shown in the figures 3.3.15, 3.3.16, 3.3.17 and 3.3.20 are located in the longitudinal reinforcement, on the upper side. More specifically, strain gauge SG9 has 18,71 μ strain maximum strain, -43,91 μ strain minimum strain and 9,76 μ strain residual. Strain gauge SG10 has 131,46 μ strain maximum strain, -122,44 μ strain minimum strain and 14,70 μ strain residual. Strain gauge SG11 has maximum strain 91,56 μ strain and minimum -91,56 μ strain deformation. The residual strain is 0 μ strain for strain gauge SG11. Strain gauge SG12 has maximum strain 91,56 μ strain and minimum strain -101,86 μ strain. The residual value is -30,52 μ strain. Strain gauge SG13 has maximum strain

91,56 μ strain and minimum strain -91,56 μ strain. The residual is 0 μ strain. Strain gauge SG14 has maximum strain 91,56 μ strain and minimum strain -91,56 μ strain. The residual is 0 μ strain. Finally strain gauges SG15 has maximum strain 91,56 μ strain and minimum strain -91,56 μ strain. The residual is 15,26 μ strain. Strain gauge SG16 has maximum strain 91,56 μ strain, minimum strain -91,56 μ strain and residual strain -15,26 μ strain.

Sg 11Max: 91,56 μ strainMin: -91,56 μ strainResidual: 0 μ strain**Sg 12**Max: 91,56 μ strainMin: -101,86 μ strainResidual: -30,52 μ strain



(a)



(b)

Figure 3.3.16 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 13 and (b) strain gauge 14

Sg 13

Max: 91,56 μ strain

Min: -91,56 μ strain

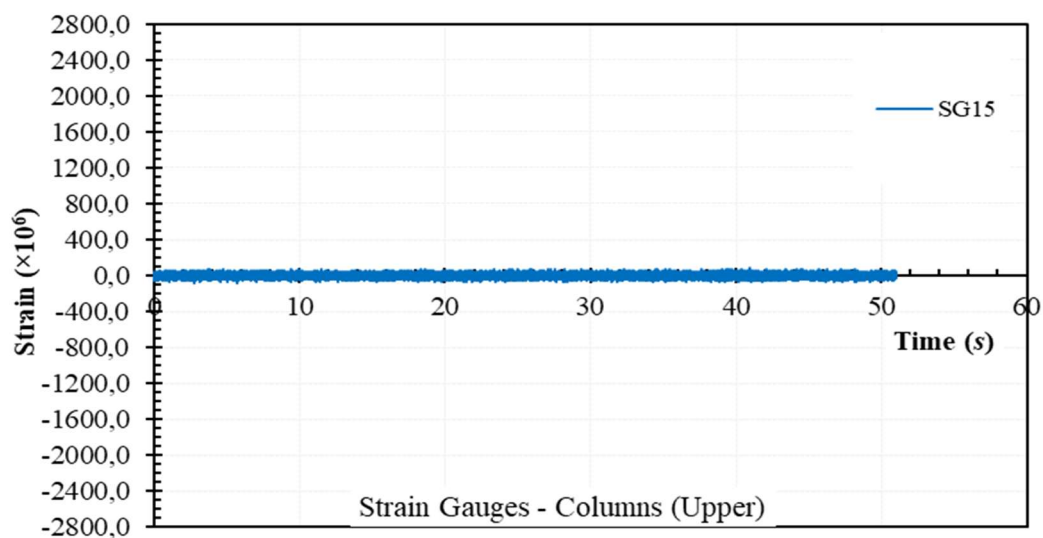
Residual: 0 μ strain

Sg 14

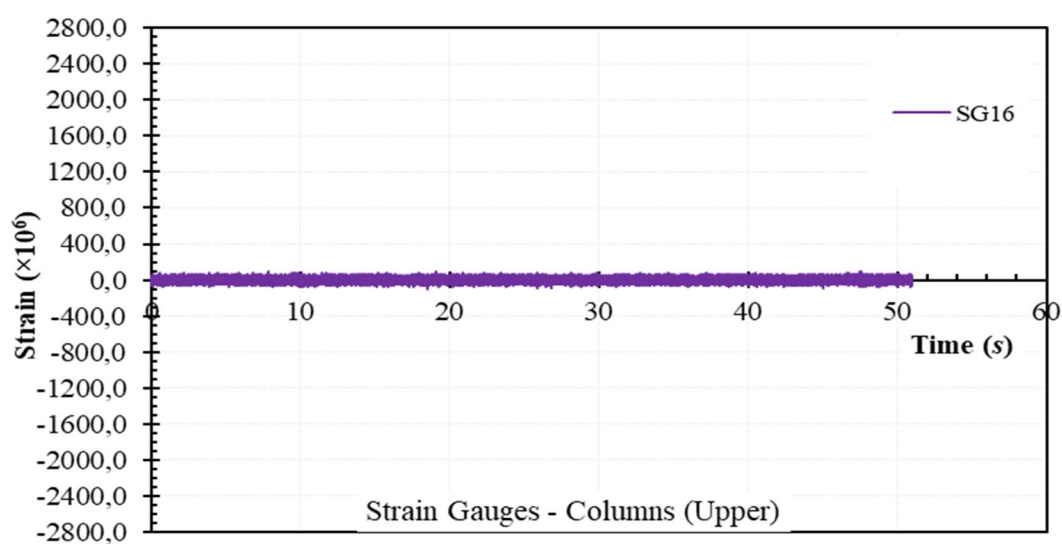
Max: 91,56 μ strain

Min: -91,56 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.3.17 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 15 and (b) strain gauge 16

Sg 15

Max: 91,56 μ strain

Min: -91,56 μ strain

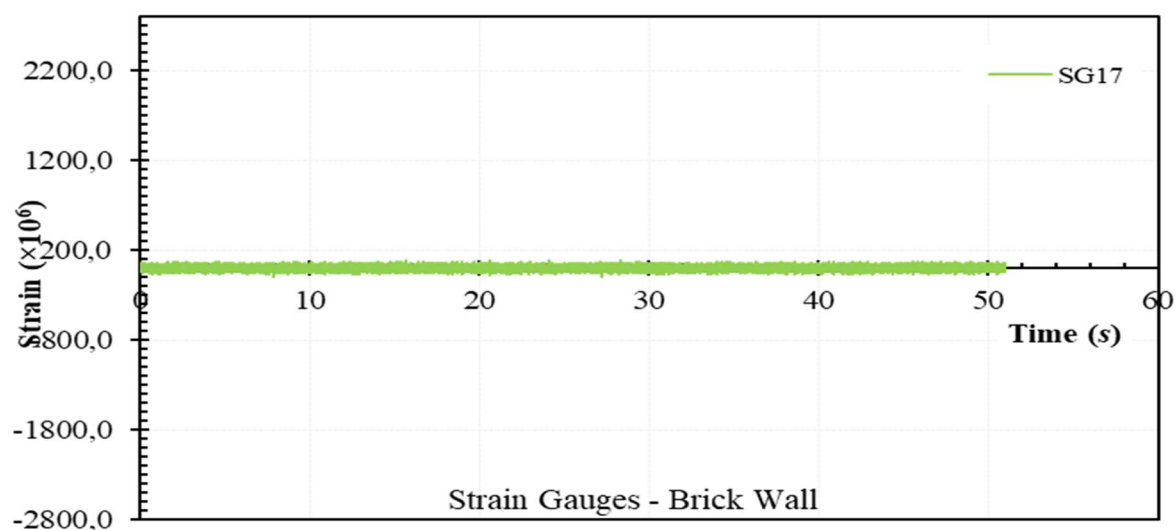
Residual: 15,26 μ strain

Sg 16

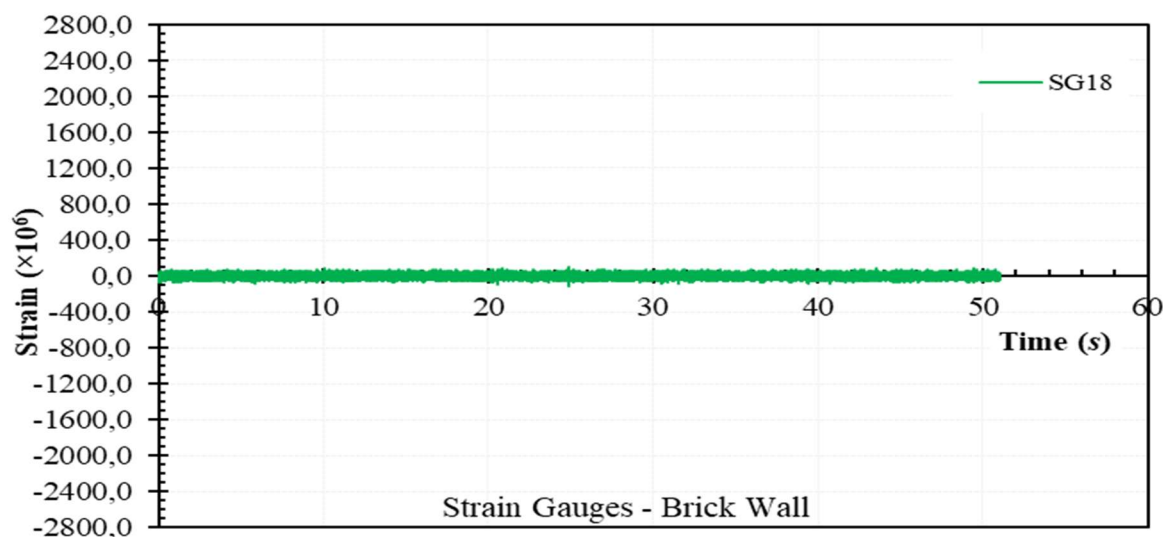
Max: 91,56 μ strain

Min: -91,56 μ strain

Residual: -15,26 μ strain



(a)



(b)

Figure 3.3.18 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 17 and (b) strain gauge 18

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauges SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge SG17 has 91,56 μ strain maximum strain. Strain gauge SG17 has minimum deformation -91,56 μ strain and strain gauge 18 -45,78 μ strain. Strain gauge SG18 has maximum strain 106,81 μ strain. Finally strain gauge SG17 presents 0 μ strain residual. Strain gauge SG18 presents -30,52 μ strain residual.

Sg 17

Max: 91,56 μ strain

Min: -91,56 μ strain

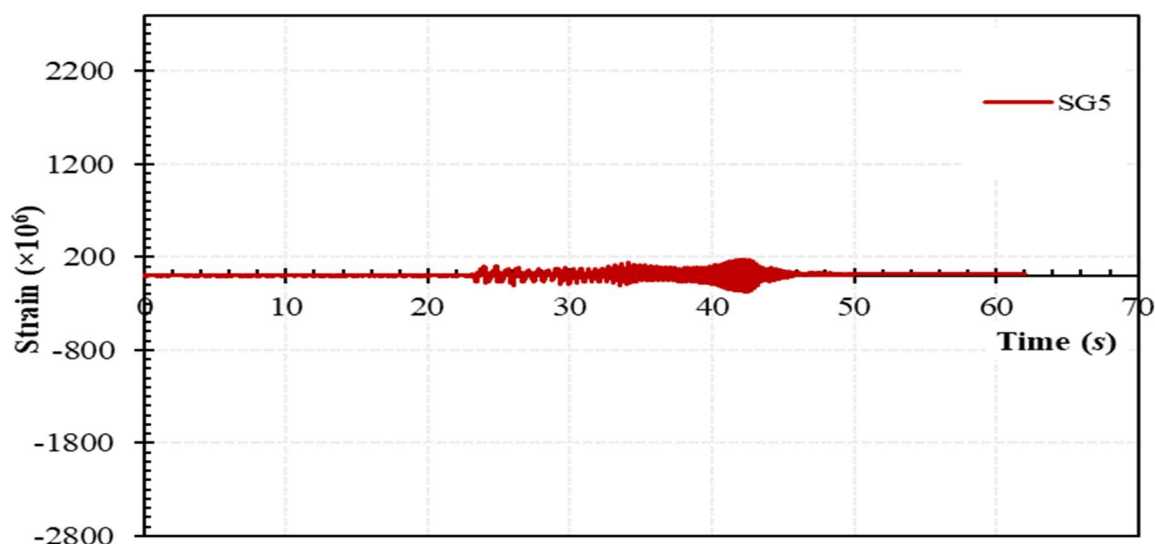
Residual: 0 μ strain

Sg 18

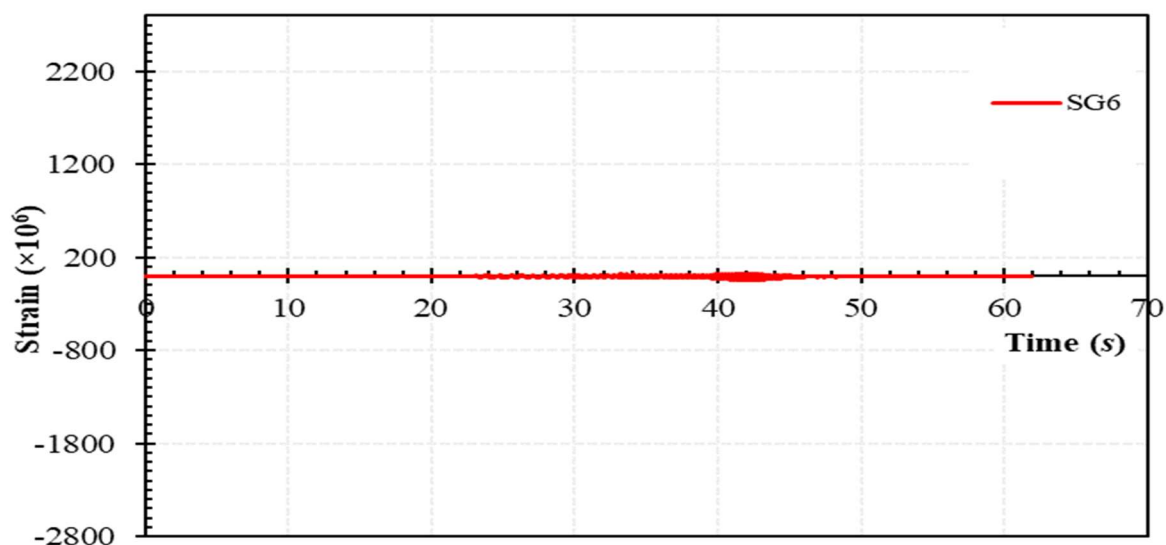
Max: 106,81 μ strain

Min: -106,81 μ strain

Residual: -30,52 μ strain



(a)



(b)

Figure 3.3.19 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 5 and (b) strain gauge 6

Sg 5

Max: 170,78 μ strain

Min: -166,66 μ strain

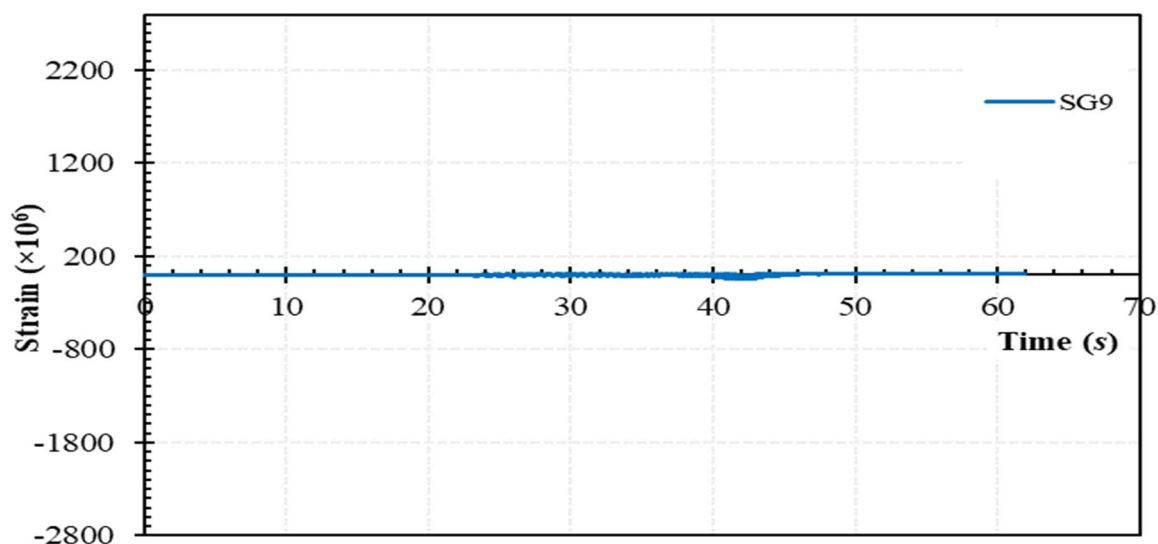
Residual: 16,26 μ strain

Sg 6

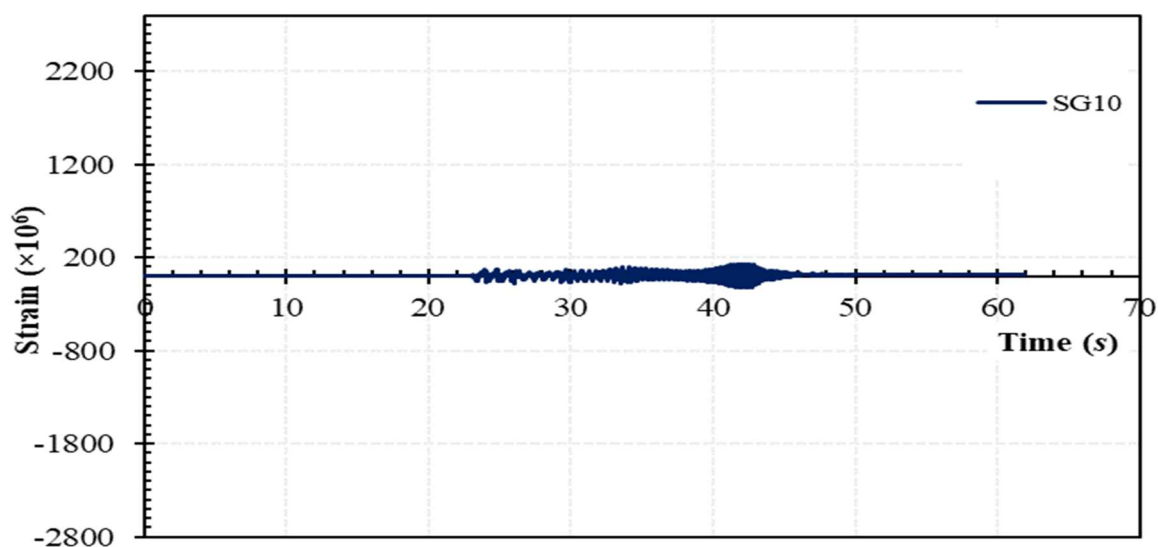
Max: 28,53 μ strain

Min: -50,54 μ strain

Residual: -6,52 μ strain



(a)



(b)

Figure 3.3.20 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 9 and (b) strain gauge 10

Sg 9

Max: 18,71 μ strain

Min: -43,91 μ strain

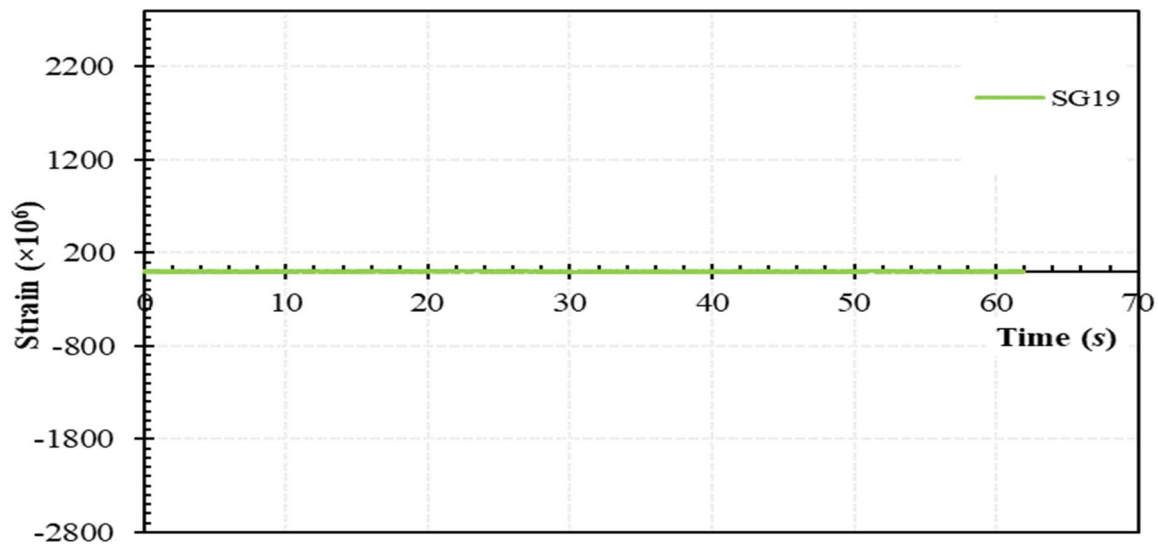
Residual: 9,76 μ strain

Sg 10

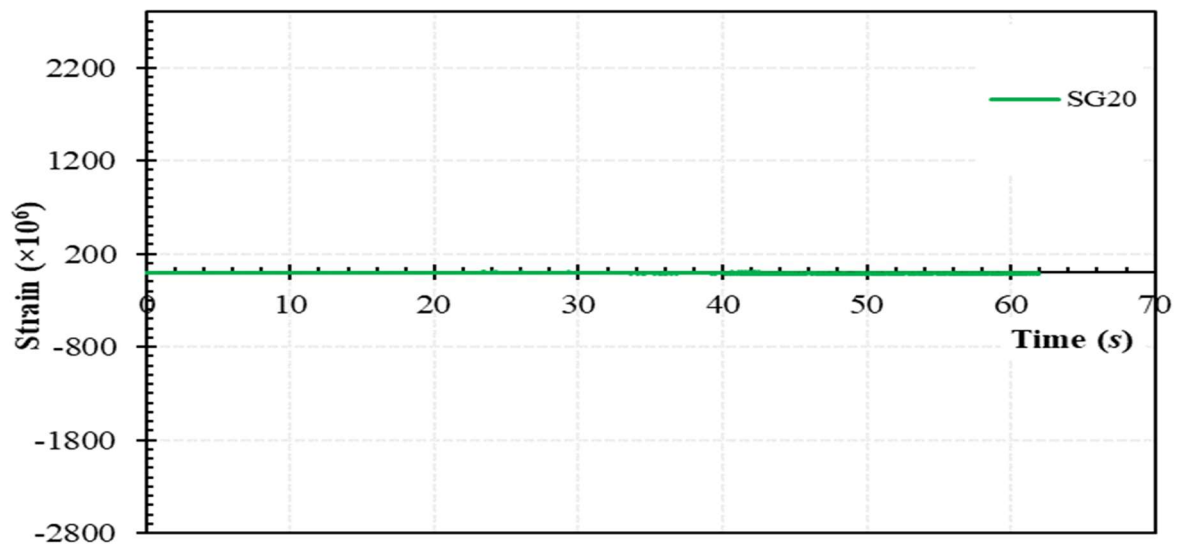
Max: 131,46 μ strain

Min: -122,44 μ strain

Residual: 14,70 μ strain



(a)



(b)

Figure 3.3.21 Characteristic results for phase A (white noise before 0,2g earthquake) (a) strain gauge 19 and (b) strain gauge 20

Strain gauge 19 is located on the centre of partial masonry 2 along direction x. Strain gauge 20 is located on the centre of partial masonry 2 along direction x. More specifically strain gauge SG19 has maximum $0,81\mu\text{strain}$ and minimum $-3,24\mu\text{strain}$. Strain gauge SG20 has maximum strain $5,69\mu\text{strain}$ and minimum $-17,07\mu\text{strain}$. The residual strain for strain gauge SG19 is $0\mu\text{strain}$ and residual for strain gauge SG20 is $-9,76\mu\text{strain}$.

Sg 19

Max: $0,81\mu\text{strain}$

Min: $-3,24\mu\text{strain}$

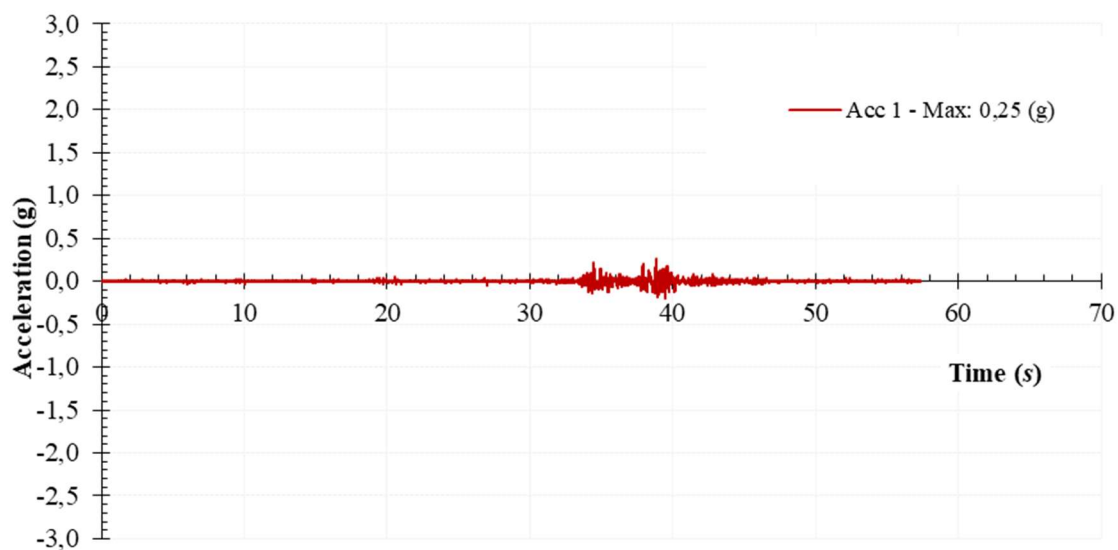
Residual: $0\mu\text{strain}$

Sg 20Max: 5,69 μ strainMin: -17,07 μ strainResidual: -9,76 μ strain

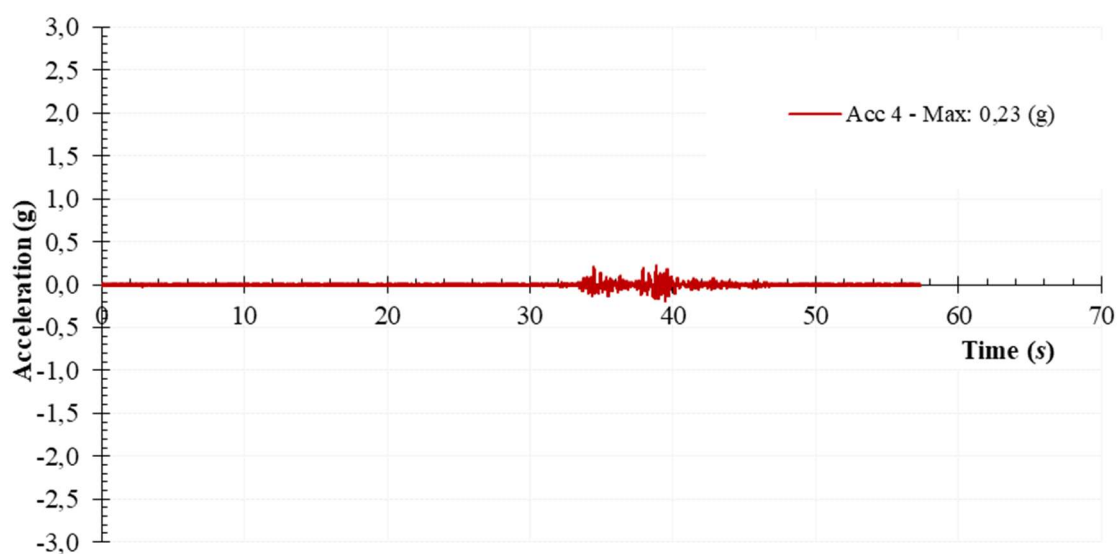
3.4) Earthquake EQ0,2g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for EQ0,2g. The max acceleration at the slab level on the accelerometer acc1 and acc4 is 0,25 and 0,23g respectively. The max acceleration at the foundation level on the accelerometer acc10 is 0,19g.

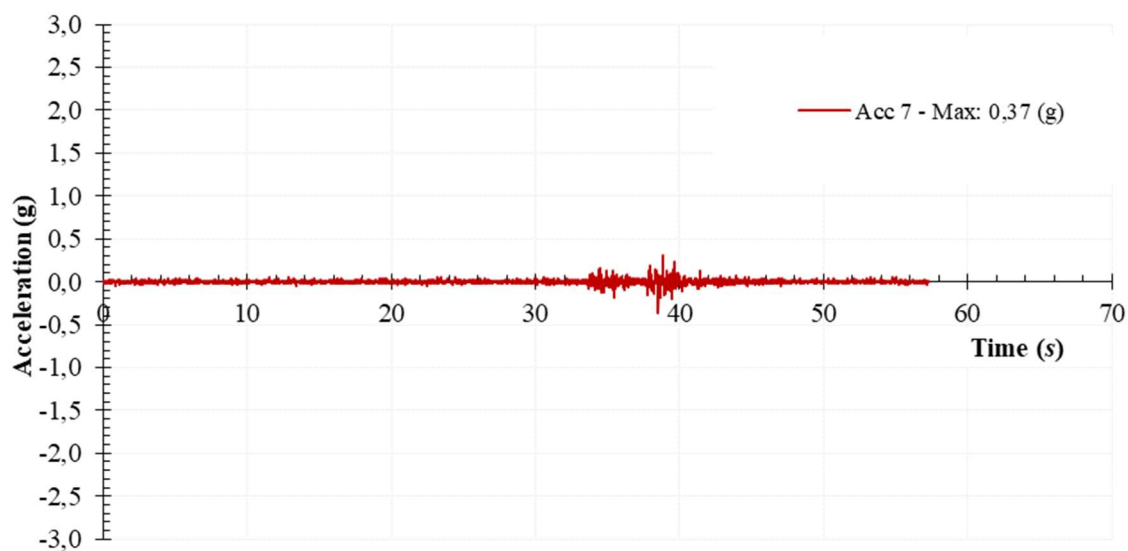


(a)

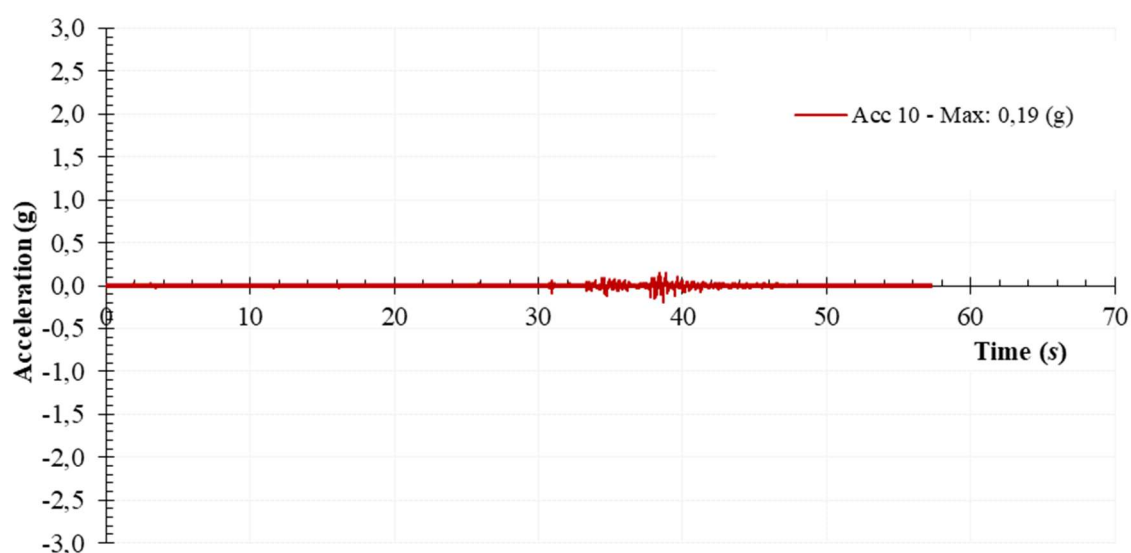


(b)

Figure 3.4.1 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 1 (b) Accelerometer 4

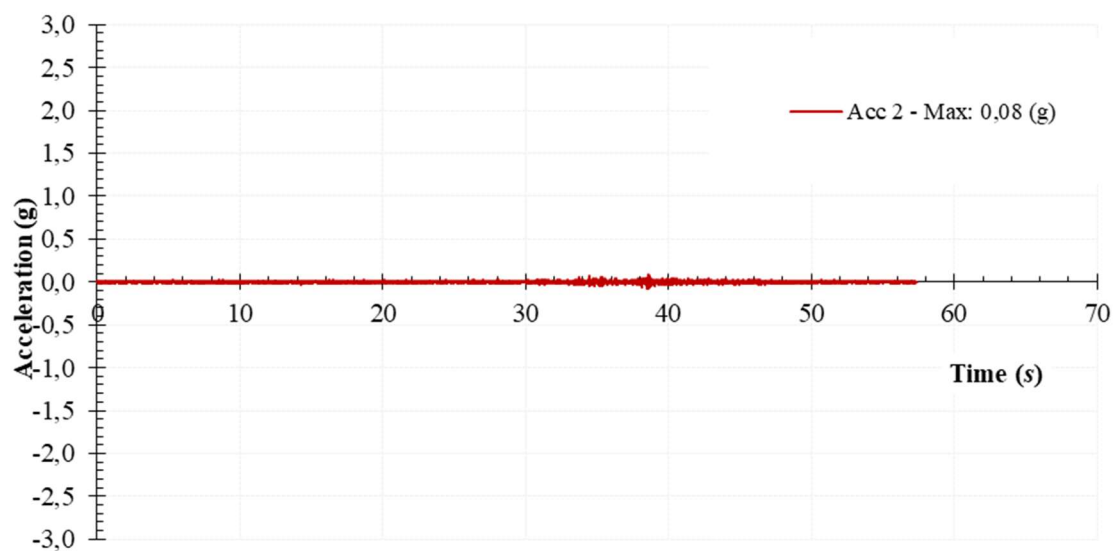


(a)

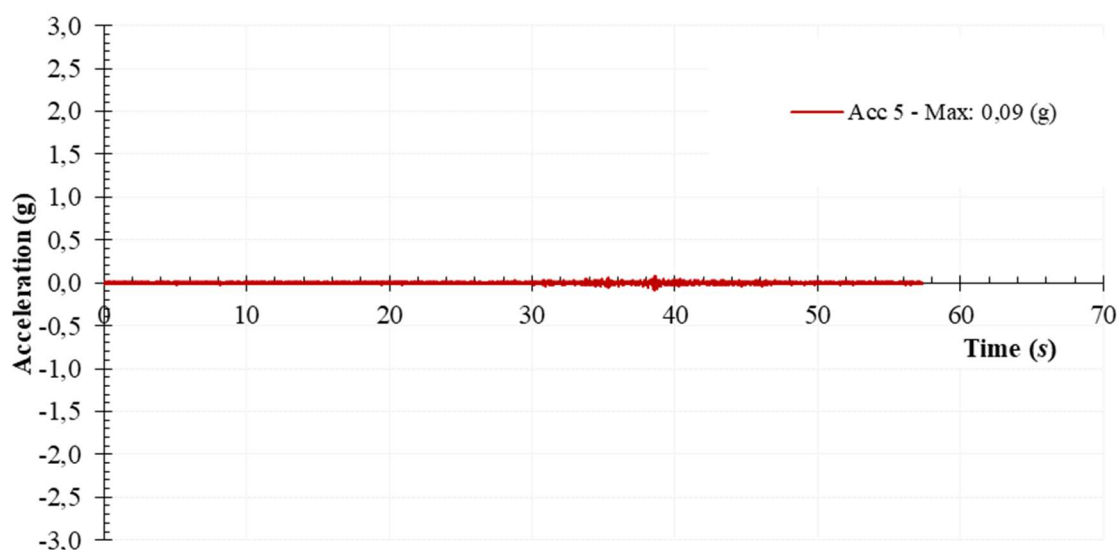


(b)

Figure 3.4.2 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

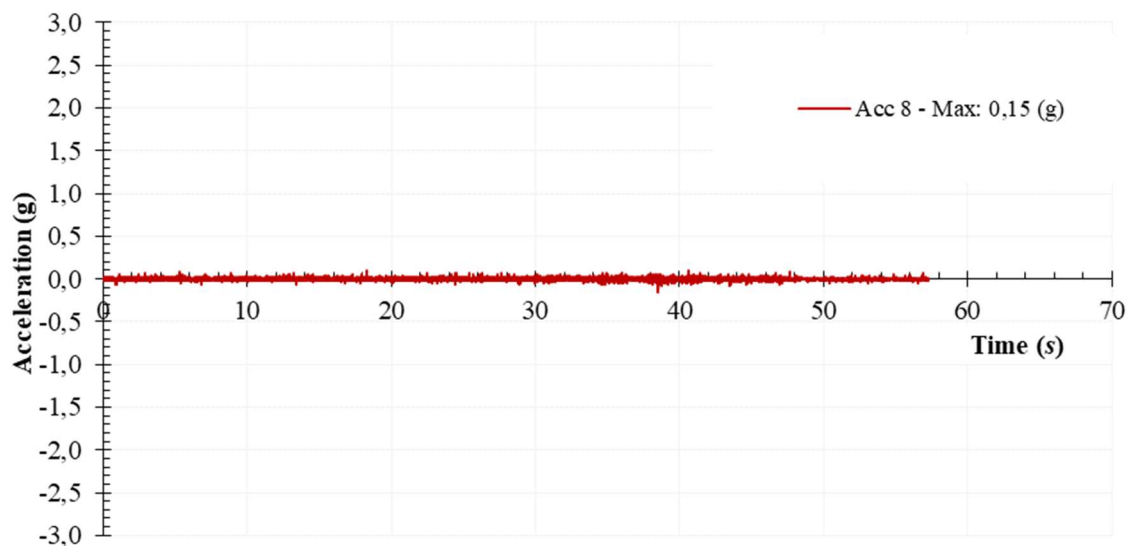


(a)

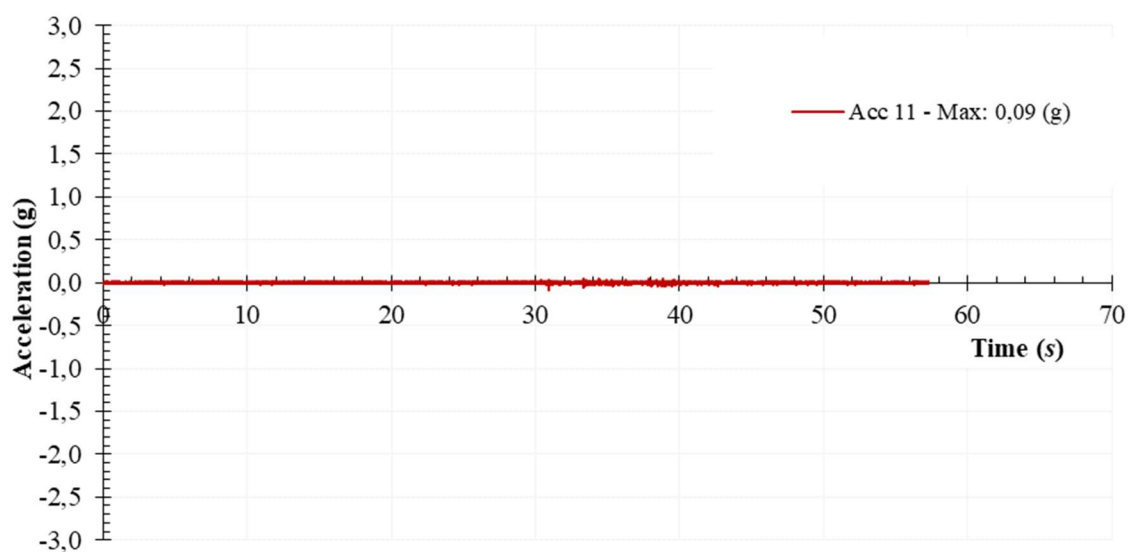


(b)

Figure 3.4.3 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

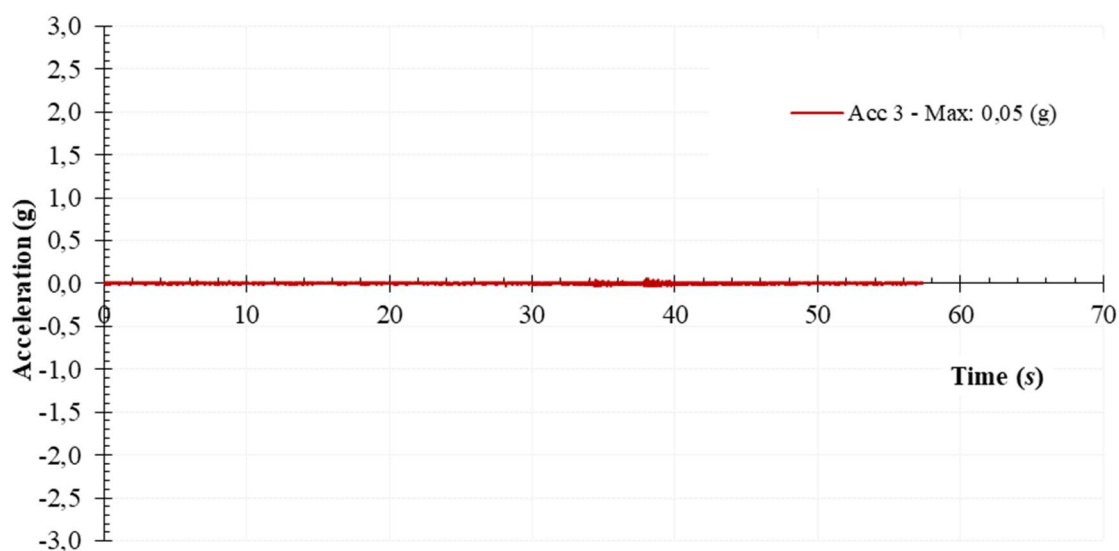


(a)

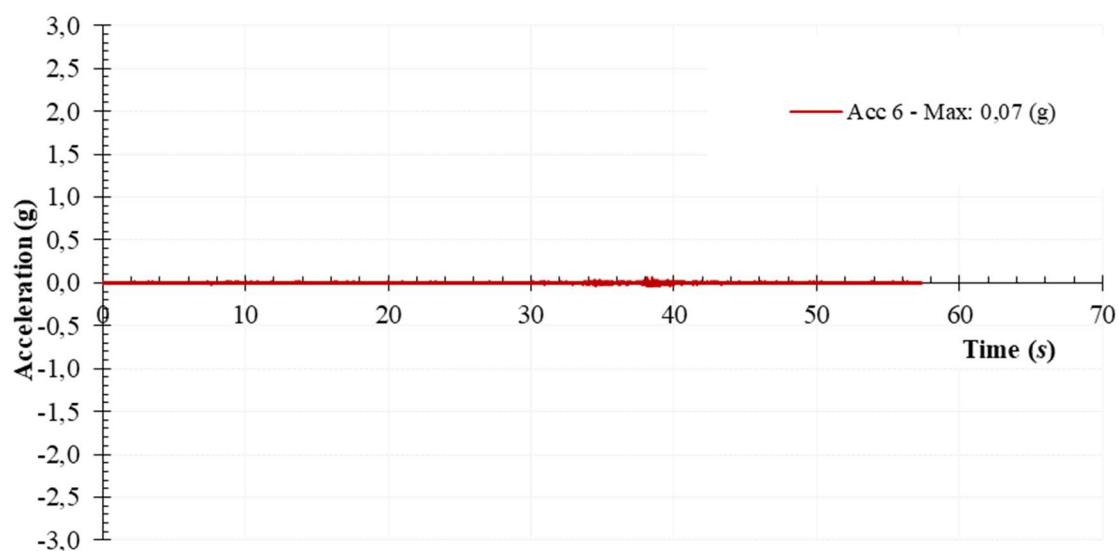


(b)

Figure 3.4.4 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 8 (b) Accelerometer 11

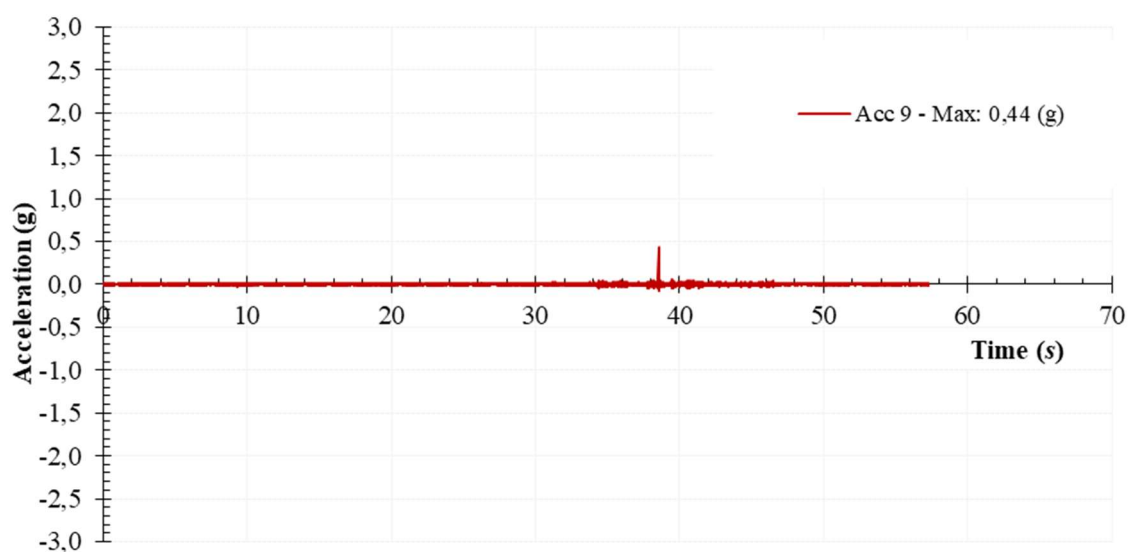


(a)

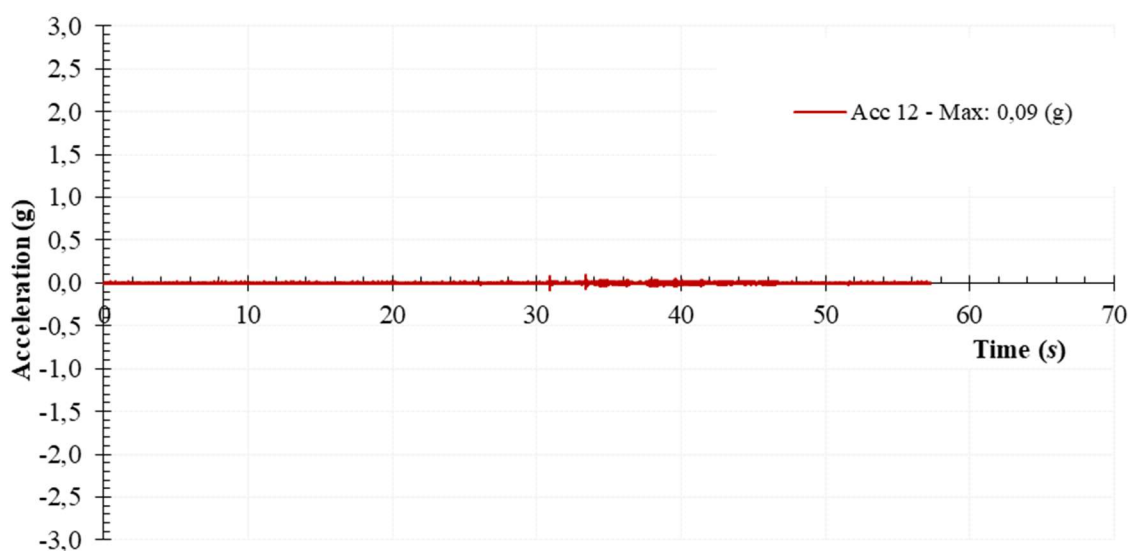


(b)

Figure 3.4.5 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 3 (b) Accelerometer 6

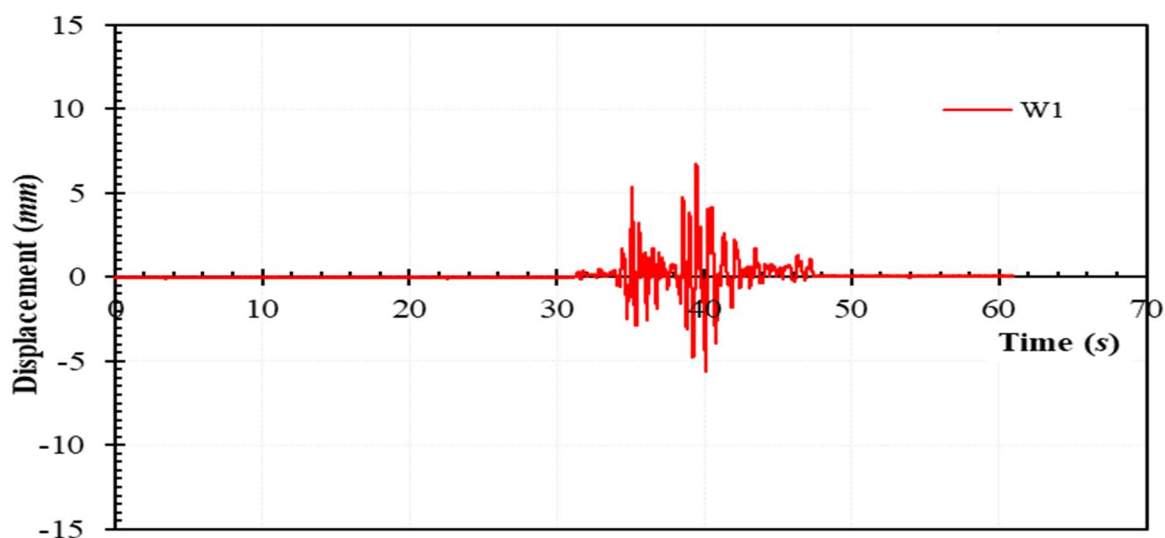


(a)

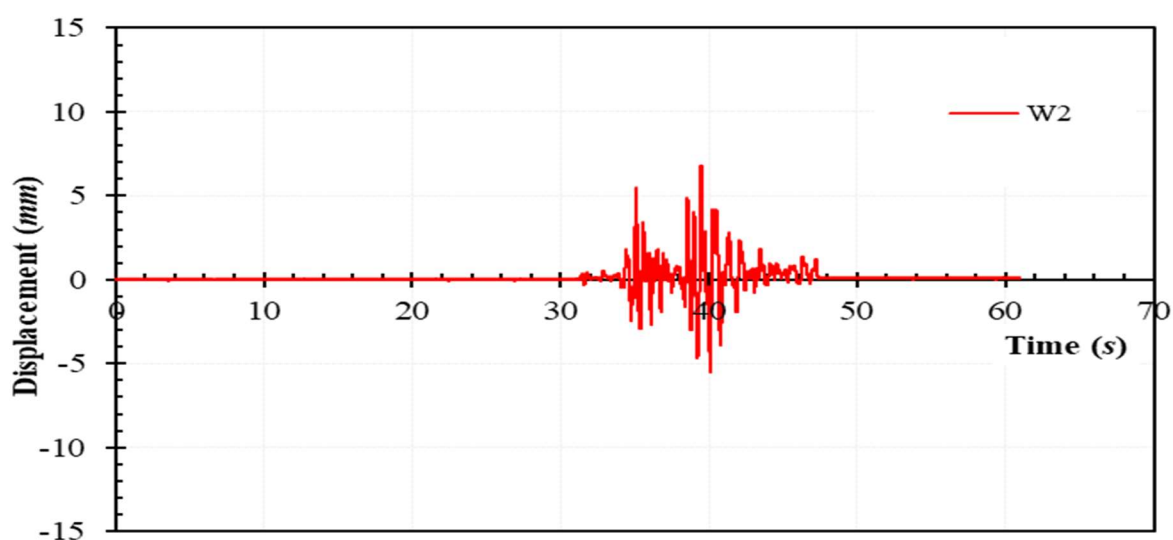


(b)

Figure 3.4.6 Characteristic results for phase A (0,2g earthquake): (a) Accelerometer 9 (b) Accelerometer 12



(a)



(b)

Figure 3.4.7 Characteristic results for phase A (0,2g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2

Figure 3.4.7 shows draw wire sensors W1 and W2. More specifically, draw wire sensor W1 is located on the slab, on the left side and draw wire sensor W2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor W1 is 6,72 mm while the minimum is -5,64 mm. The maximum movement detected by draw wire sensor W2 is 6,81 mm while the minimum is -5,50 mm.

W 1

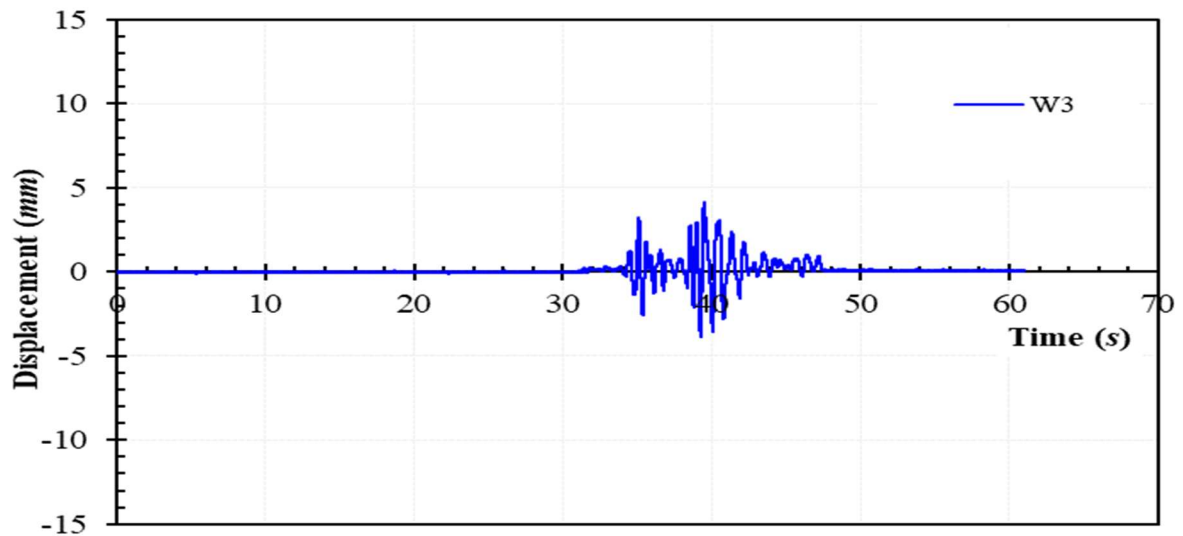
Max: 6,72 mm

Min: -5,64 mm

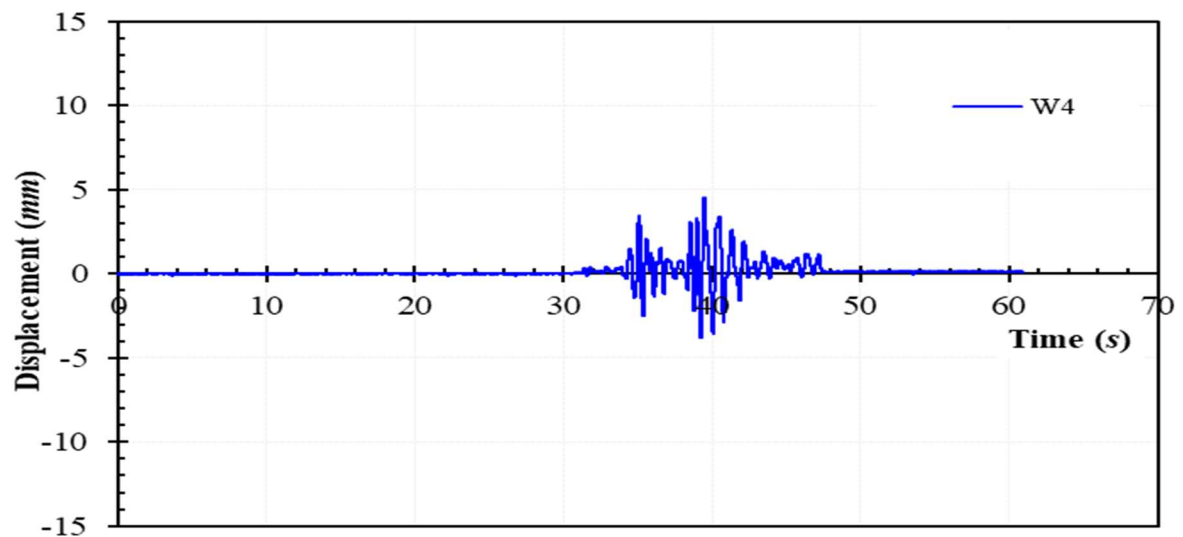
W 2

Max: 6,81 mm

Min: -5,50 mm



(a)



(b)

Figure 3.4.8 Characteristic results for phase A (0,2g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor 4

Figure 3.4.8 shows draw wire sensors W3 and W4. More specifically, draw wire sensor W3 is located on the foundation, on the left side and draw wire sensor WW4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor W3 is 4,16 mm while the minimum is -3,84 mm. The maximum movement detected by draw wire sensor W2 is 4,52 mm while the minimum is -3,82 mm.

W 3

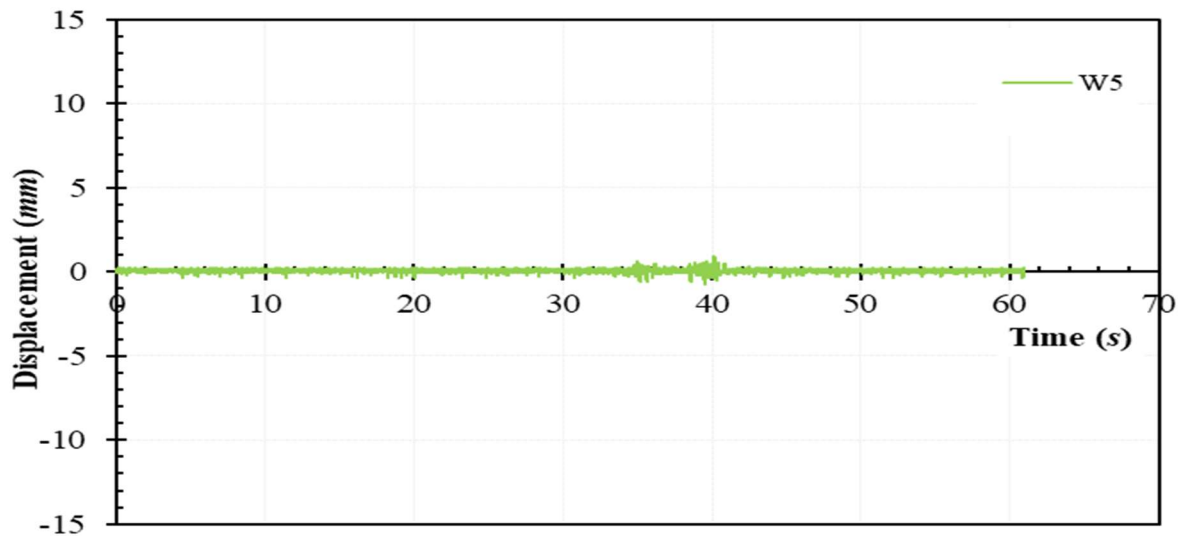
Max: 4,16 mm

Min: -3,84 mm

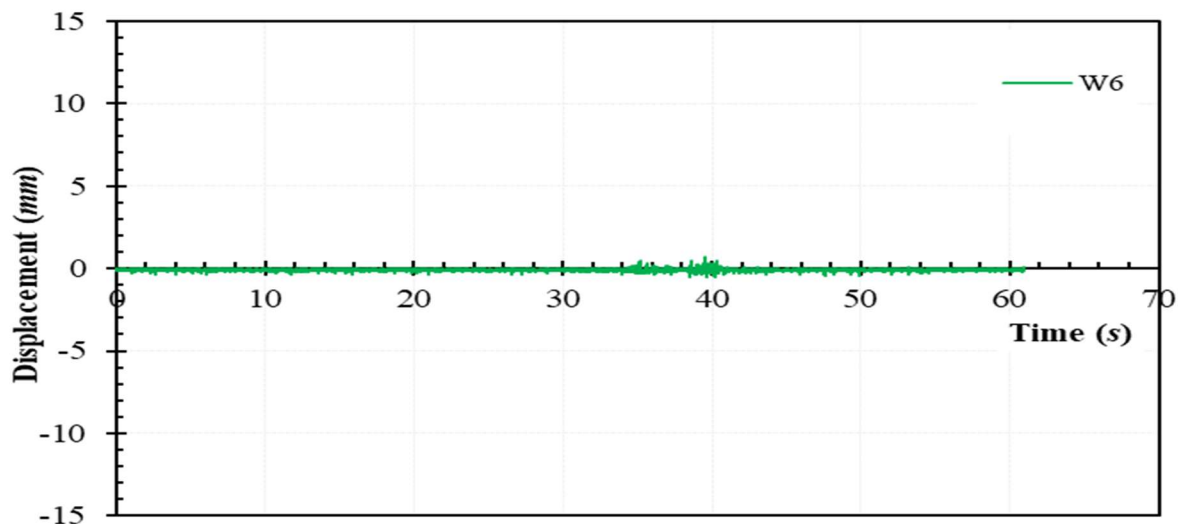
W 4

Max: 4,52 mm

Min: -3,82 mm



(a)



(b)

Figure 3.4.9 Characteristic results for phase A (0,2g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6

Figure 3.4.9 shows draw wire sensors W5 and W6. More specifically, draw wire sensor W5 is located along the partial masonry infill diagonal and draw wire sensor W6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W5 is 0,92 mm while the minimum is -0,71 mm. The maximum movement detected by draw wire sensor W6 is 0,70 mm while the minimum is -0,52 mm.

W 5

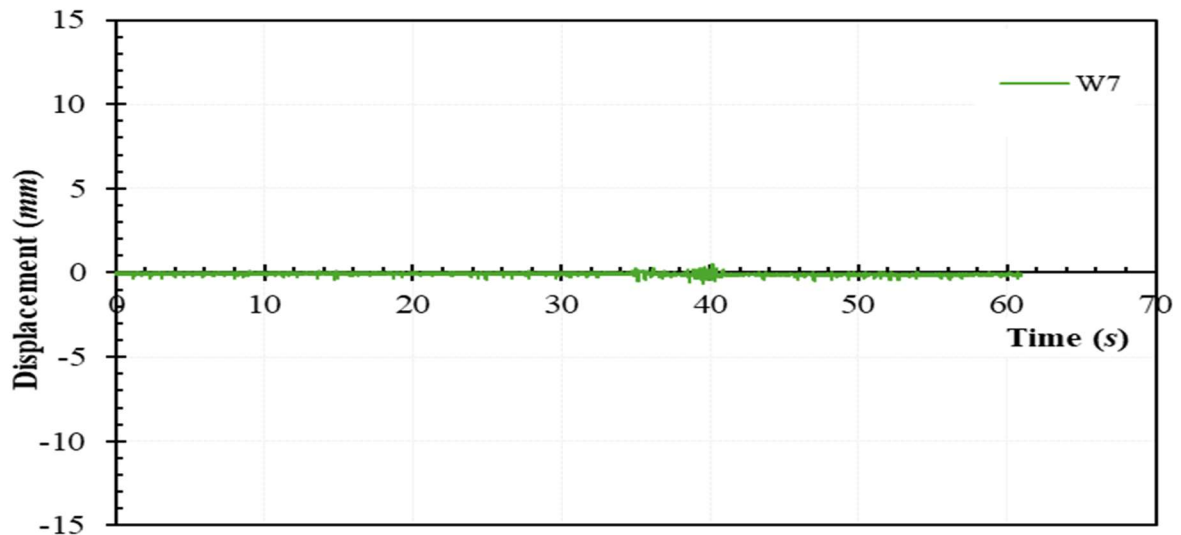
Max: 0,92 mm

Min: -0,71 mm

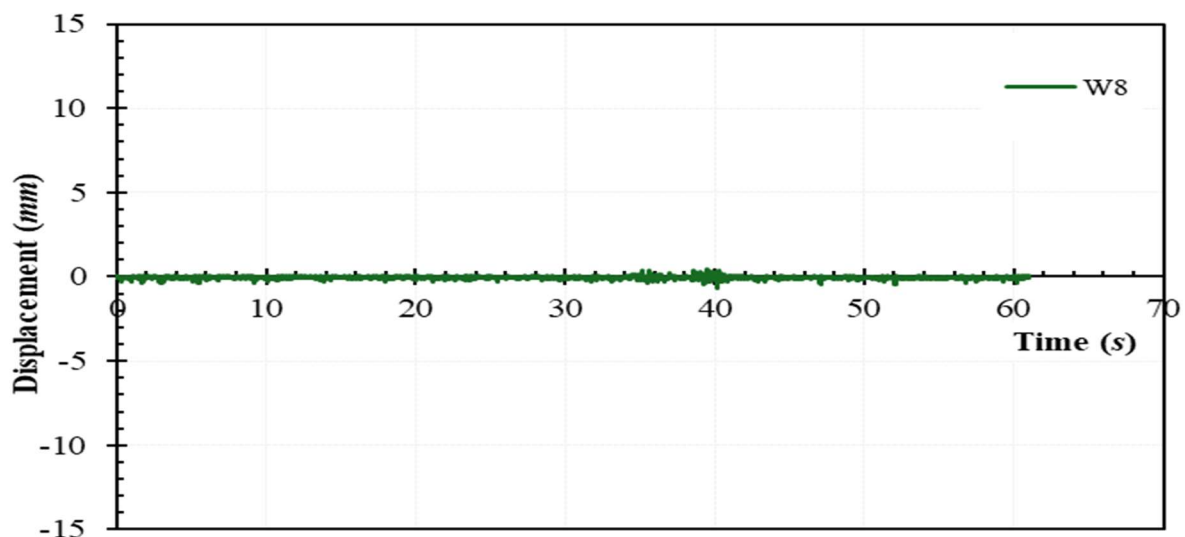
W 6

Max: 0,70 mm

Min: -0,52 mm



(a)



(b)

Figure 3.4.10 Characteristic results for phase A (0,2g earthquake) : (a) Draw wire sensor 7 and (b) Draw wire sensor 8

Figure 3.4.10 shows draw wire sensors W7 and W8. More specifically, draw wire sensor WW7 is located along the partial masonry infill diagonal and draw wire sensor 8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W7 is 0,50 mm while the minimum is -0,68 mm. The maximum movement detected by draw wire sensor W8 is 0,44 mm while the minimum is -0,68 mm.

W 7

Max: 0,50 mm

Min: -0,68 mm

W 8

Max: 0,44 mm

Min: -0,68 mm

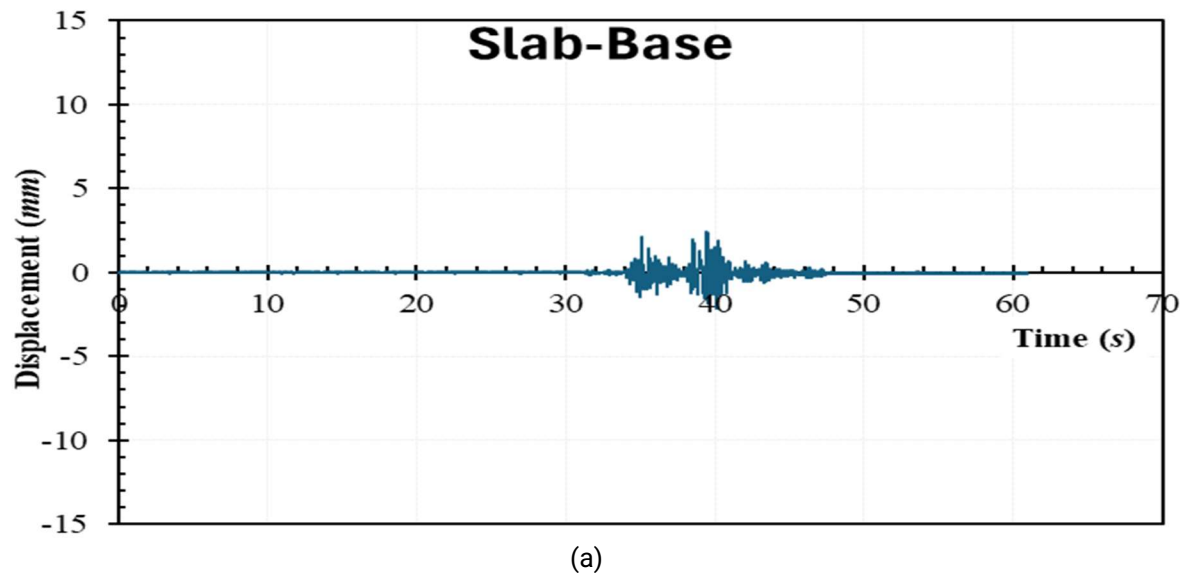


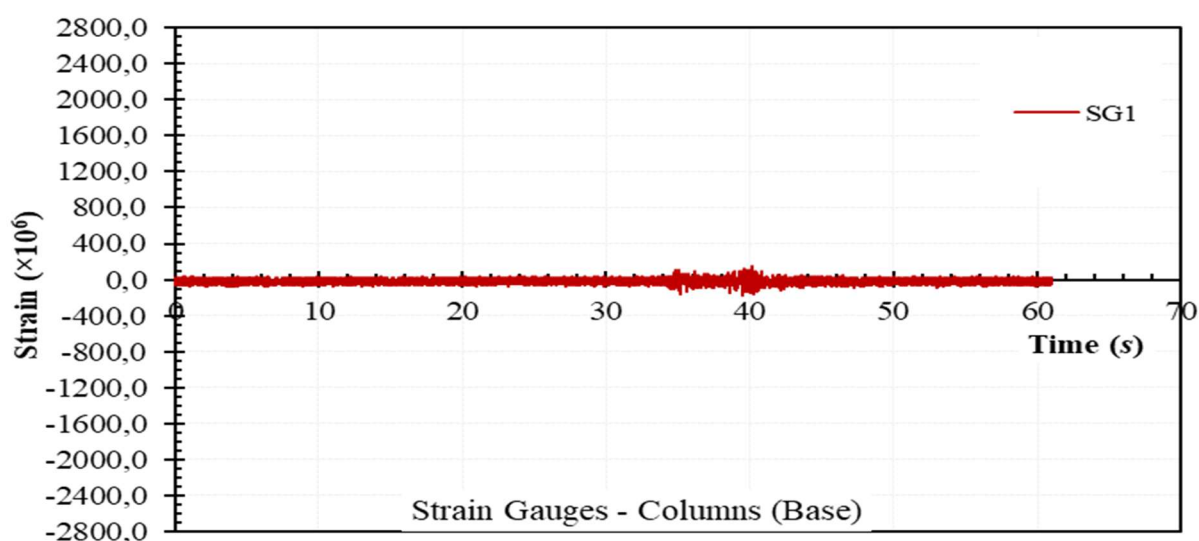
Figure 3.4.11 Characteristic results for phase A (0,2g earthquake): (a) Diagram of displacement Slab – Base

Figure 3.4.11 shows slab – base displacement. More specifically, the maximum drift detected is 1,99 ‰ while the minimum is -1,75 ‰. The residual drift is -0,04 mm.

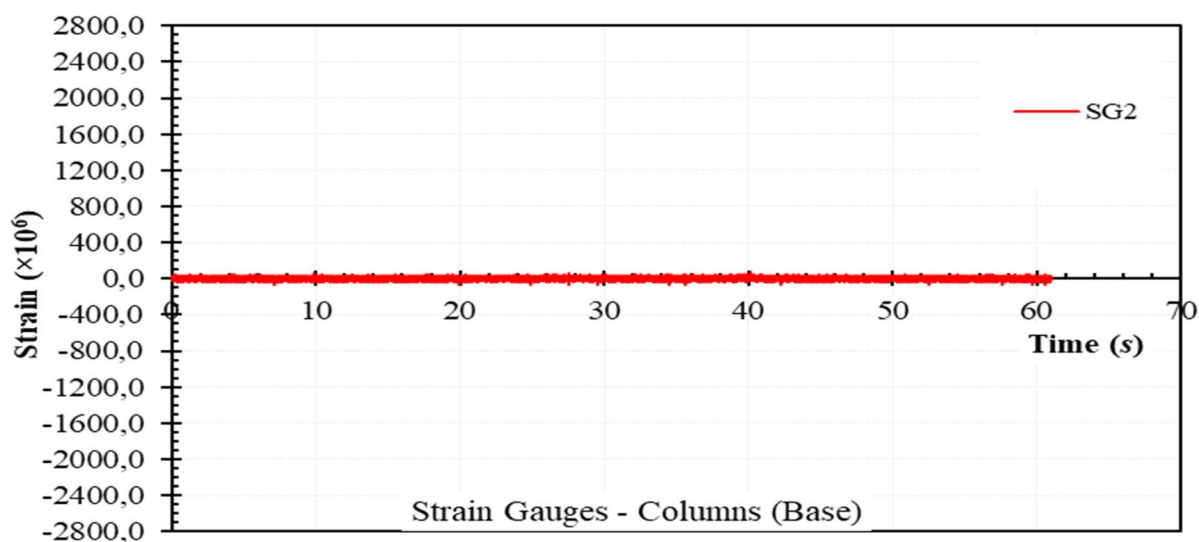
Maximum drift (‰): 1,99 (2,43775 m/1,225 m = 1,99 ‰)

Minimum drift (‰): -1,75

Residual drift: -0,04 mm



(a)



(b)

Figure 3.4.12 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 1 and (b) strain gauge 2

Strain gauges detect strain. The strain gauges shown in the figures 3.4.12, 3.4.13, 3.4.14 and 3.4.19 are located in the longitudinal reinforcement, on the underside. More specifically, strain gauge SG1 has maximum strain $152,29\mu\text{strain}$ and minimum strain $-183,11\mu\text{strain}$. The residual strain is $-15,26\mu\text{strain}$. Strain gauge SG2 has maximum deformation $76,30\mu\text{strain}$ and minimum $-61,04\mu\text{strain}$. The residual strain is $-15,26\mu\text{strain}$. Strain gauge SG3 has $76,30\mu\text{strain}$ and $-45,78\mu\text{strain}$ maximum and minimum strain respectively. The residual strain is $-15,26\mu\text{strain}$. Strain gauge SG4 as we can see in figure 3.4.13 has maximum $198,37\mu\text{strain}$ and minimum $-137,33\mu\text{strain}$ deformation. The residual strain is $-30,52\mu\text{strain}$. Figure 3.4.19 shows strain gauges SG5 and SG6. Strain gauge SG5 has $315,62\mu\text{strain}$ and $-357,67\mu\text{strain}$ maximum and minimum strain respectively. Strain gauge SG5 presents $-2,44\mu\text{strain}$ residual strain. Strain gauge 6 has $48,92\mu\text{strain}$ maximum strain, $-76,63\mu\text{strain}$ minimum strain and $1,63\mu\text{strain}$ residual. Finally in figure 3.4.14 see strain gauge SG7 and SG8. Strain gauge SG7 has maximum strain $61,04\mu\text{strain}$ and SG8 has maximum strain $228,89\mu\text{strain}$. Strain gauge SG7 has -

61,04 μ strain minimum deformation and 8 has -183,11 μ strain. The residual strain for strain gauge SG7 and SG8 is 0 μ strain.

Sg 1

Max: 152,29 μ strain

Min: -183,11 μ strain

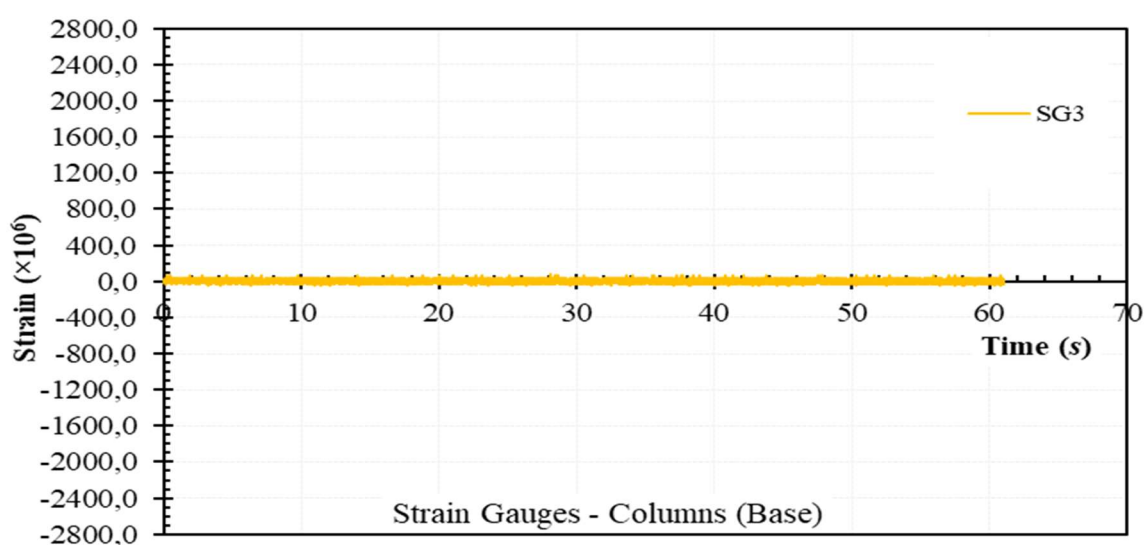
Residual: -15,26 μ strain

Sg 2

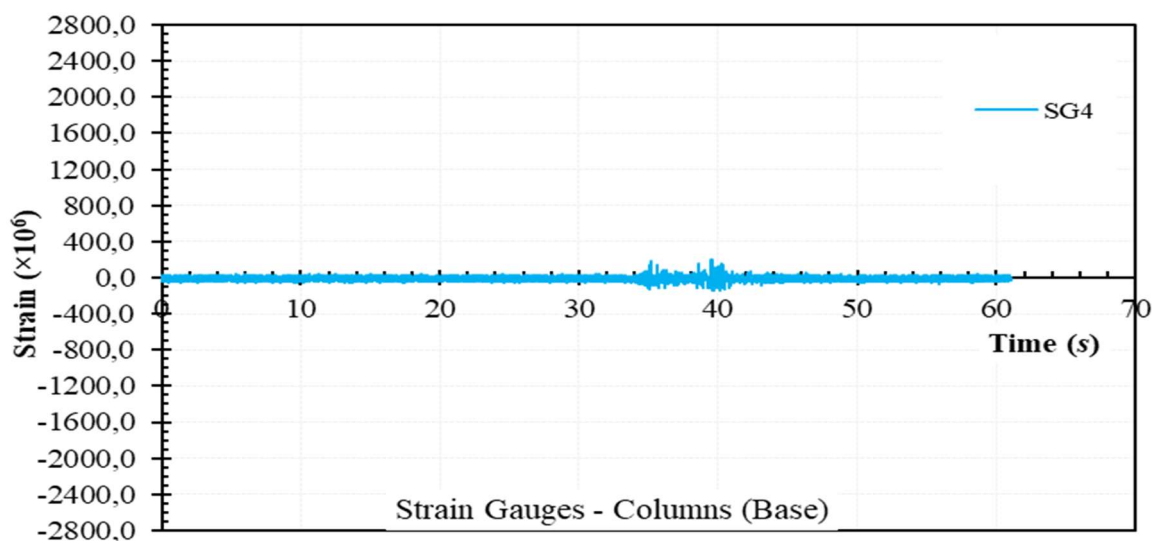
Max: 76,30 μ strain

Min: -61,04 μ strain

Residual: -15,26 μ strain



(a)



(b)

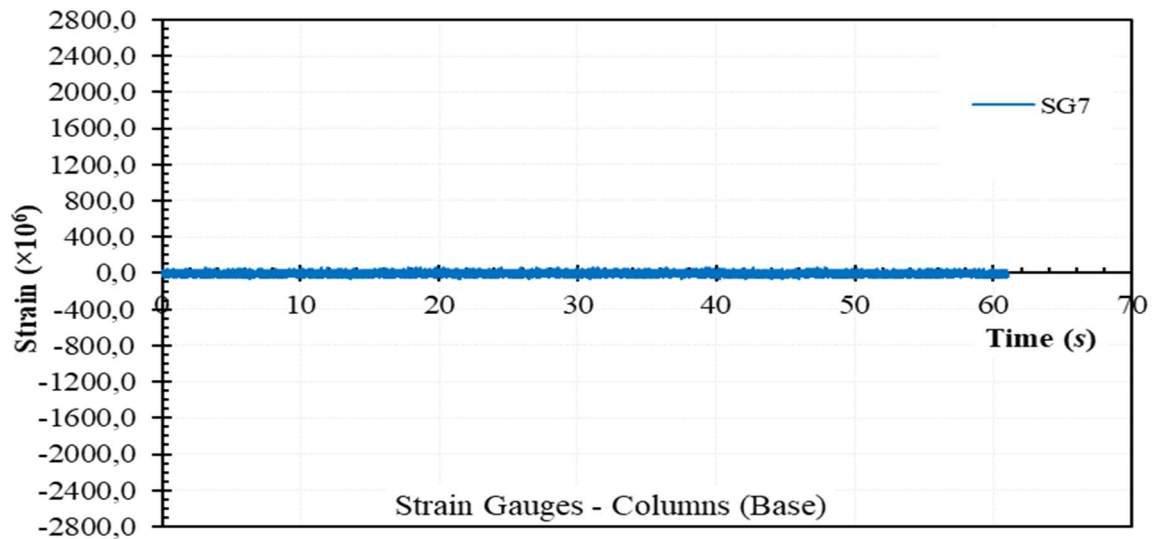
Figure 3.4.13 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 3 and (b) strain gauge 4

Sg 3

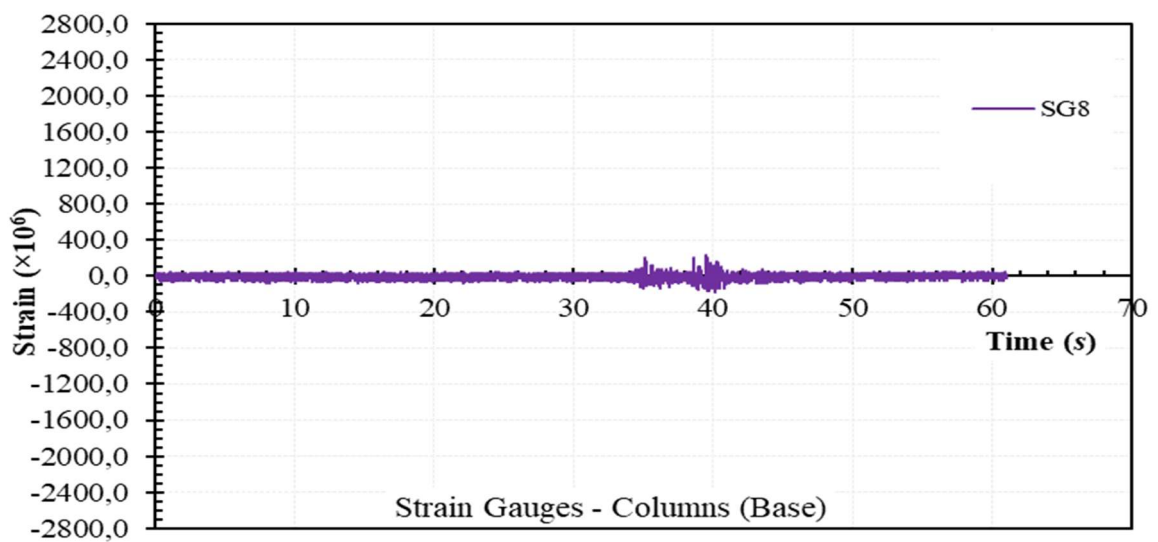
Max: 76,30 μ strain
Min: -45,78 μ strain
Residual: -15,26 μ strain

Sg 4

Max: 198,37 μ strain
Min: -137,33 μ strain
Residual: -30,52 μ strain



(a)



(b)

Figure 3.4.14 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 7 and (b) strain gauge 8

Sg 7

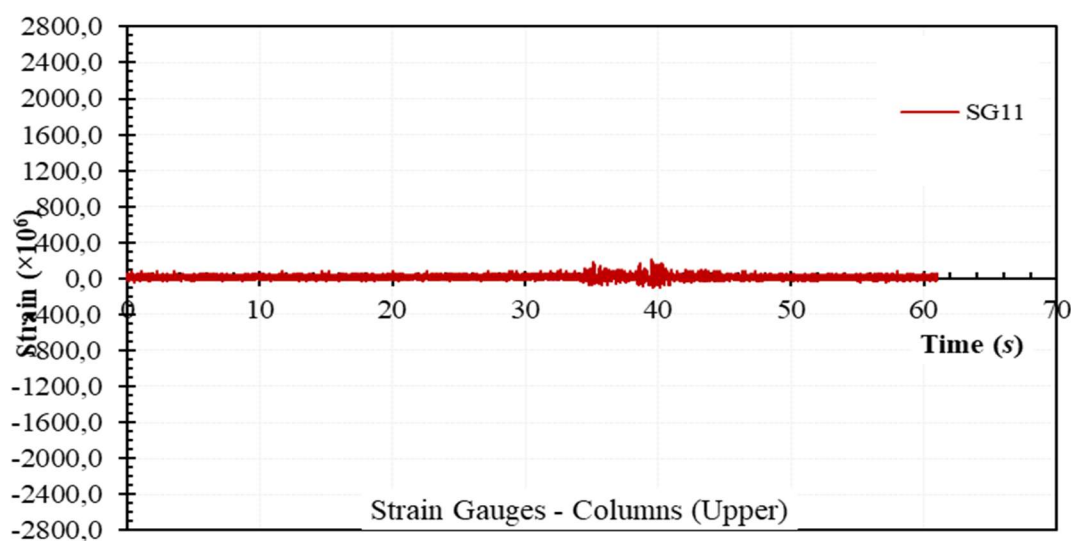
Max: 61,04 μ strain
Min: -61,04 μ strain
Residual: 0 μ strain

Sg 8

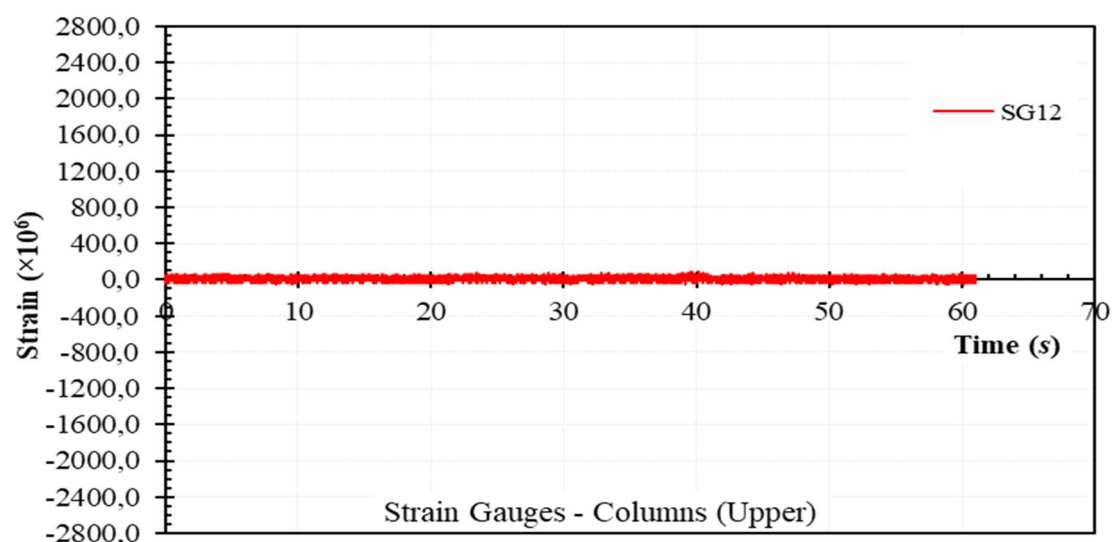
Max: 228,89 μ strain

Min: -183,11 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.4.15 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 11 and (b) strain gauge 12

The strain gauges shown in the figures 3.4.15, 3.4.16, 3.4.17 and 3.4.20 are located in the longitudinal reinforcement, on the upper side. More specifically, strain gauge SG9 has 9,76 μ strain maximum strain, -76,63 μ strain minimum strain and 3,25 μ strain residual. Strain gauge SG10 has 207,43 μ strain maximum strain, -255,48 μ strain minimum strain and 2,45 μ strain residual. Strain gauge SG11 has maximum strain 213,63 μ strain and minimum -106,81 μ strain deformation. The residual strain is 30,52 μ strain for strain gauge SG11. Strain gauge SG12 has maximum strain 91,56 μ strain and minimum strain -45,78 μ strain. The residual value is -0 μ strain. Strain gauge SG13 has maximum strain 133,33 μ strain and minimum strain -76,30 μ strain. The residual is -15,26 μ strain. Strain gauge SG14 has maximum strain 152,59 μ strain and minimum strain -152,59 μ strain. The residual is -15,26 μ strain. Finally strain gauges SG15 has maximum strain 213,63 μ strain and minimum strain -122,07 μ strain. The

residual is 15,26 μ strain. Strain gauge SG16 has maximum strain 137,33 μ strain, minimum strain -106,81 μ strain and residual strain -30,52 μ strain.

Sg 11

Max: 213,63 μ strain

Min: -106,81 μ strain

Residual: 30,52 μ strain

Sg 12

Max: 91,56 μ strain

Min: -45,78 μ strain

Residual: 0 μ strain

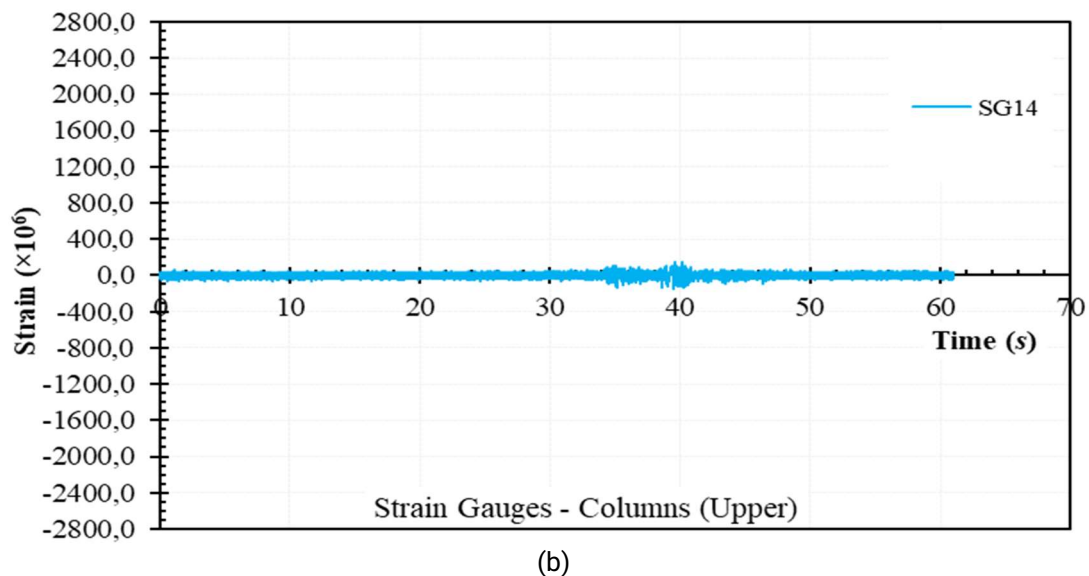
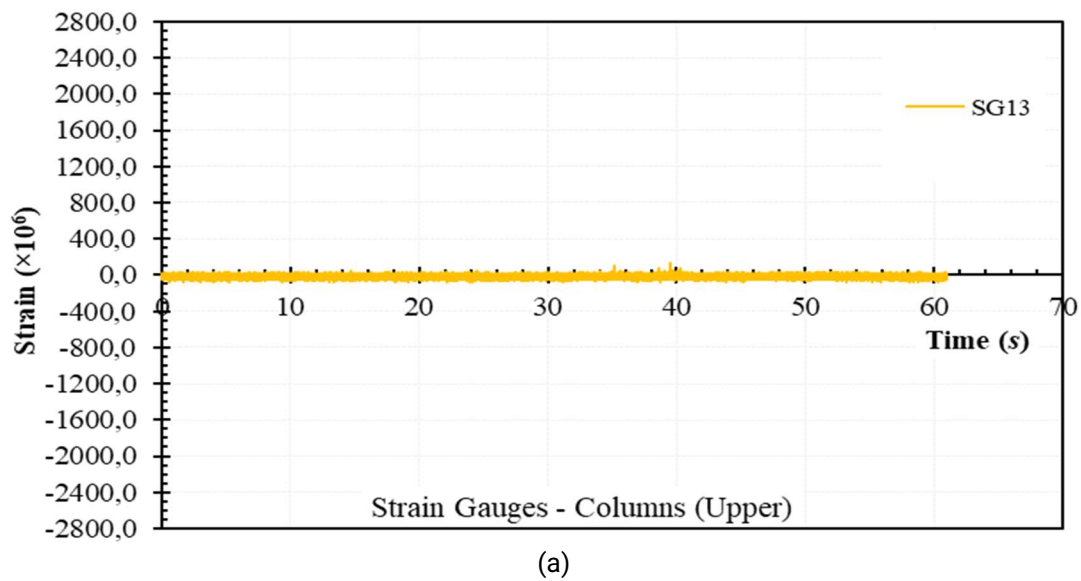


Figure 3.4.16 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 13 and (b) strain gauge 14

Sg 13

Max: 133,33 μ strain

Min: -76,30 μ strain

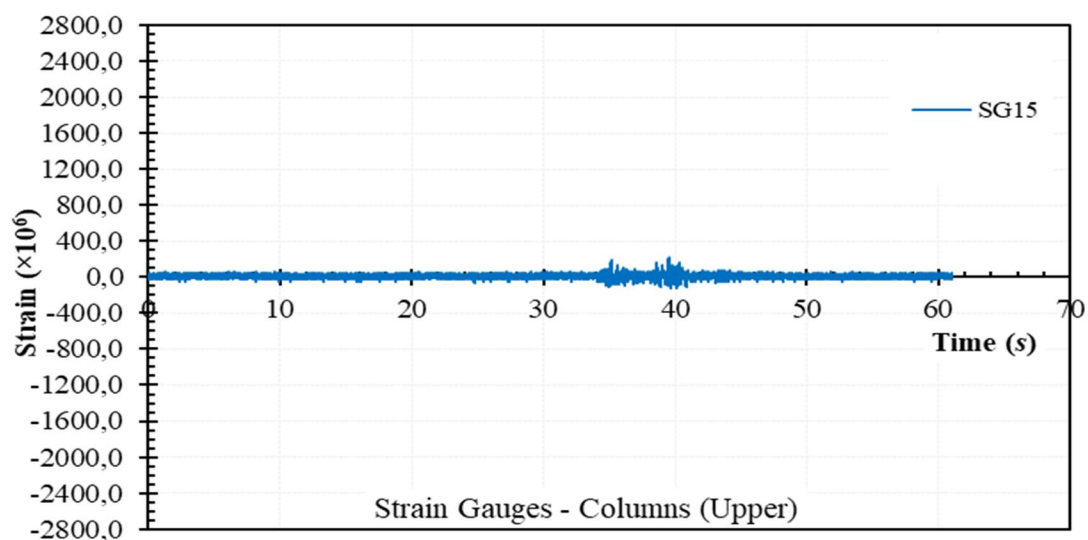
Residual: -15,26 μ strain

Sg 14

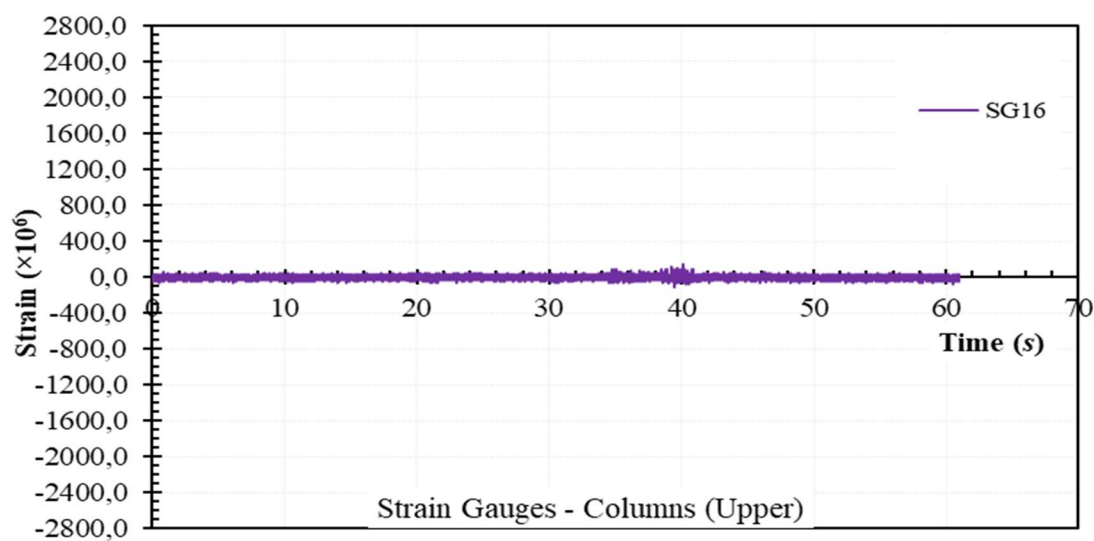
Max: 152,59 μ strain

Min: -152,59 μ strain

Residual: -15,26 μ strain



(a)



(b)

Figure 3.4.17 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 15 and (b) strain gauge 16

Sg 15

Max: 213,63 μ strain

Min: -122,07 μ strain

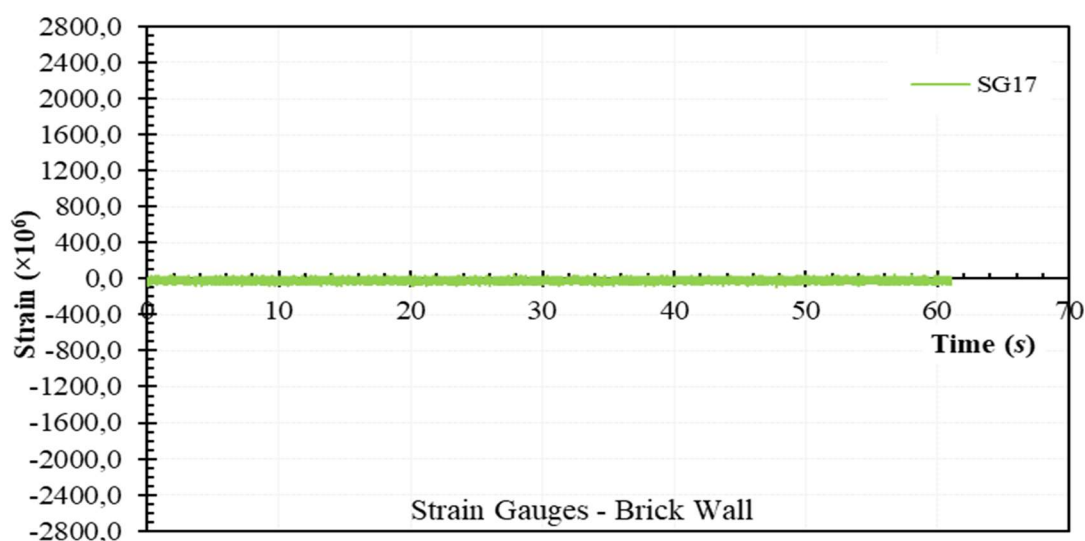
Residual: 15,26 μ strain

Sg 16

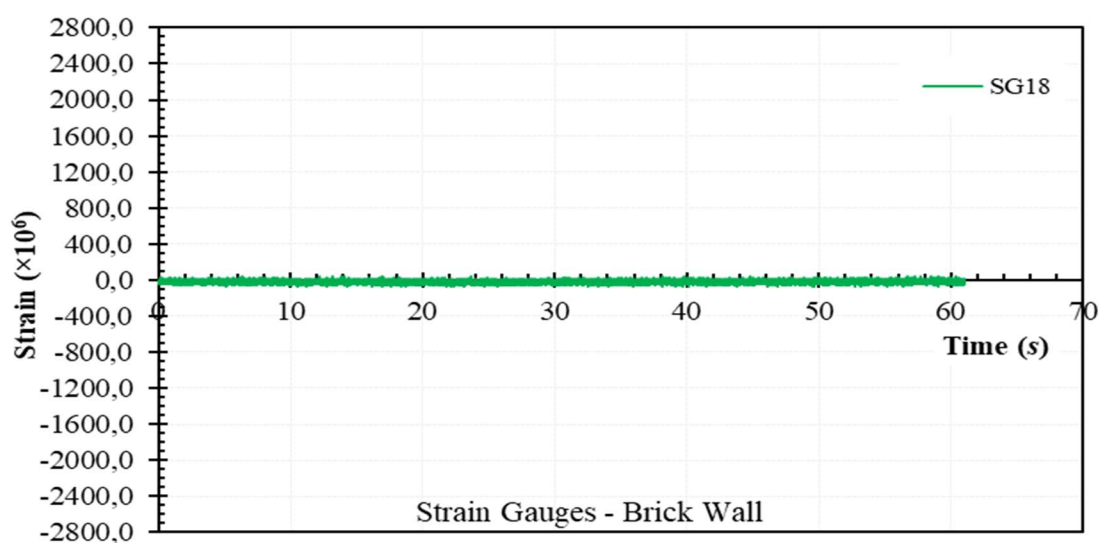
Max: 137,33 μ strain

Min: -106,81 μ strain

Residual: -30,52 μ strain



(a)



(b)

Figure 3.4.18 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 17 and (b) strain gauge 18

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauges SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge SG17 has 45,78 μ strain maximum strain. Strain gauge SG17 has minimum deformation -91,56 μ strain and strain gauge SG18 -76,30 μ strain. Strain gauge SG18 has maximum strain 45,78 μ strain. Finally strain gauge SG17 presents 0 μ strain residual. Strain gauge SG18 presents -15,26 μ strain residual.

Sg 17

Max: 45,78 μ strain

Min: -91,56 μ strain

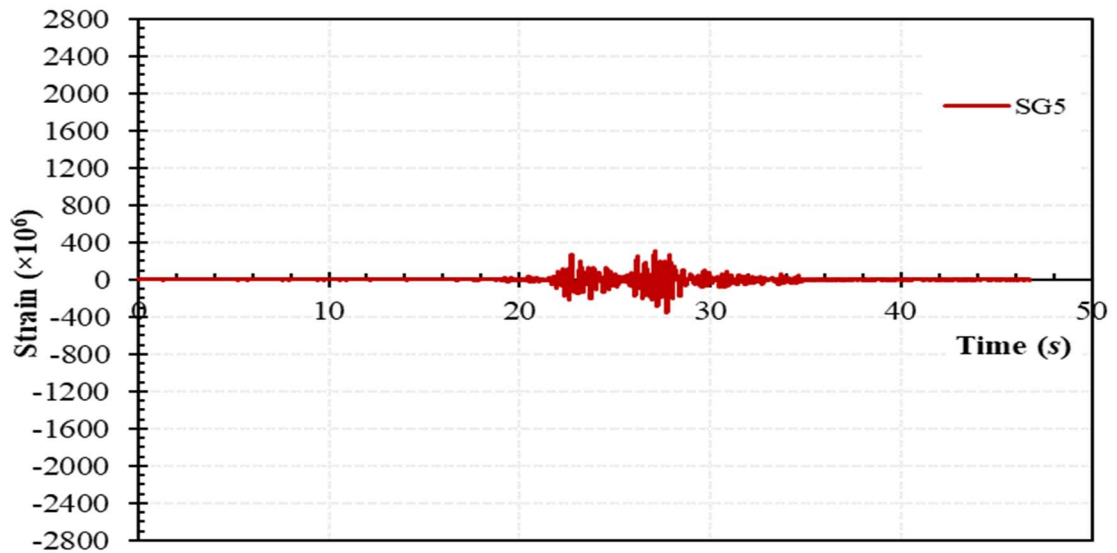
Residual: 0 μ strain

Sg 18

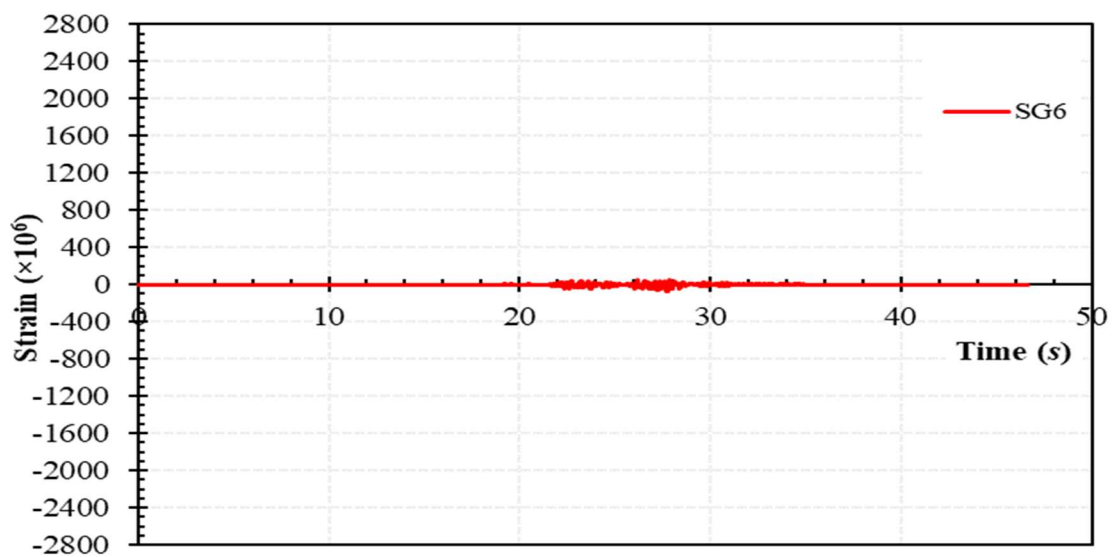
Max: 45,78 μ strain

Min: -76,30 μ strain

Residual: -15,26 μ strain



(a)



(b)

Figure 3.4.19 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 5 and (b) strain gauge 6

Sg 5

Max: 315,62 μ strain

Min: -357,67 μ strain

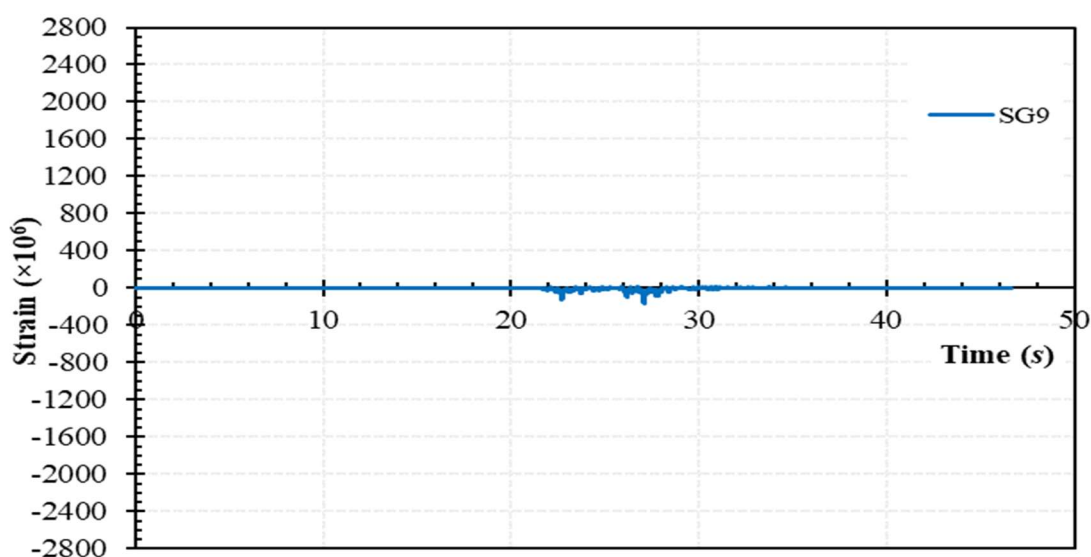
Residual: -2,44 μ strain

Sg 6

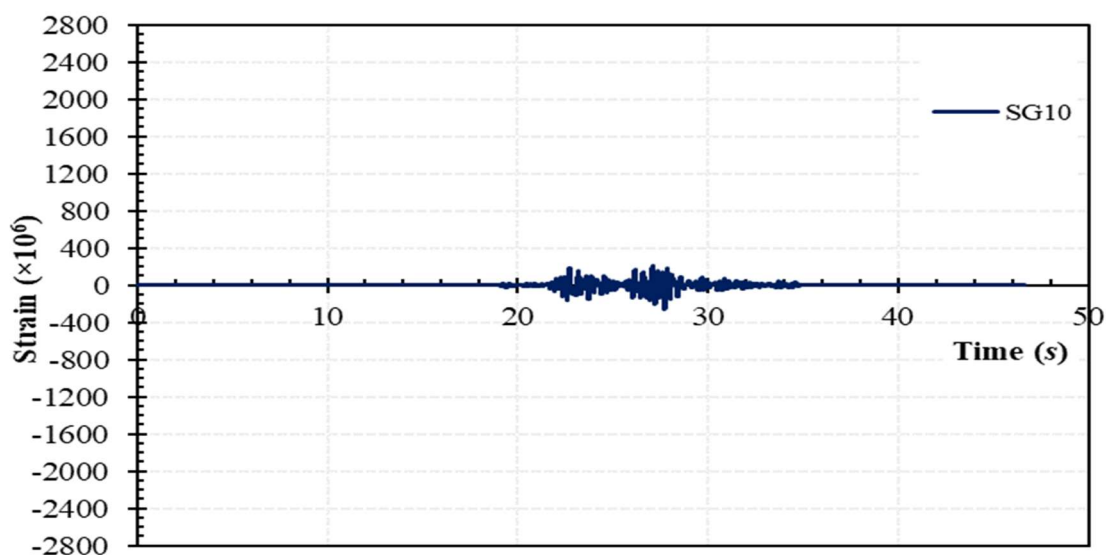
Max: 48,92 μ strain

Min: -76,63 μ strain

Residual: 1,63 μ strain



(a)



(b)

Figure 3.4.20 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 9 and (b) strain gauge 10

Sg 9

Max: 9,76 μ strain

Min: -76,63 μ strain

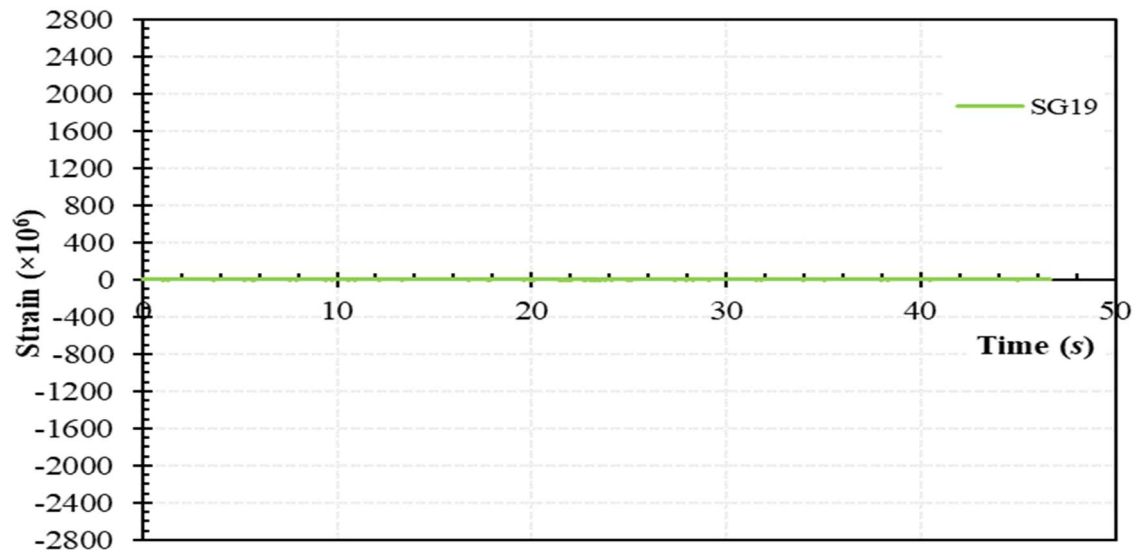
Residual: 3,25 μ strain

Sg 10

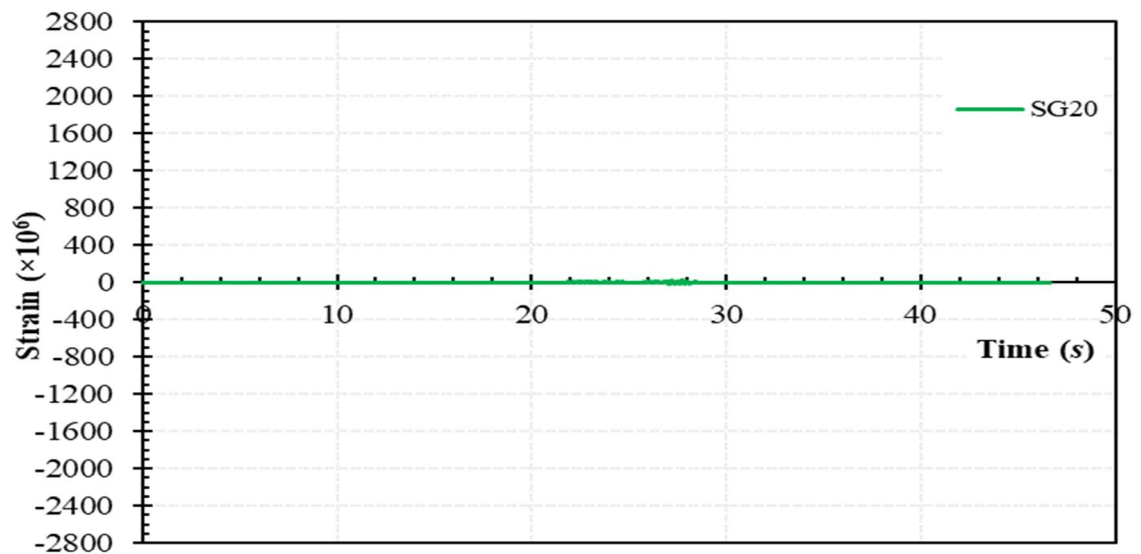
Max: 207,43 μ strain

Min: -255,48 μ strain

Residual: 2,45 μ strain



(a)



(b)

Figure 3.4.21 Characteristic results for phase A (0,2g earthquake) (a) strain gauge 19 and (b) strain gauge 20

Strain gauge SG19 is located on the centre of partial masonry 2 along direction x. Strain gauges 20 is located on the centre of partial masonry 2 along direction x. More specifically strain gauge SG19 has maximum 2,43 μ strain and minimum -1,62 μ strain. Strain gauge SG20 has maximum strain 22,77 μ strain and minimum -13,82 μ strain. The residual strain for strain gauge SG19 is -0,81 μ strain and residual for strain gauge SG20 is -3,25 μ strain.

Sg 19

Max: 2,43 μ strain

Min: -1,62 μ strain

Residual: -0,81 μ strain

Sg 20

Max: 22,77 μ strain

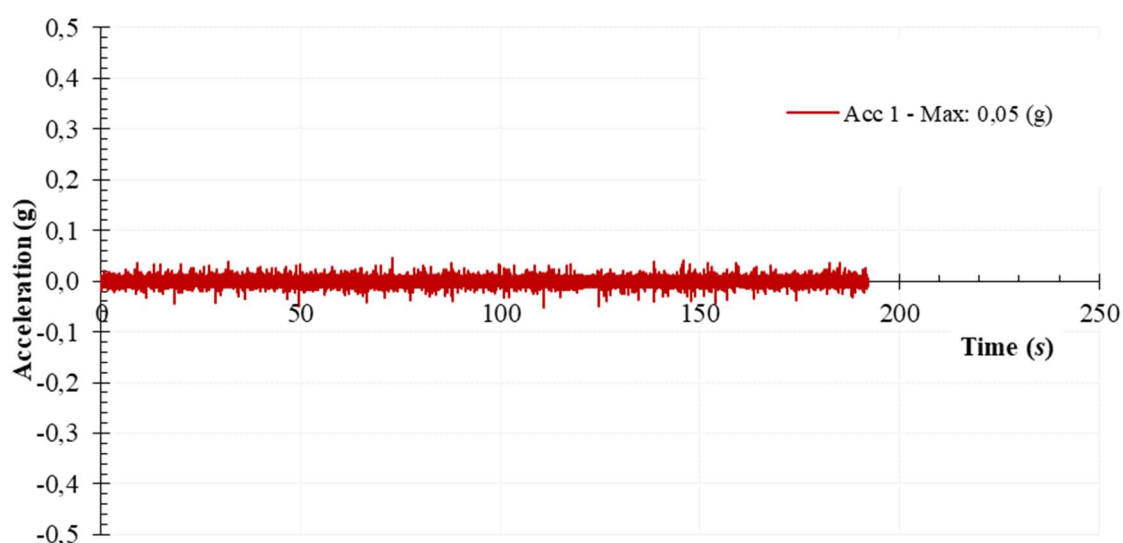
Min: -13,82 μ strain

Residual: -3,25 μ strain

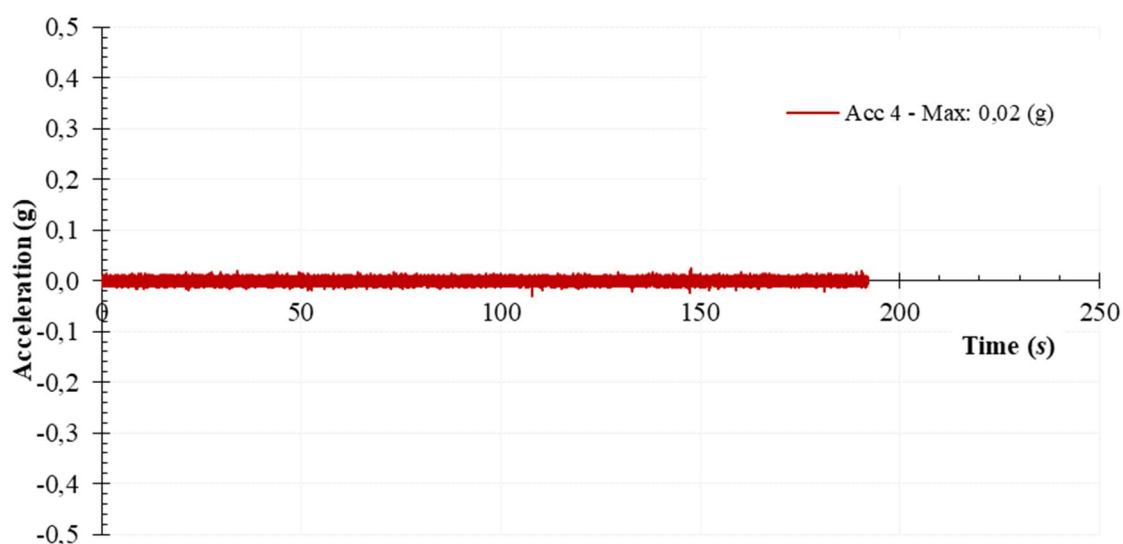
3.5) White noise test before EQ0,5g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for white noise test before EQ0,5g. The max acceleration at the slab level on the accelerometer acc1 and acc4 is 0,05g and 0,02g respectively. The max acceleration at the foundation level on the accelerometer acc10 is 0,03g.

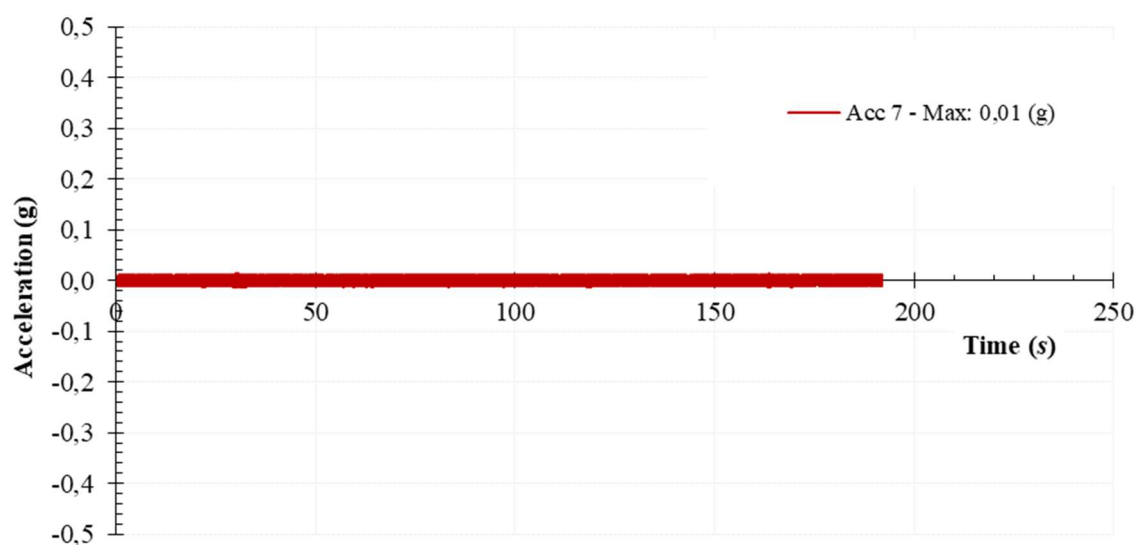


(a)

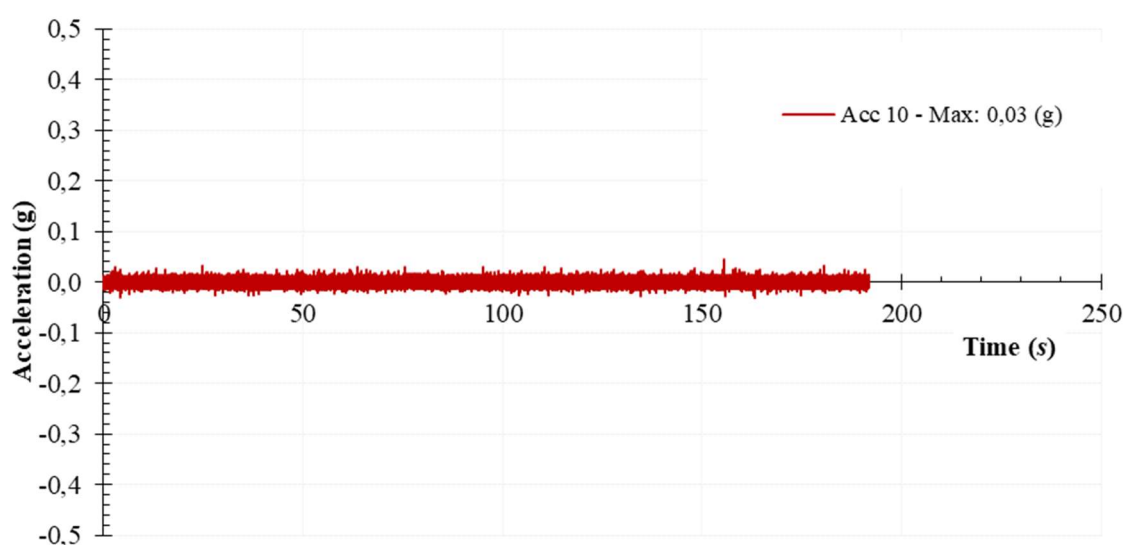


(b)

Figure 3.5.1 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 1 (b) Accelerometer 4

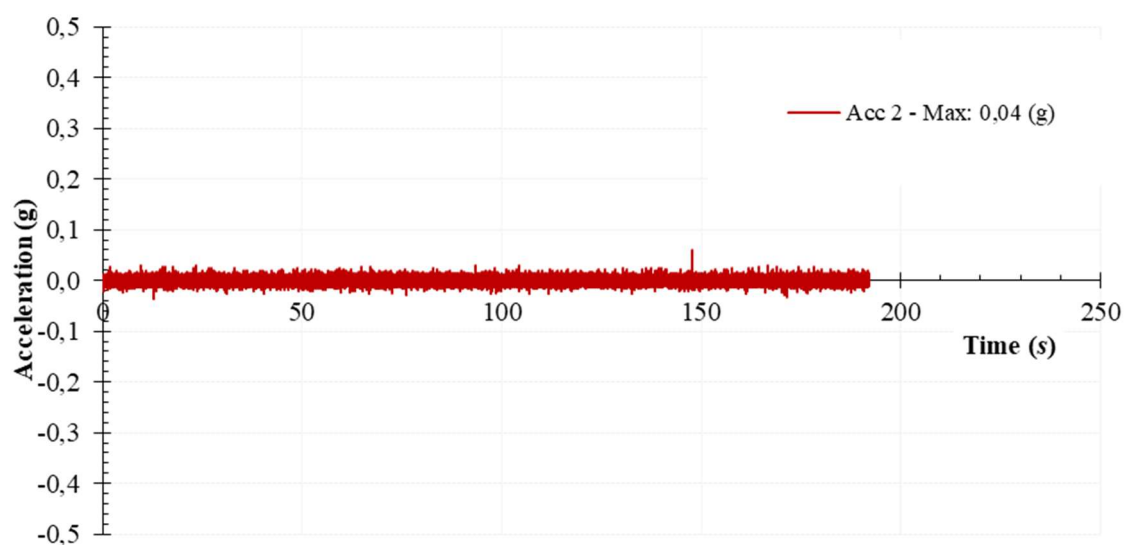


(a)

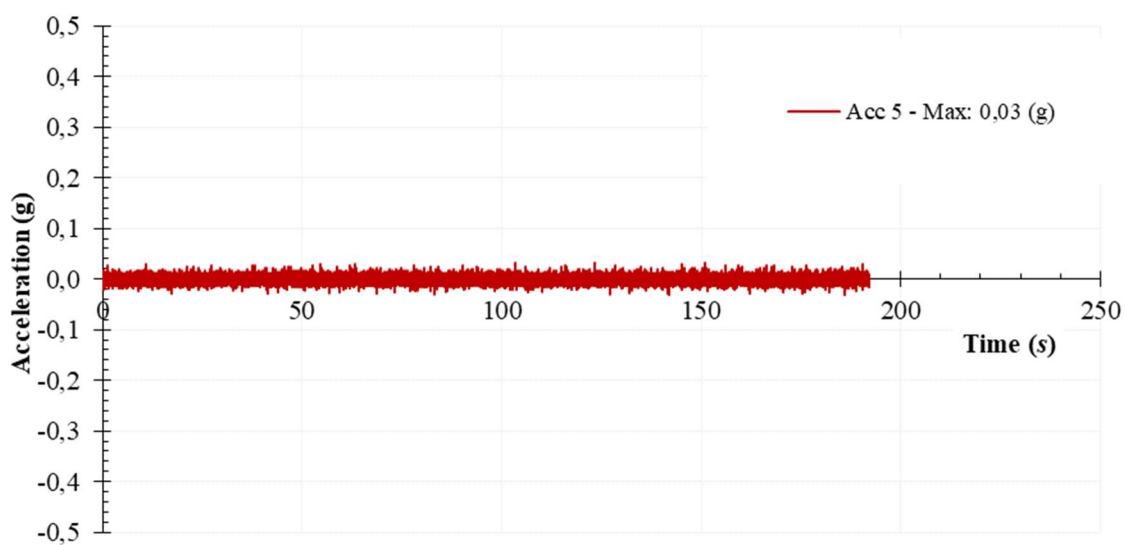


(b)

Figure 3.5.2 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

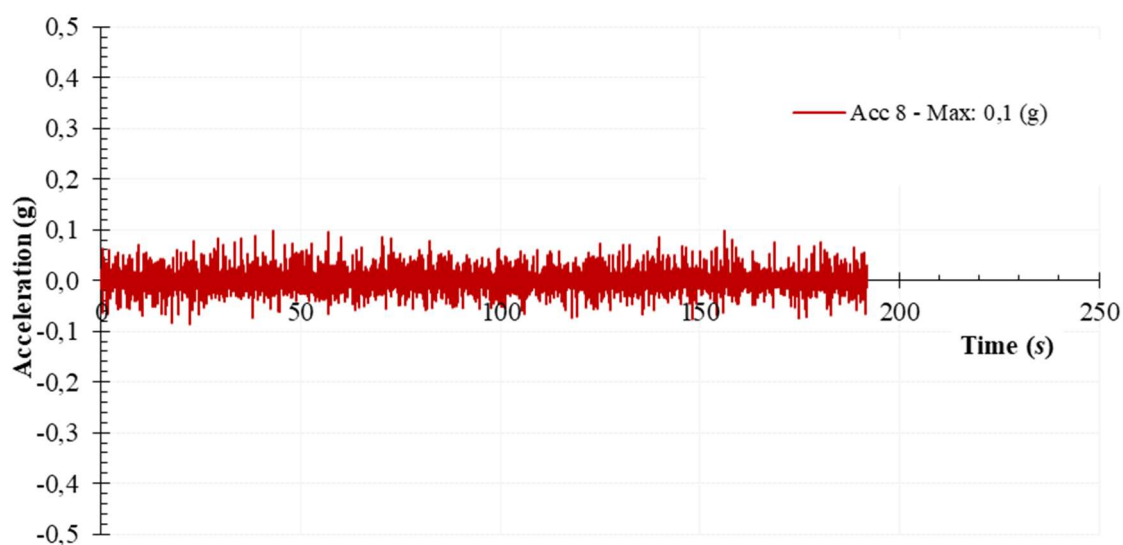


(a)

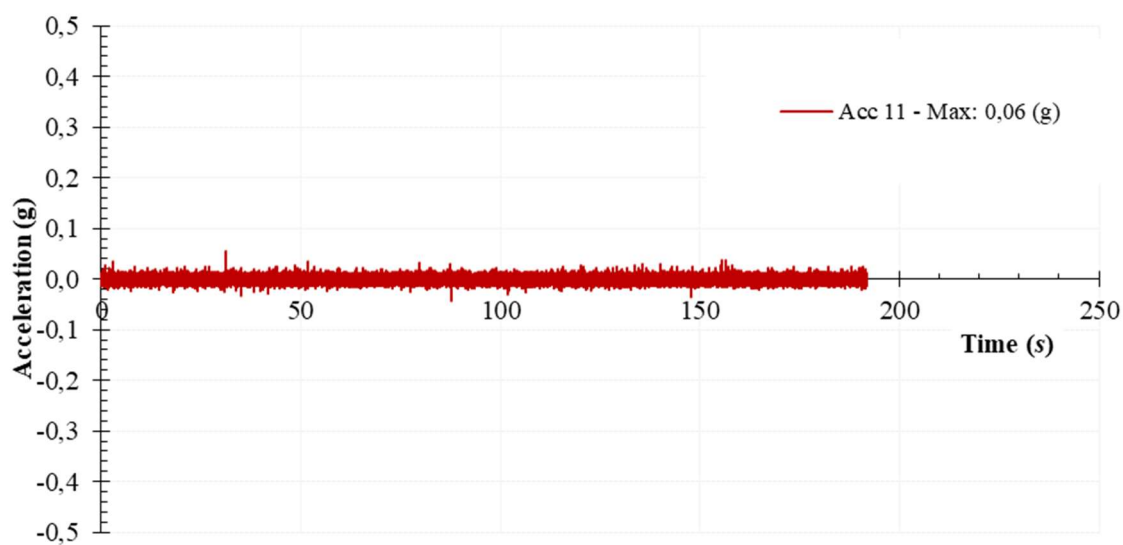


(b)

Figure 3.5.3 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

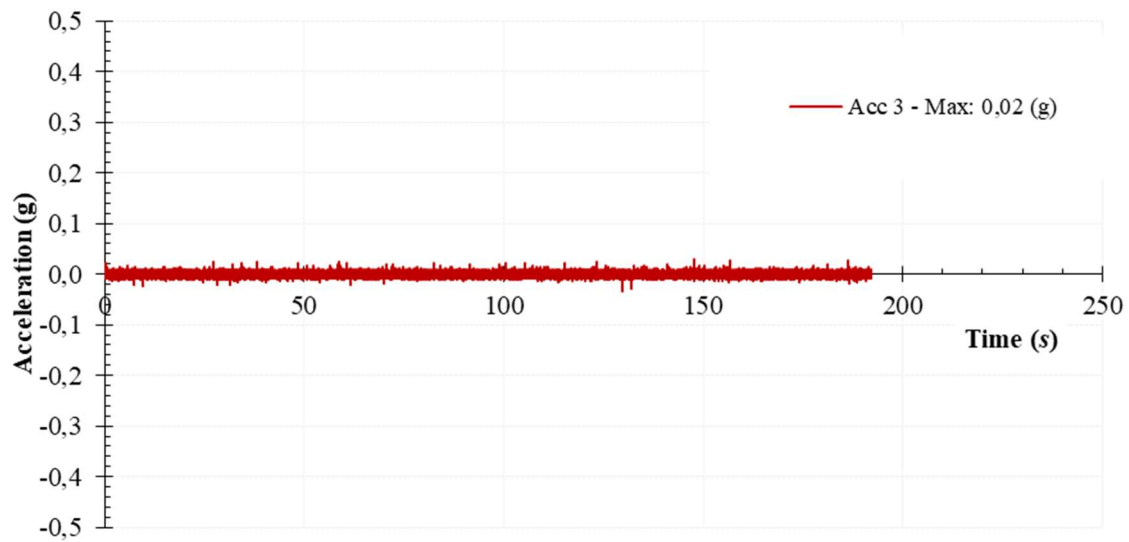


(a)

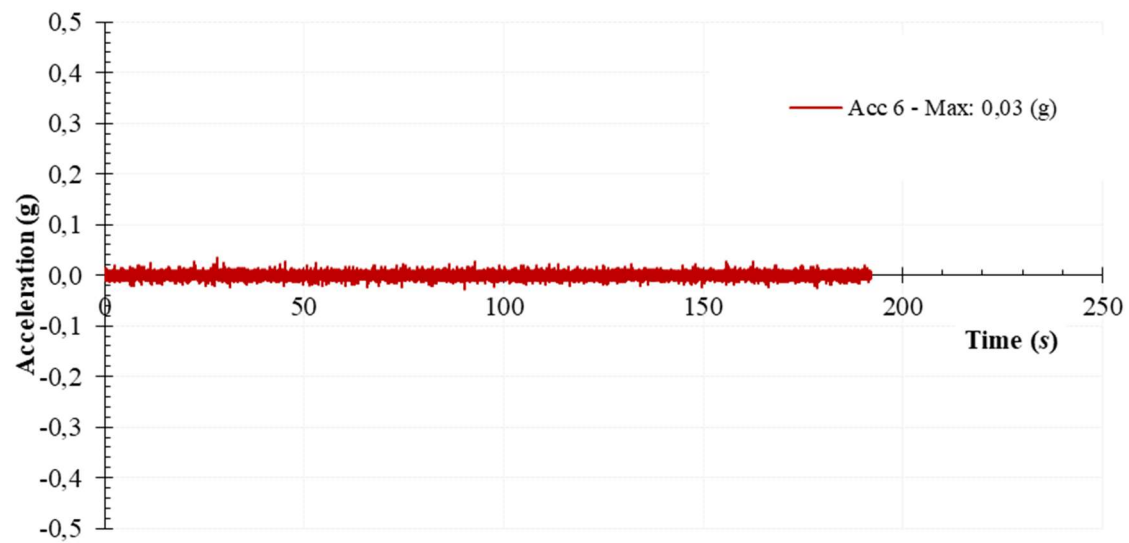


(b)

Figure 3.5.4 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 8 (b) Accelerometer 11

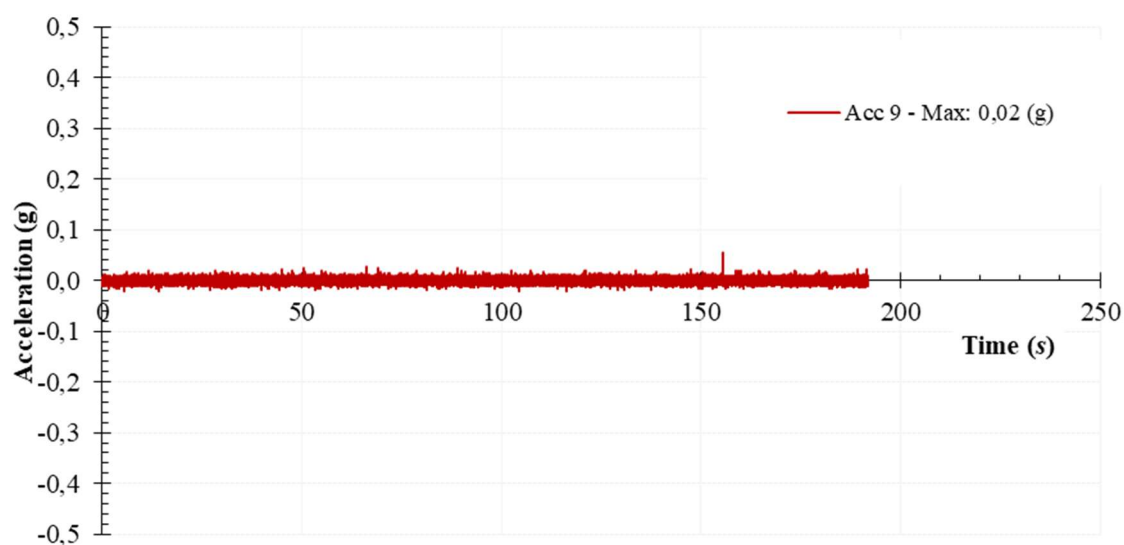


(a)

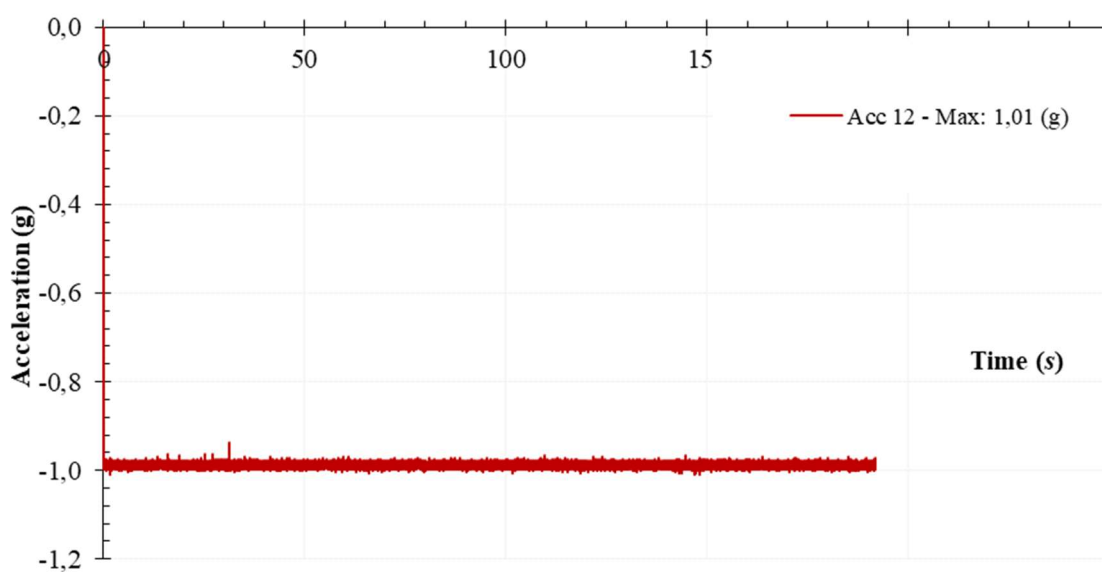


(b)

Figure 3.5.5 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 3 (b) Accelerometer 6



(a)



(b)

Figure 3.5.6 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Accelerometer 9 (b) Accelerometer 12

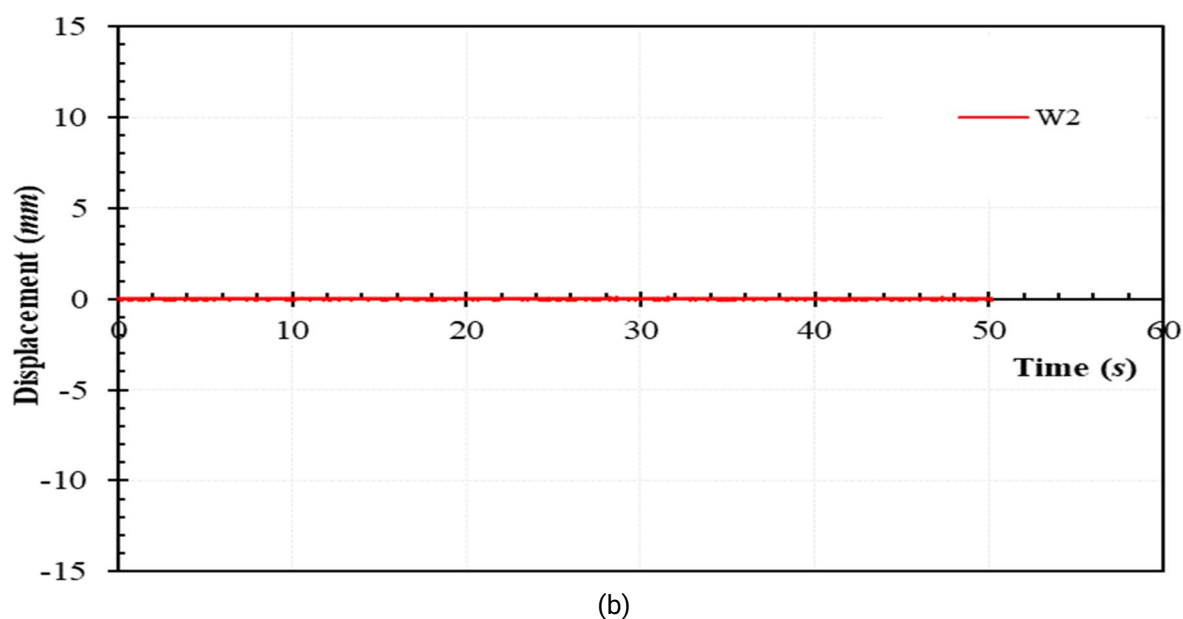
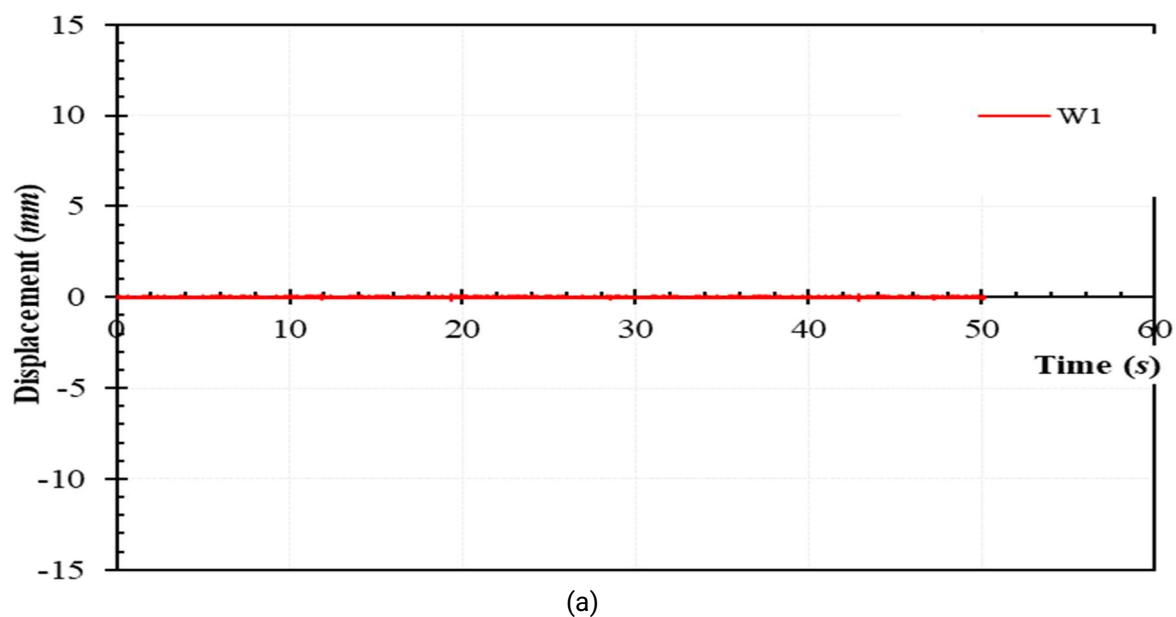


Figure 3.5.7 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2

Figure 3.5.7 shows draw wire sensors W1 and W2. More specifically, draw wire sensor W1 is located on the slab, on the left side and draw wire sensor W2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor W1 is 0,32 mm while the minimum is -0,33 mm. The maximum movement detected by draw wire sensor W2 is 0,19 mm while the minimum is -0,20 mm.

W 1

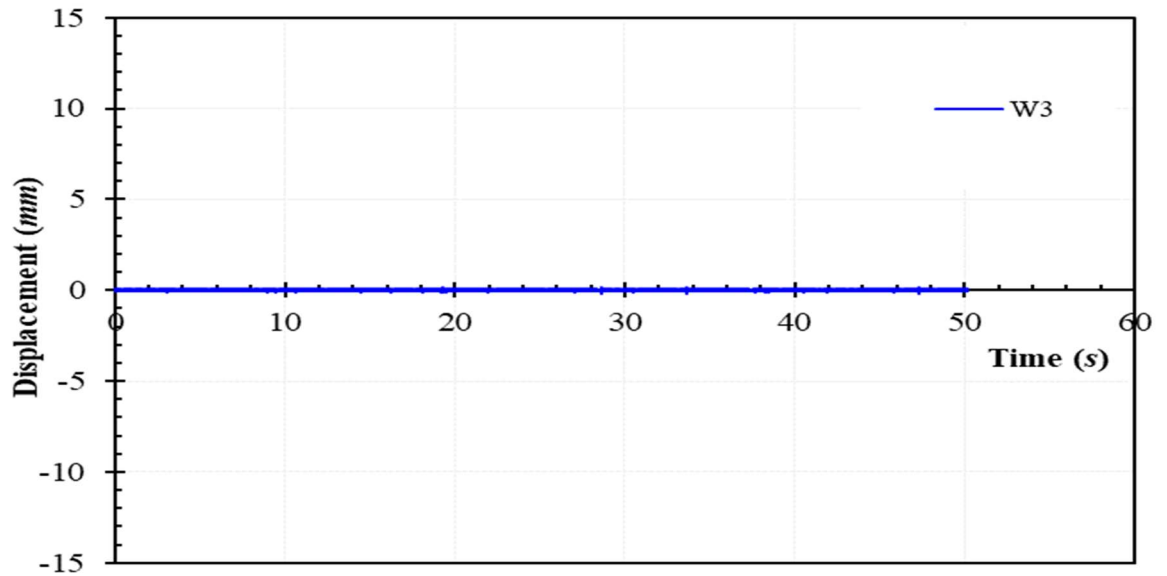
Max: 0,32 mm

Min: -0,33 mm

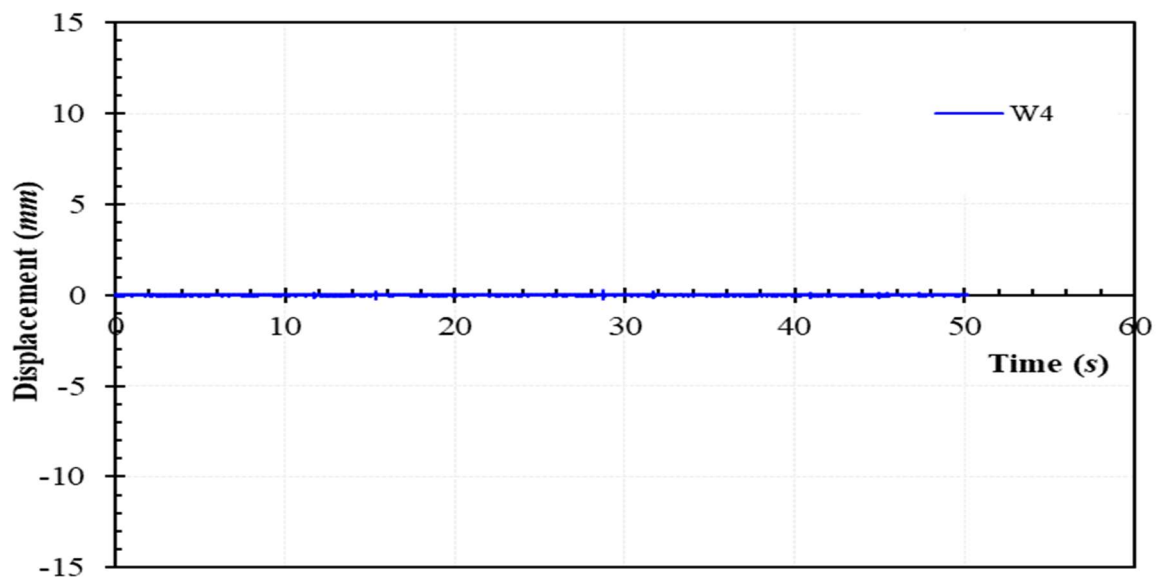
W 2

Max: 0,19 mm

Min: -0,20 mm



(a)



(b)

Figure 3.5.8 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor 4

Figure 3.5.8 shows draw wire sensors W3 and W4. More specifically, draw wire sensor WW3 is located on the foundation, on the left side and draw wire sensor W4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor3 is 0,27 mm while the minimum is -0,29 mm. The maximum movement detected by draw wire sensor 2 is 0,29 mm while the minimum is -0,29 mm.

W 3

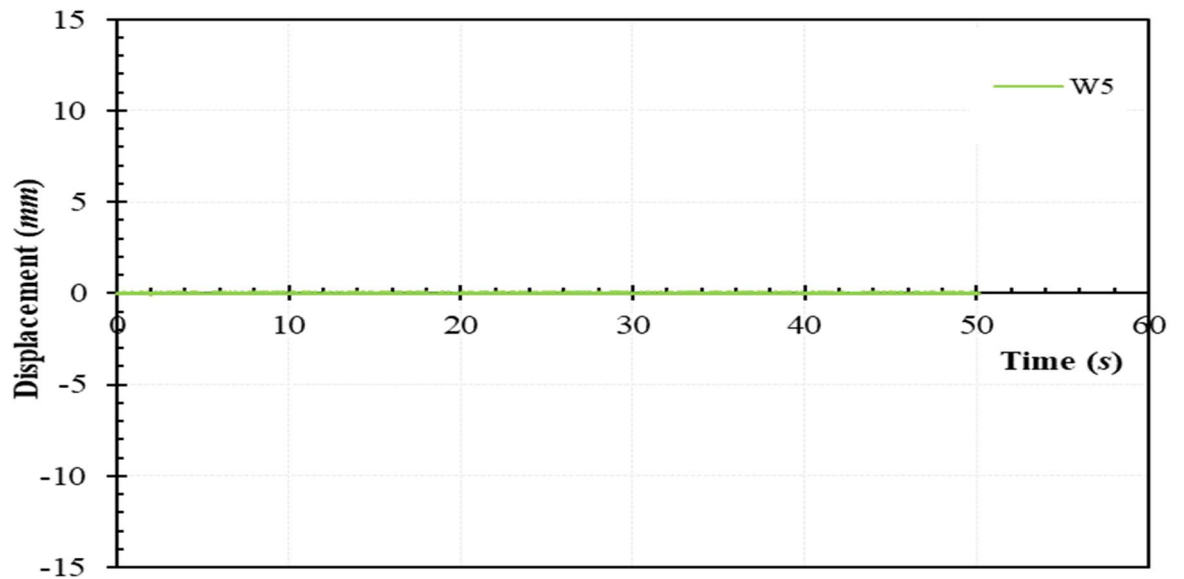
Max: 0,27 mm

Min: -0,29 mm

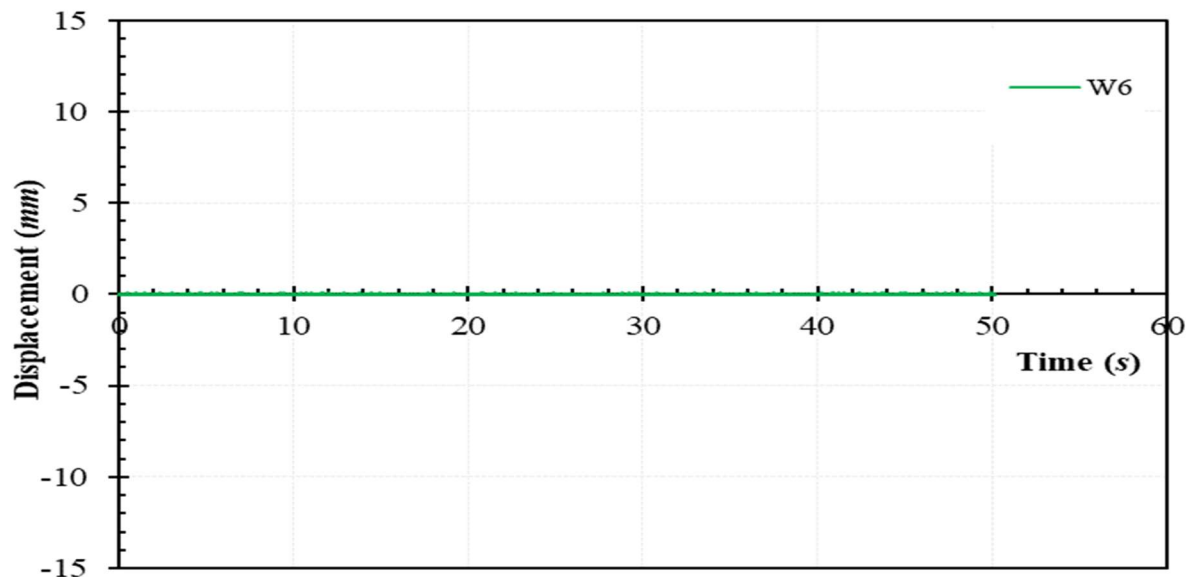
W 4

Max: 0,29 mm

Min: -0,29 mm



(a)



(b)

Figure 3.5.9 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6

Figure 3.5.9 shows draw wire sensors 5 and 6. More specifically, draw wire sensor 5 is located along the partial masonry infill diagonal and draw wire sensor 6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor 5 is 0,11 mm while the minimum

is -0,09 mm. The maximum movement detected by draw wire sensor 6 is 0,08 mm while the minimum is -0,08 mm.

W 5

Max: 0,11 mm

Min: -0,09 mm

W 6

Max: 0,08 mm

Min: -0,08 mm

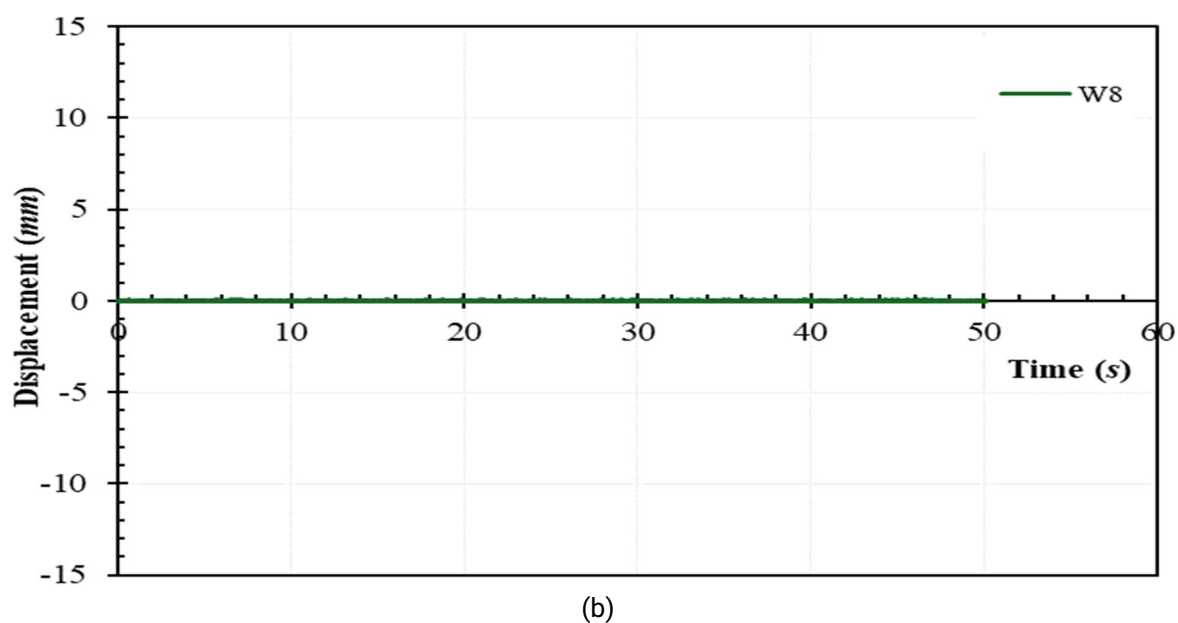
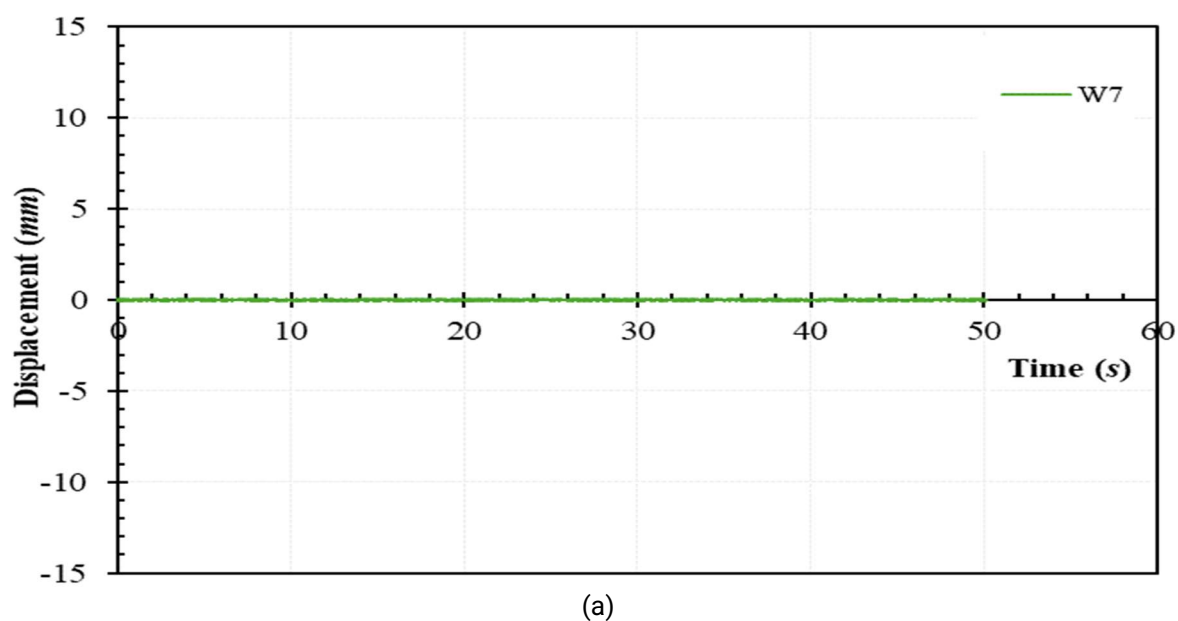


Figure 3.5.10 Characteristic results for phase A (white noise before 0,5g earthquake) : (a) Draw wire sensor 7 and (b) Draw wire sensor 8

Figure 3.5.10 shows draw wire sensors 7 and 8. More specifically, draw wire sensor 7 is located along the partial masonry infill diagonal and draw wire sensor 8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor 7 is 0,08 mm while the minimum is -0,08 mm. The maximum movement detected by draw wire sensor 8 is 0,07 mm while the minimum is -0,08 mm.

W 7

Max: 0,08 mm

Min: -0,08 mm

W 8

Max: 0,07 mm

Min: -0,08 mm

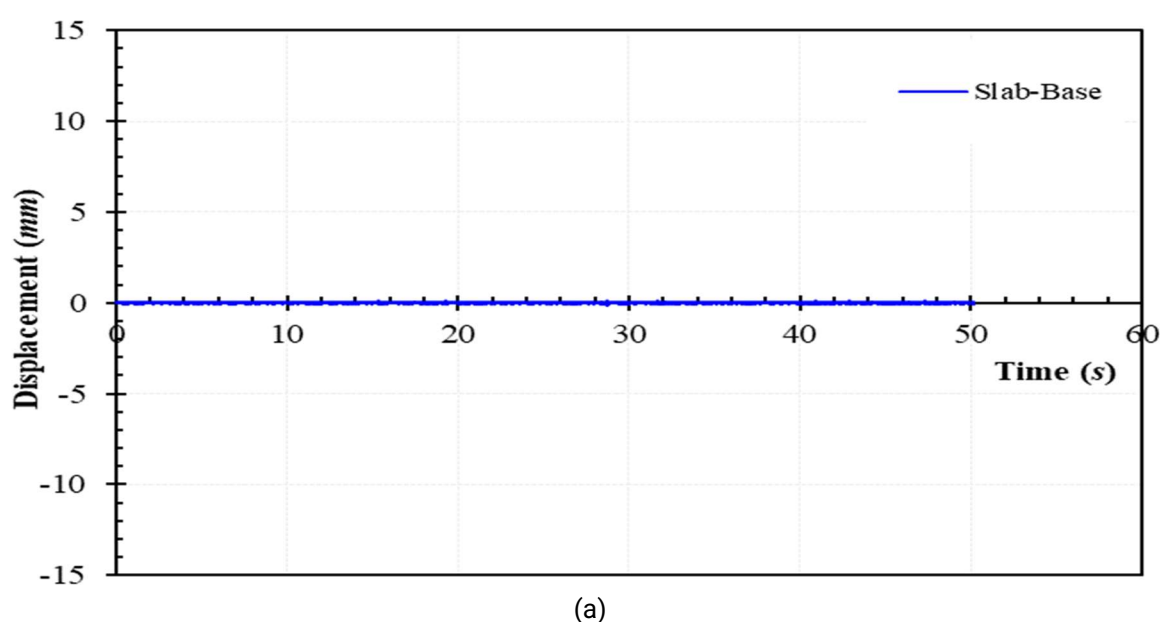


Figure 3.5.11 Characteristic results for phase A (white noise before 0,5g earthquake): (a) Diagram of displacement Slab – Base

Figure 3.5.11 shows slab – base displacement. More specifically, the maximum drift detected is 0,15 ‰ while the minimum is -0,15‰. The residual drift is 0,02 mm.

Maximum drift (‰): 0,15 ($0,18375 \text{ m} / 1,225 \text{ m} = 0,15 \text{ ‰}$)

Minimum drift (‰): -0,15

Residual drift: 0,02 mm

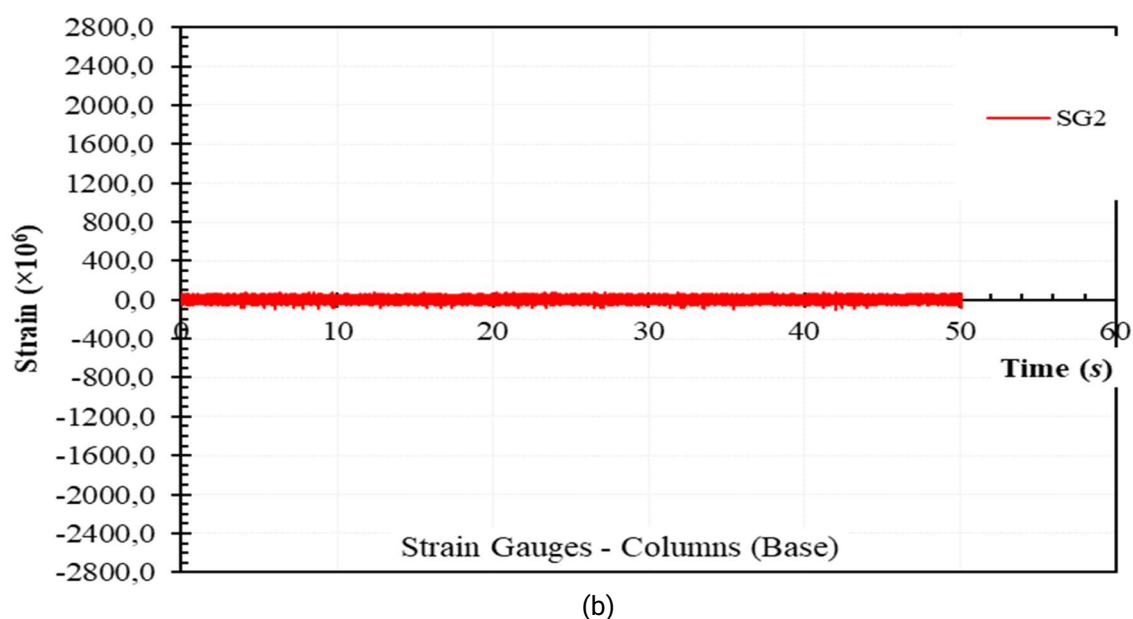
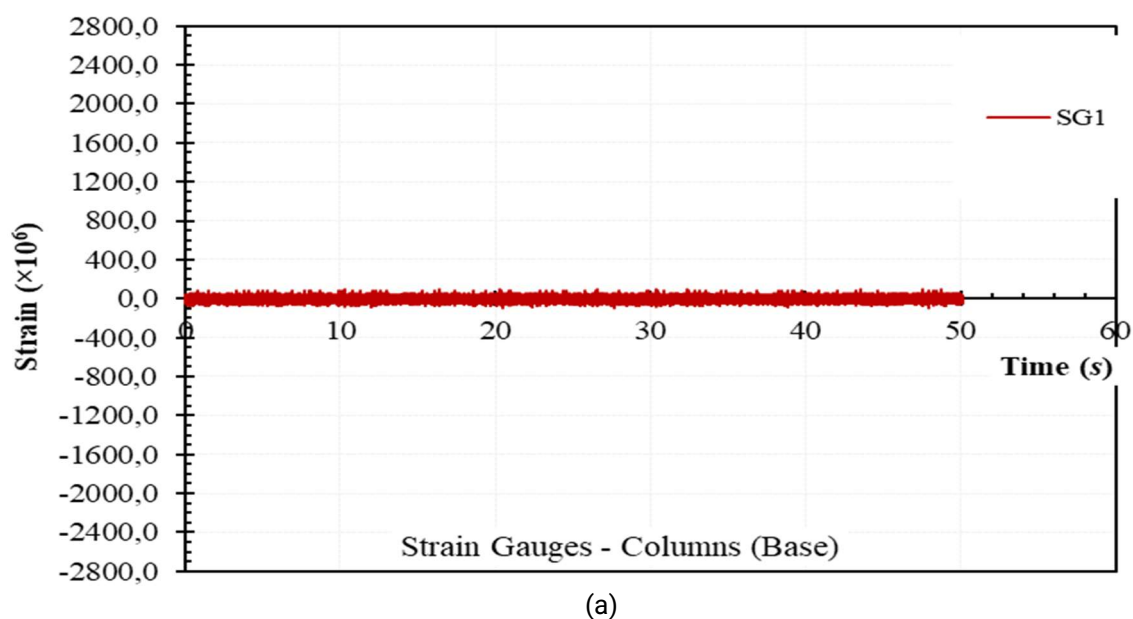


Figure 3.5.12 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 1 and (b) strain gauge 2

Strain gauges detect strain. The strain gauges shown in the figures 3.5.12, 3.5.13, 3.5.14 are located in the longitudinal reinforcement, on the underside. More specifically, strain gauge SG1 has maximum strain $91,56\mu\text{strain}$ and minimum strain $-106,81\mu\text{strain}$. The residual strain is $0\mu\text{strain}$. Strain gauge SG2 has maximum deformation $106,81\mu\text{strain}$ and minimum $-91,56\mu\text{strain}$. The residual strain is $15,26\mu\text{strain}$. Strain gauge SG3 has $122,07\mu\text{strain}$ and $-106,81\mu\text{strain}$ maximum and minimum strain respectively. The residual strain is $0\mu\text{strain}$. Strain gauge SG4 as we can see in figure 3.2.13 has maximum $91,56\mu\text{strain}$ and minimum $-91,56\mu\text{strain}$ deformation. The residual strain is $-30,52\mu\text{strain}$. Finally in figure 3.5.14 see strain gauge SG7 and SG8. Strain gauge SG7 has maximum strain $106,81\mu\text{strain}$ and SG8 has maximum strain $106,81\mu\text{strain}$. Strain gauge SG7 has $-106,81\mu\text{strain}$

minimum deformation and SG8 has $-106,81 \mu\text{strain}$. The residual strain for strain gauge SG7 and SG8 is 30,52, 15,26 respectively.

Sg 1

Max: $91,56 \mu\text{strain}$

Min: $-106,81 \mu\text{strain}$

Residual: $0 \mu\text{strain}$

Sg 2

Max: $106,81 \mu\text{strain}$

Min: $-91,56 \mu\text{strain}$

Residual: $15,26 \mu\text{strain}$

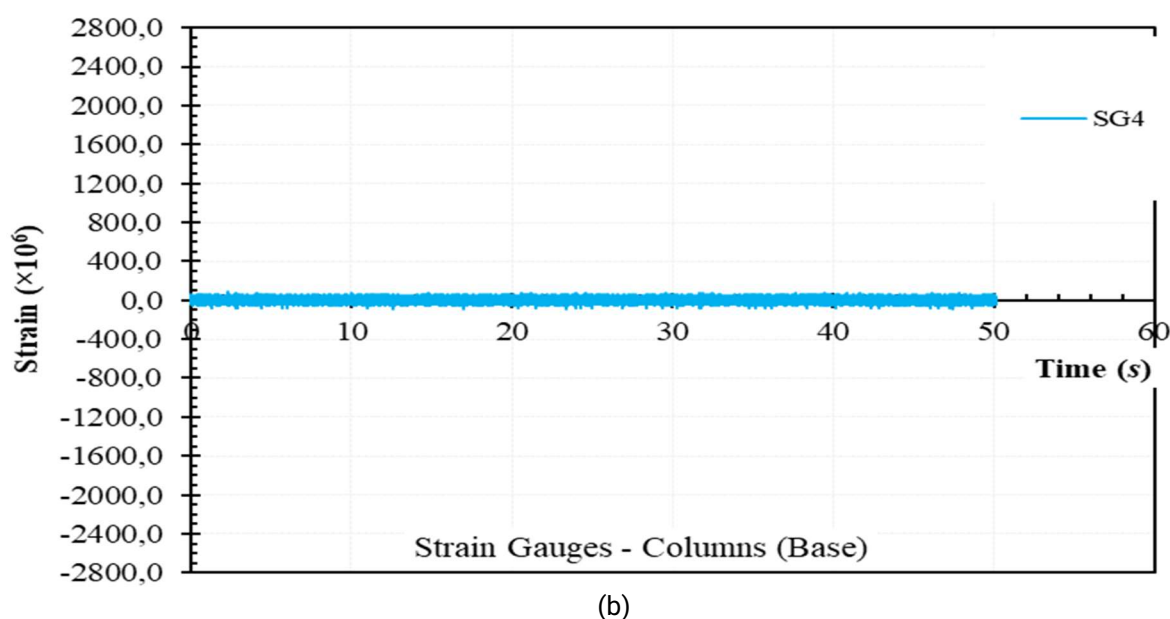
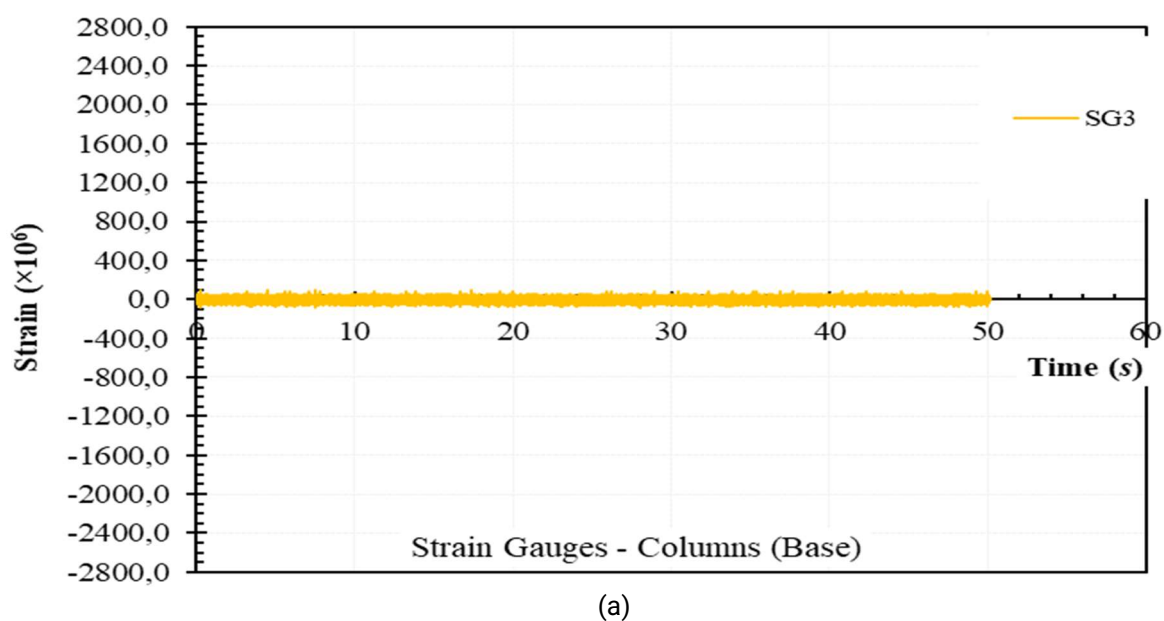


Figure 3.5.13 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 3 and (b) strain gauge 4

Sg 3

Max: 122,07 μ strain

Min: -106,81 μ strain

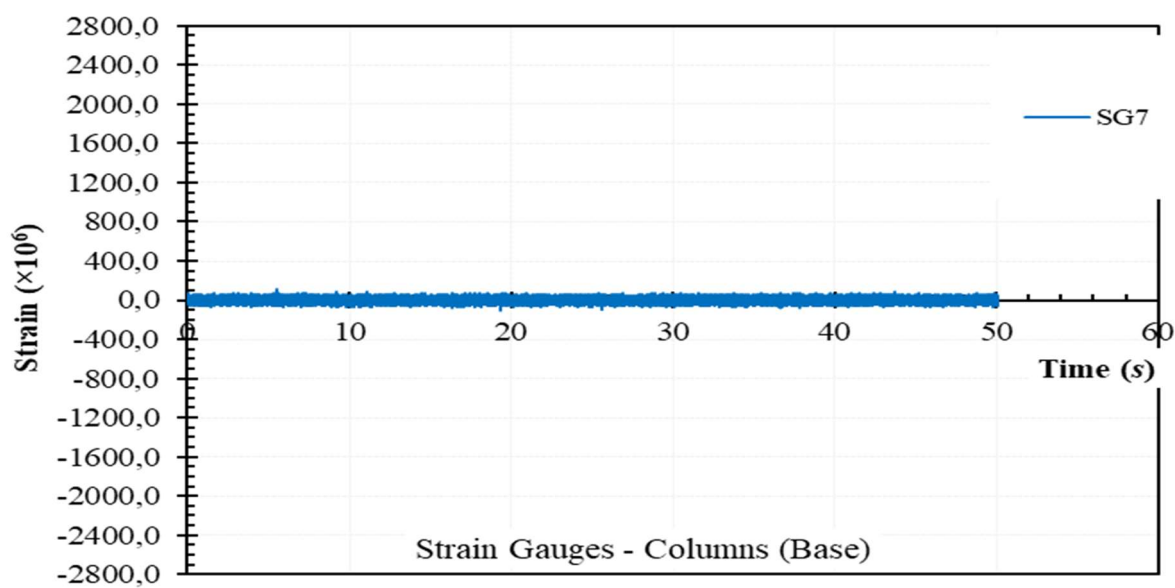
Residual: 0 μ strain

Sg 4

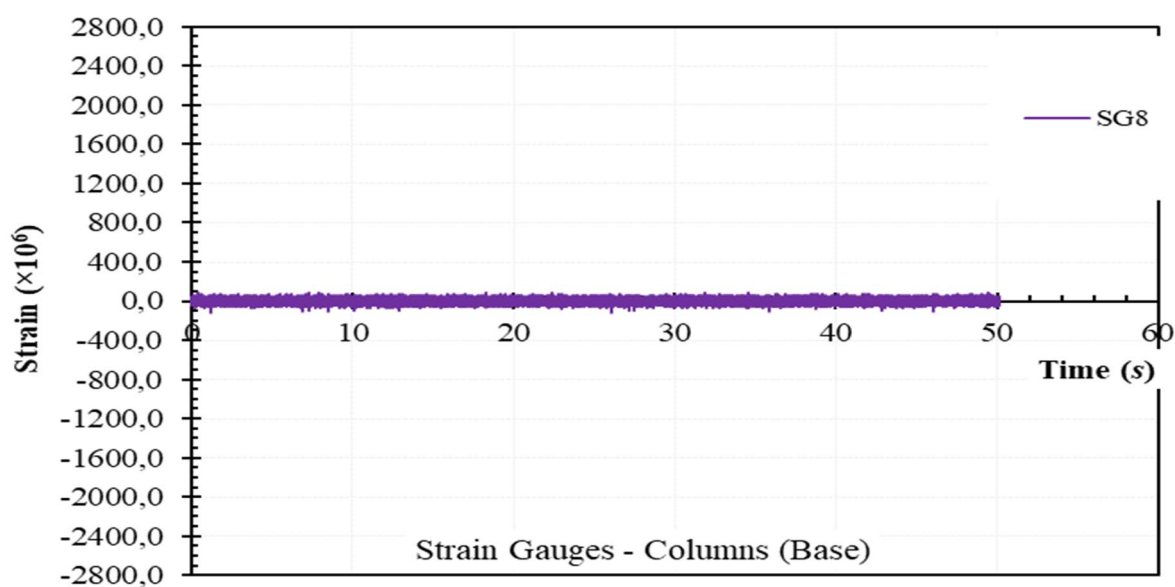
Max: 91,56 μ strain

Min: -91,56 μ strain

Residual: -30,52 μ strain



(a)



(b)

Figure 3.5.14 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 7 and (b) strain gauge 8

Sg 7

Max: 106,81 μ strain

Min: -106,81 μ strain

Residual: -30,52 μ strain

Sg 8

Max: 106,81 μ strain

Min: -106,81 μ strain

Residual: 15,26 μ strain

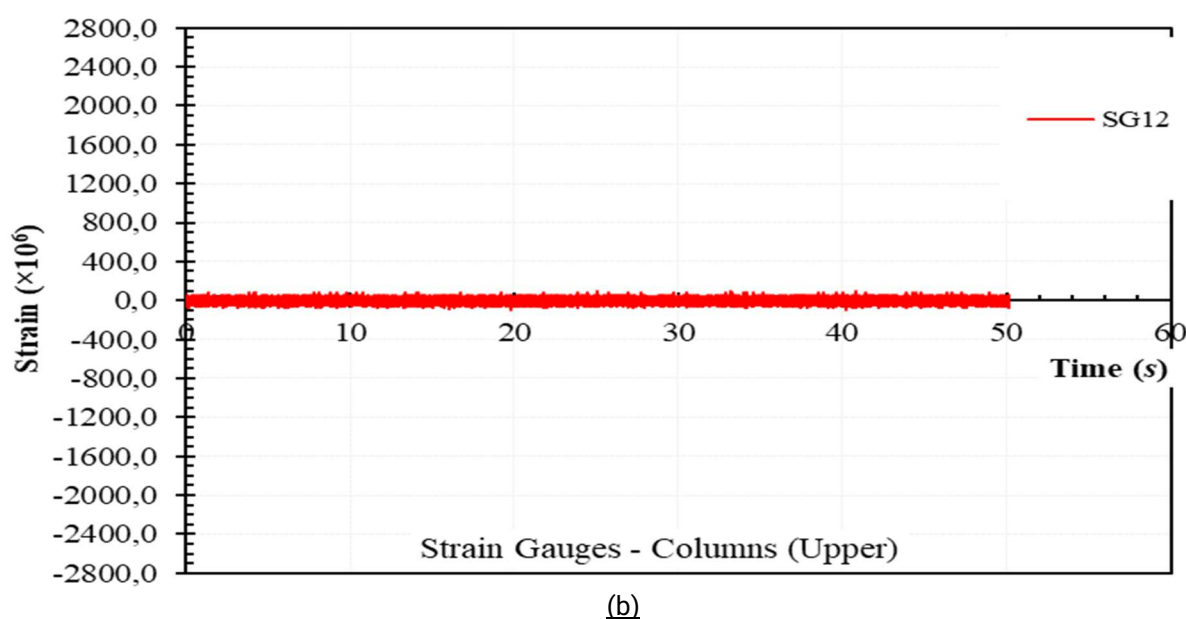
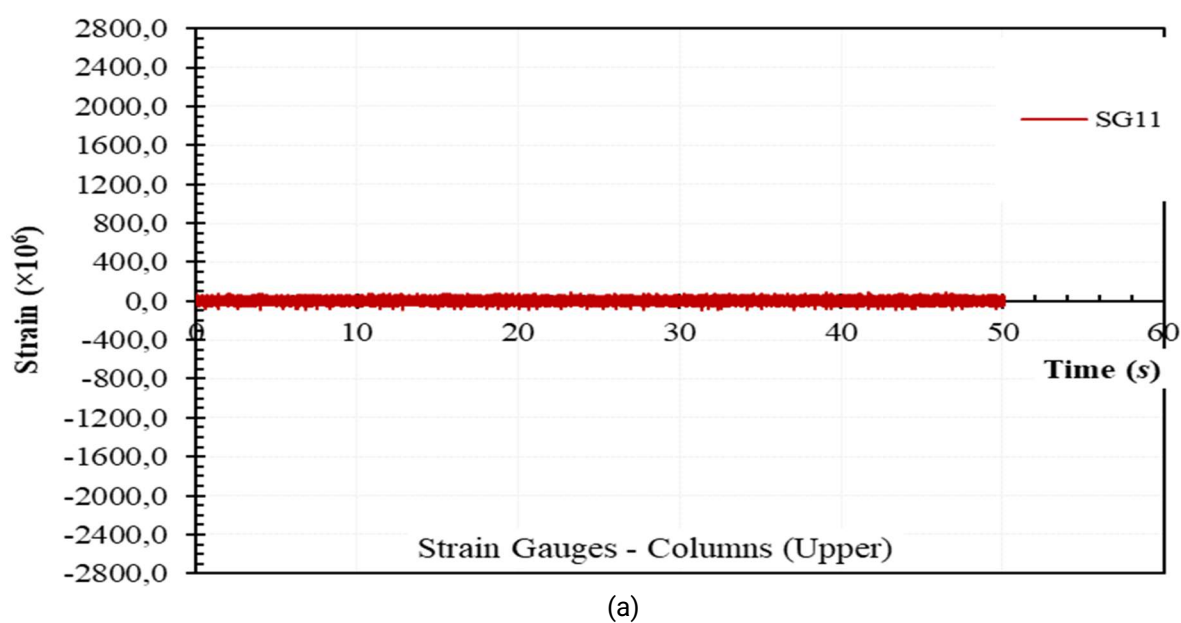
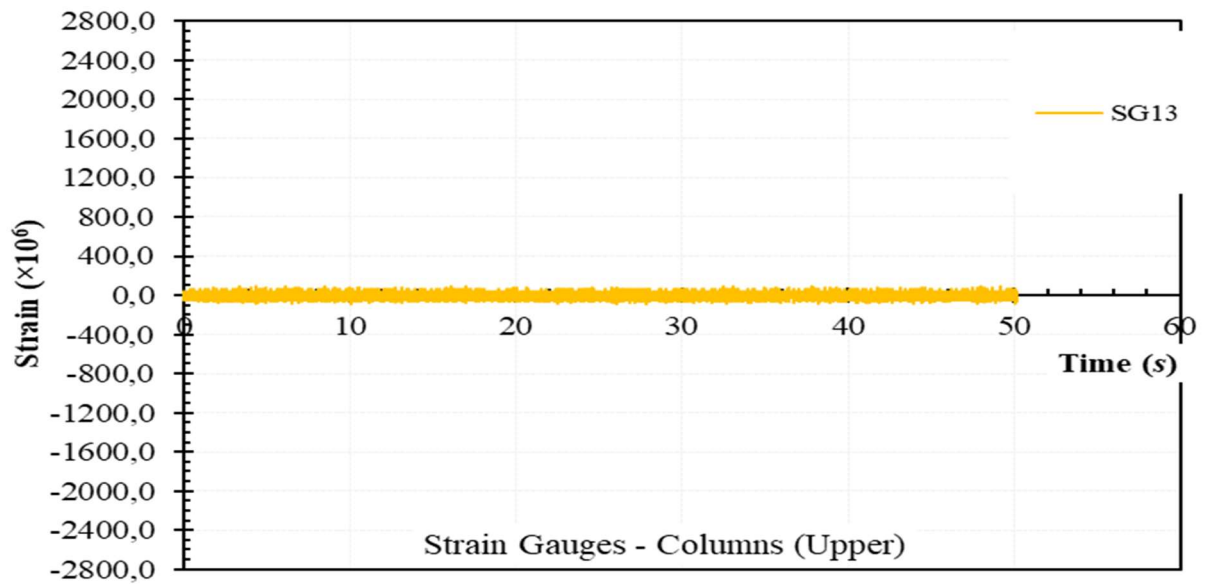


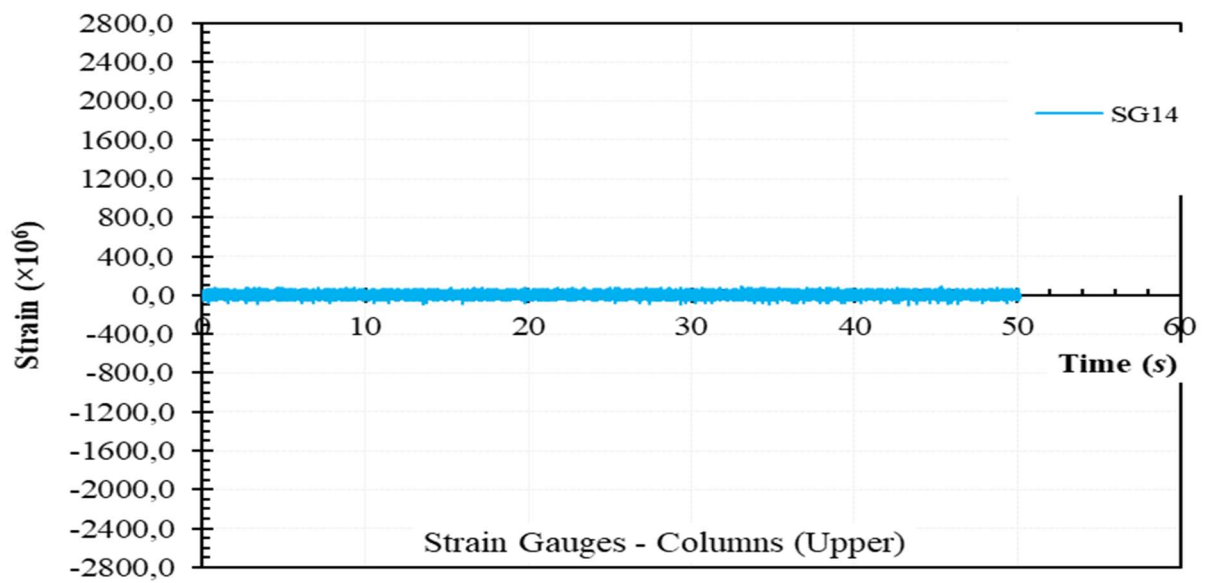
Figure 3.5.15 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 11 and (b) strain gauge 12

The strain gauges shown in the figures 3.5.15, 3.5.16 and 3.5.17 are located in the longitudinal reinforcement, on the upper side. More specifically, strain gauge SG11 has maximum strain 106,81 μ strain and minimum -106,81 μ strain deformation. The residual strain is 30,52 μ strain for strain gauge SG11. Strain gauge SG12 has maximum strain 91,56 μ strain and minimum strain -106,81 μ strain. The residual value is 0 μ strain. Strain gauge SG13 has maximum strain 106,81 μ strain and minimum strain -106,81 μ strain. The residual is -45,78 μ strain. Strain gauge SG14 has maximum strain 122,07 μ strain and minimum strain -91,56 μ strain. The residual is 15,26 μ strain. Finally strain gauges SG15 has maximum strain 91,56 μ strain and minimum strain -106,81 μ strain. The residual is -45,78 μ strain. Strain gauge SG16 has maximum strain 106,81 μ strain, minimum strain -106,81 μ strain and residual strain -15,26 μ strain.

Sg 11Max: 106,81 μ strainMin: -106,81 μ strainResidual: 30,52 μ strain**Sg 12**Max: 91,56 μ strainMin: -106,81 μ strainResidual: 0 μ strain



(a)



(b)

Figure 3.5.16 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 13 and (b) strain gauge 14

Sg 13

Max: 106,81 μ strain

Min: -106,81 μ strain

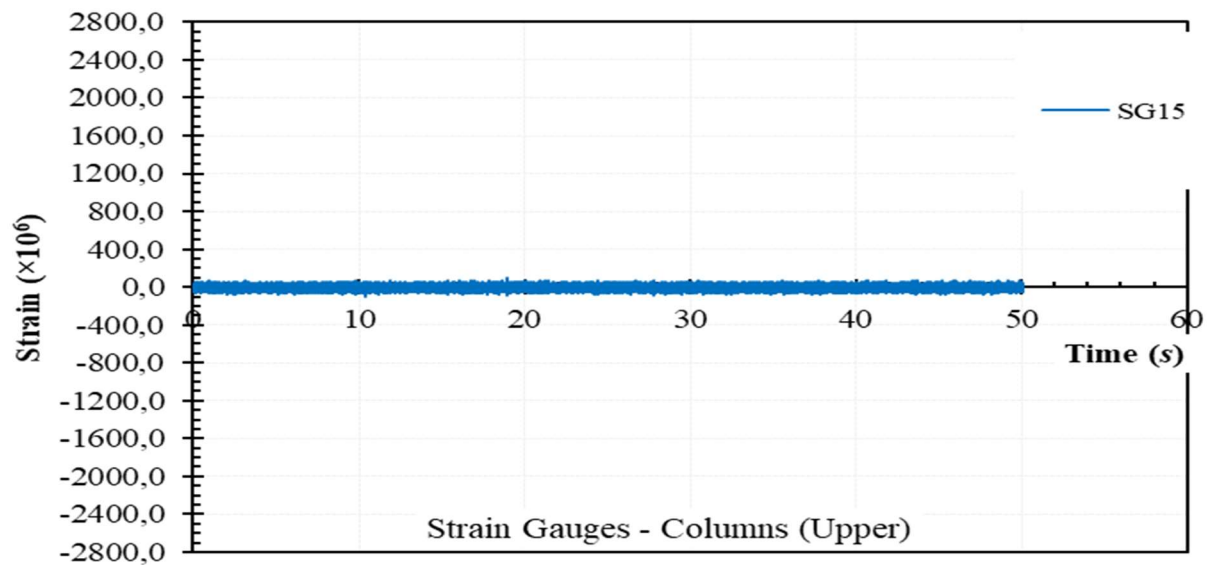
Residual: -45,78 μ strain

Sg 14

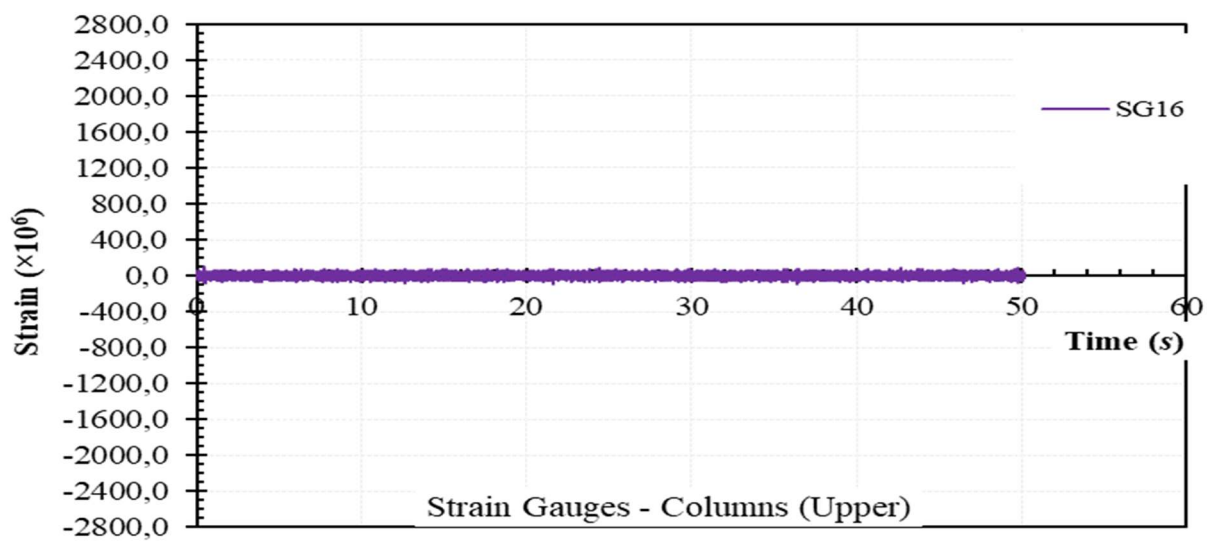
Max: 122,07 μ strain

Min: -91,56 μ strain

Residual: 15,26 μ strain



(a)



(b)

Figure 3.5.17 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 15 and (b) strain gauge 16

Sg 15

Max: 91,56 μ strain

Min: -106,81 μ strain

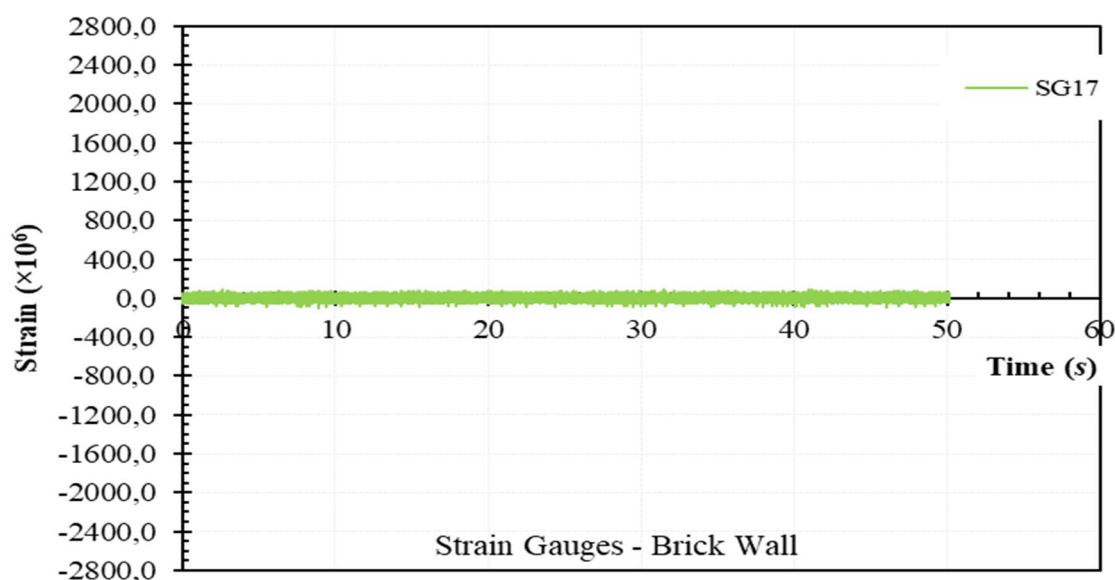
Residual: -45,78 μ strain

Sg 16

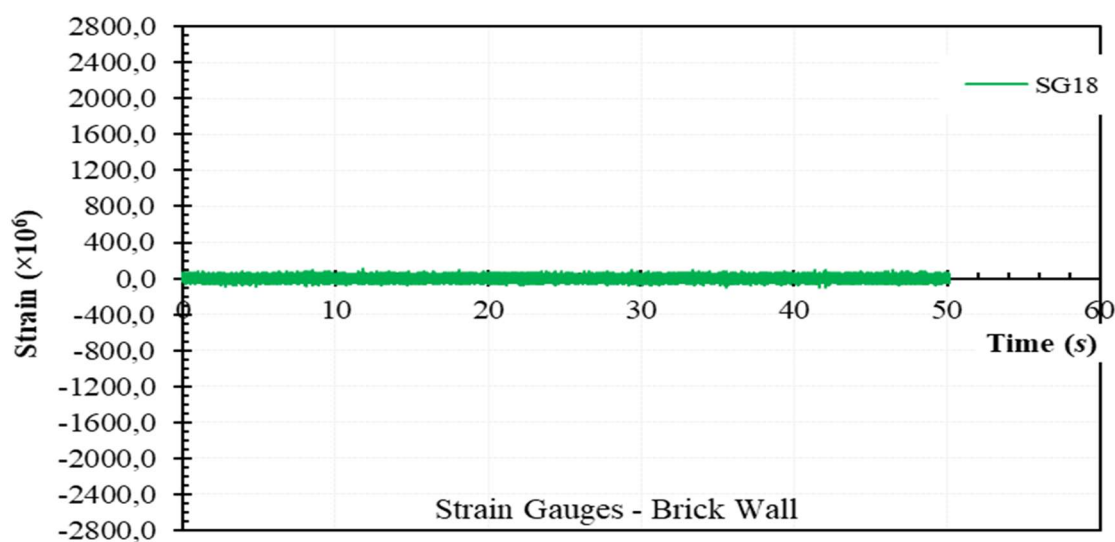
Max: 106,81 μ strain

Min: -106,81 μ strain

Residual: -15,26 μ strain



(a)



(b)

Figure 3.5.18 Characteristic results for phase A (white noise before 0,5g earthquake) (a) strain gauge 17 and (b) strain gauge 18

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauges SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge SG17 has 122,07 μ strain maximum strain. Strain gauge SG17 has minimum deformation -122,07 μ strain and strain gauge 18 -91,56 μ strain. Strain gauge SG18 has maximum strain 106,81 μ strain. Finally strain gauge SG17 presents 0 μ strain residual. Strain gauge SG18 presents 30,52 μ strain residual.

Sg 17

Max: 122,07 μ strain

Min: -122,07 μ strain

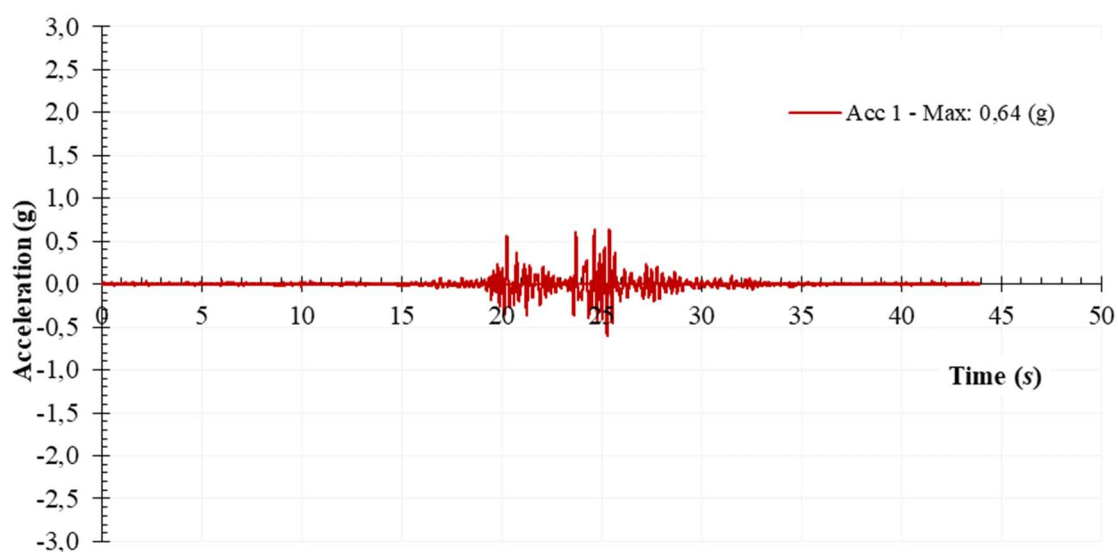
Residual: 0

Sg 18Max: 106,81 μ strainMin: -91,56 μ strainResidual: 30,52 μ strain

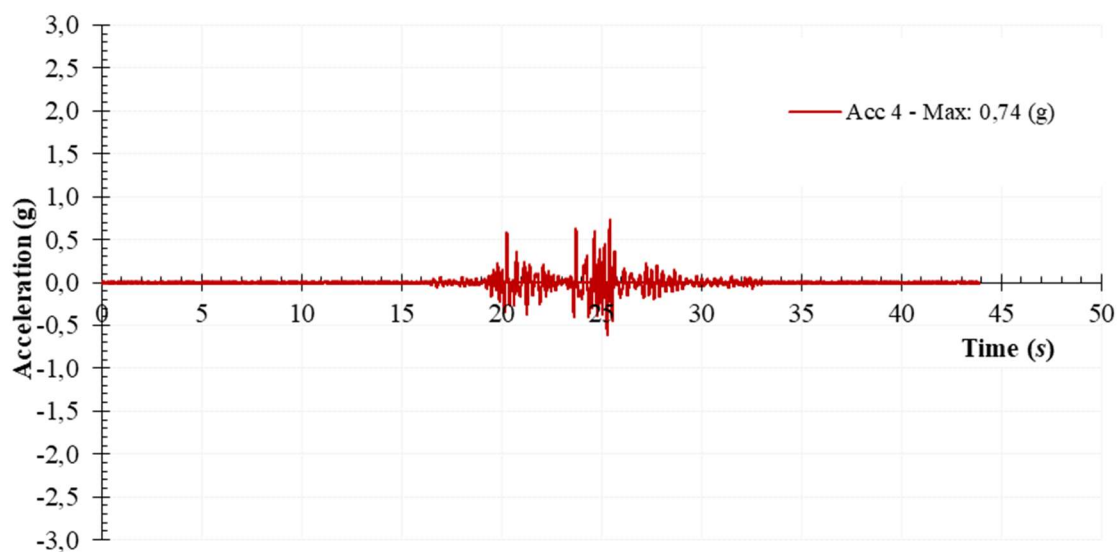
3.6) Earthquake EQ0,5g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for EQ0,5g. The max acceleration at the slab level on the accelerometer acc1 and acc4 is 0,64g and 0,74g respectively. The max acceleration at the foundation level on the accelerometer acc10 is 0,52g.

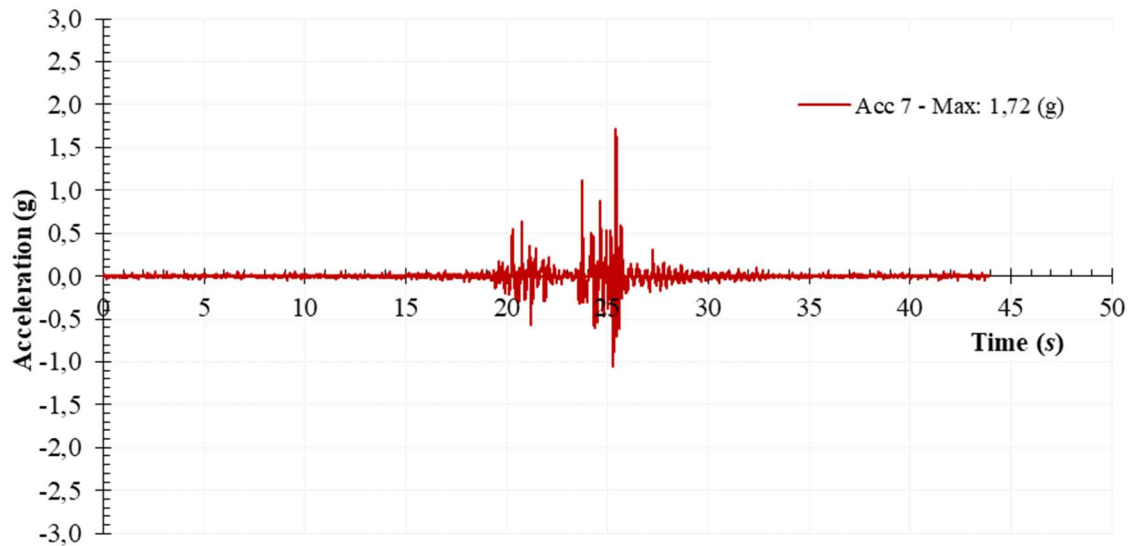


(a)

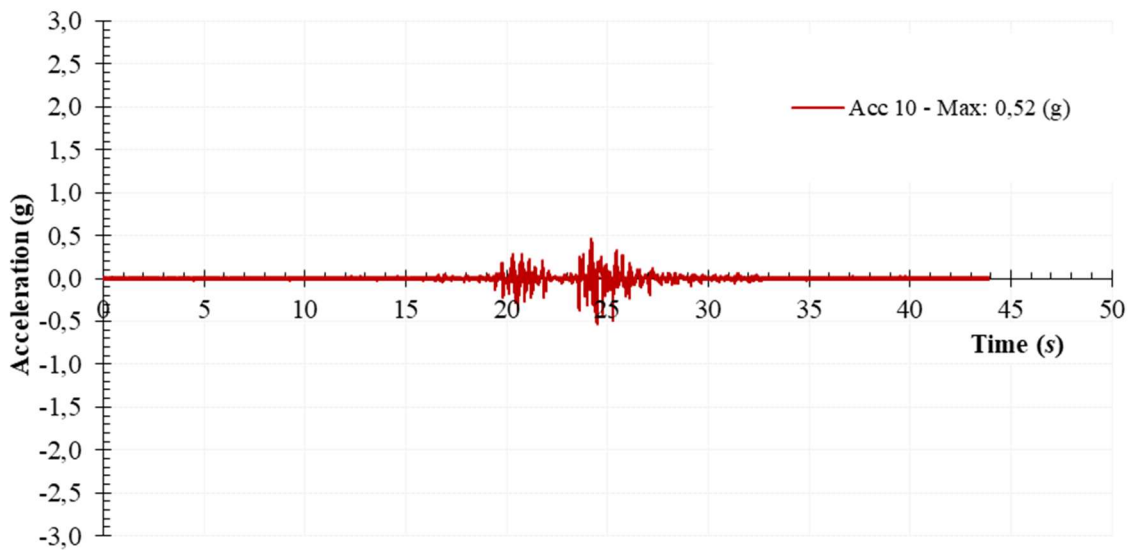


(b)

Figure 3.6.1 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 1 (b) Accelerometer 4

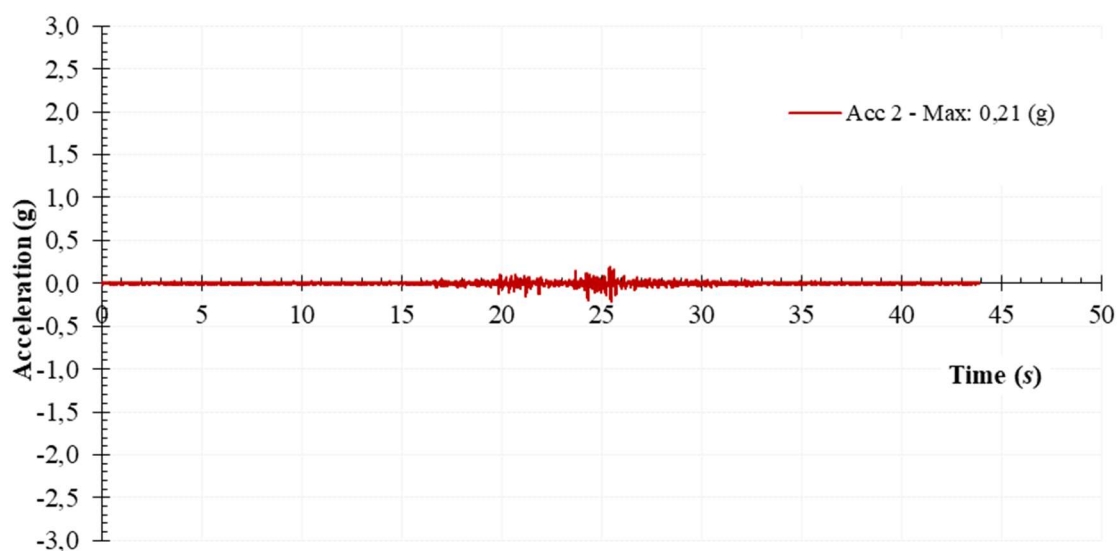


(a)

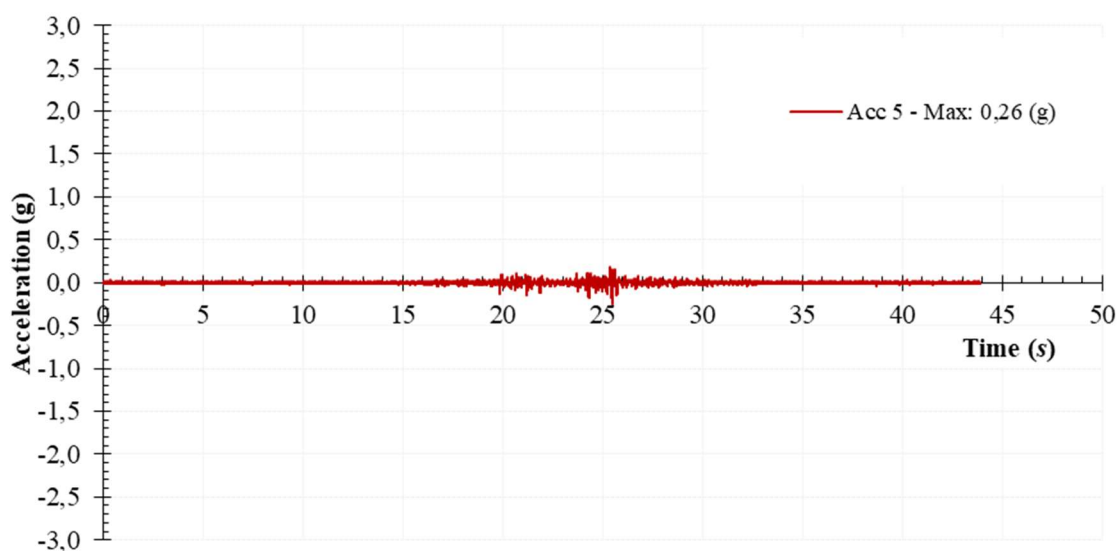


(b)

Figure 3.6.2 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

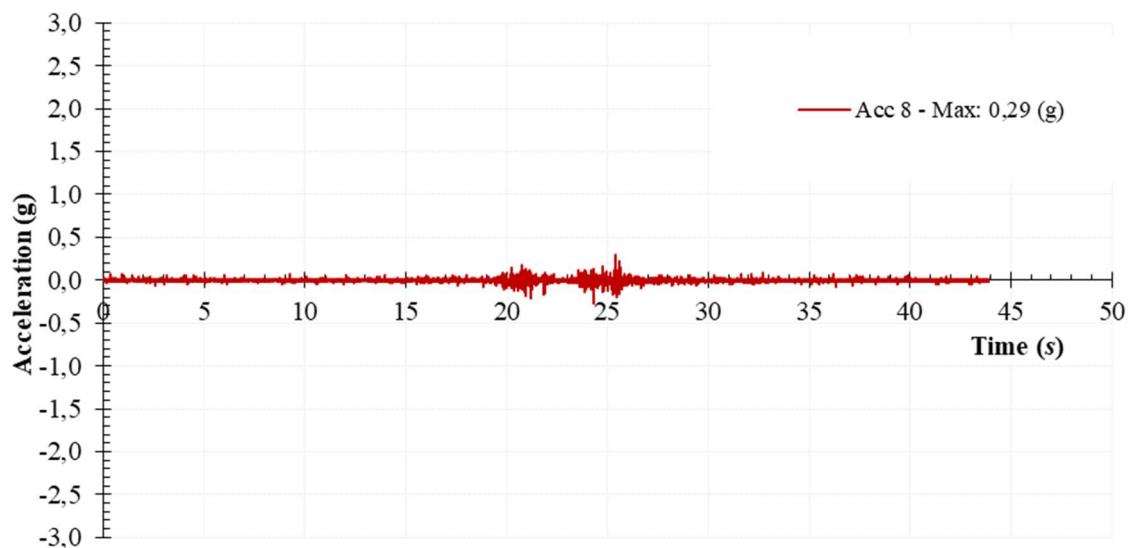


(a)

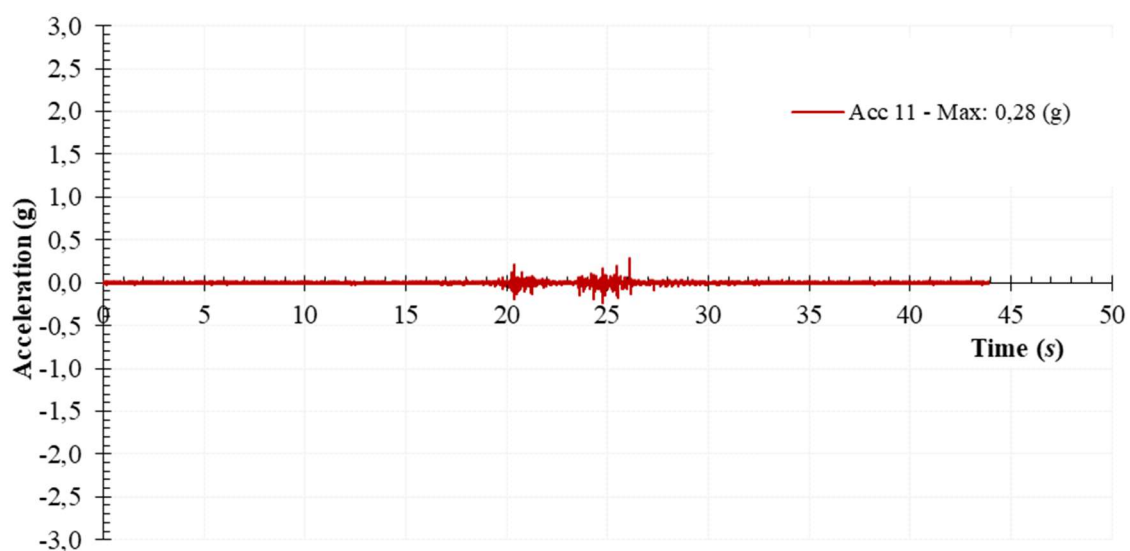


(b)

Figure 3.6.3 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

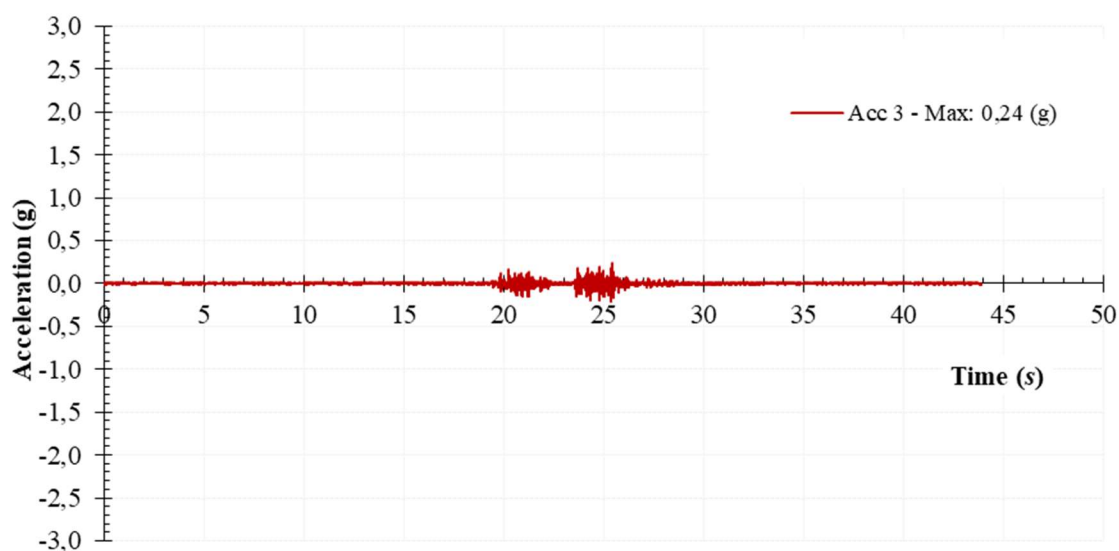


(a)

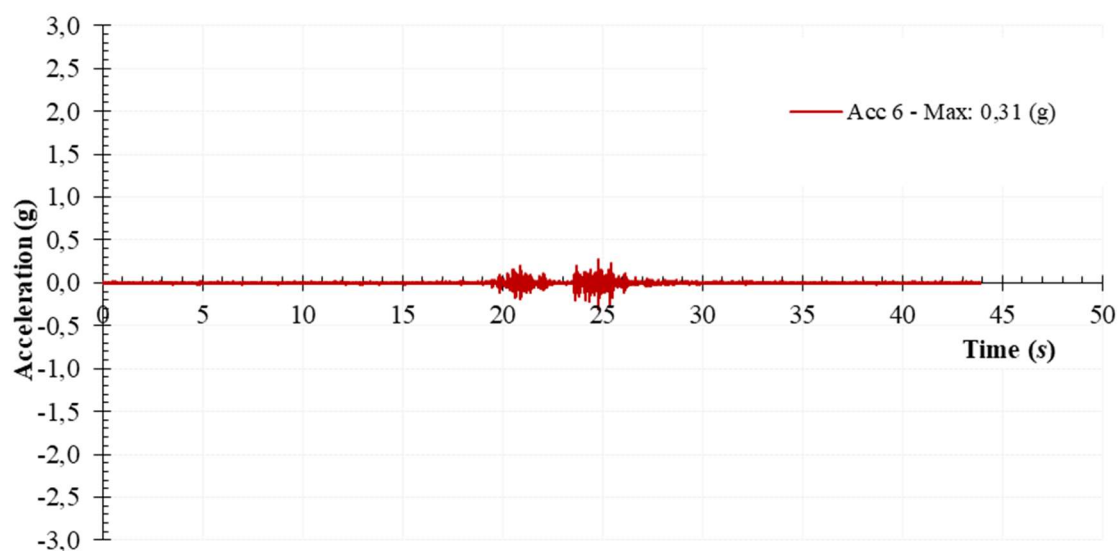


(b)

Figure3.6.4 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 8 (b) Accelerometer 11

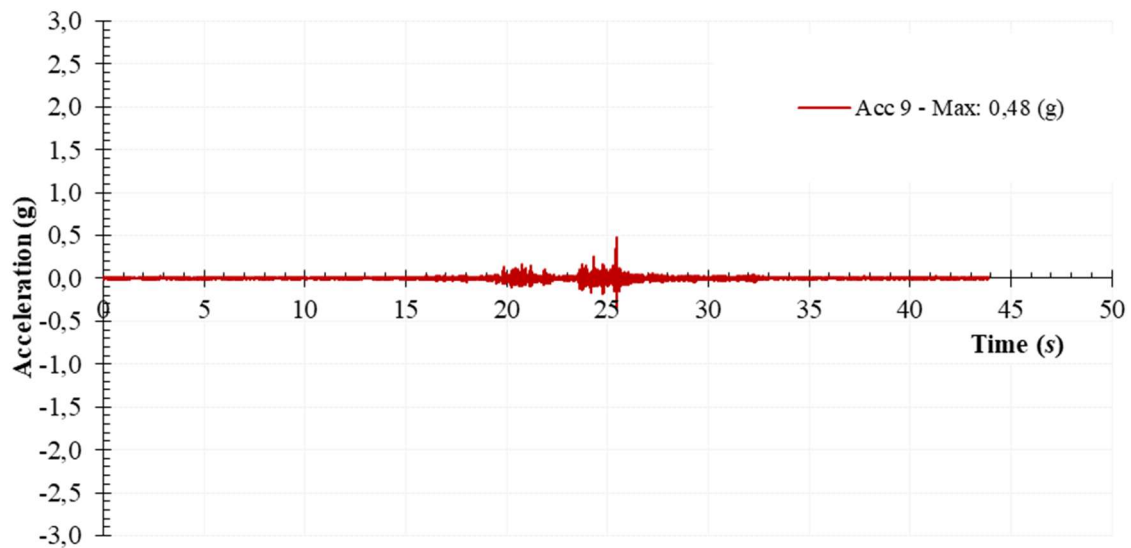


(a)

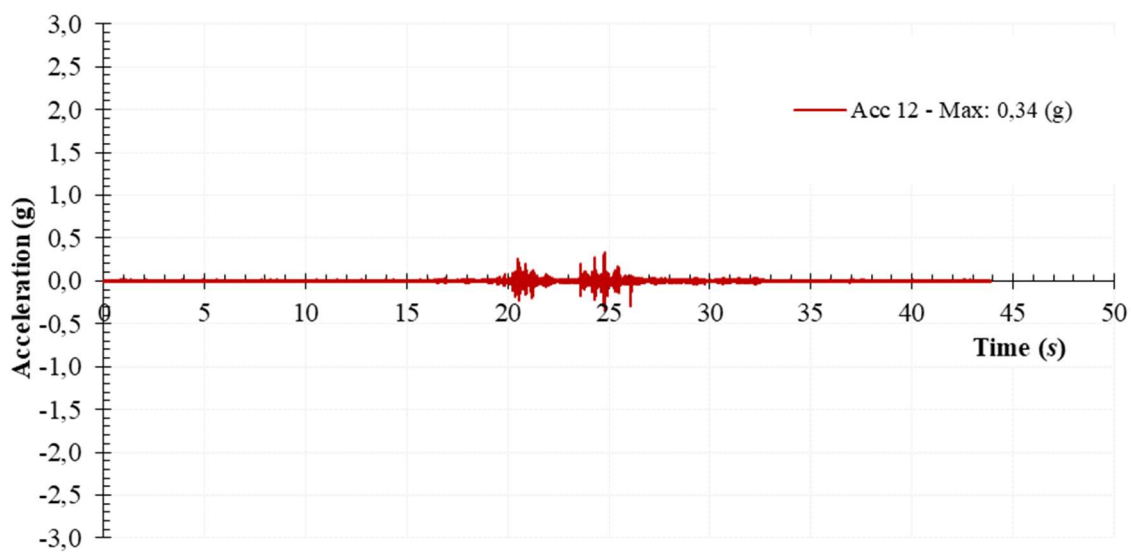


(b)

Figure 3.6.5 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 3 (b) Accelerometer 6

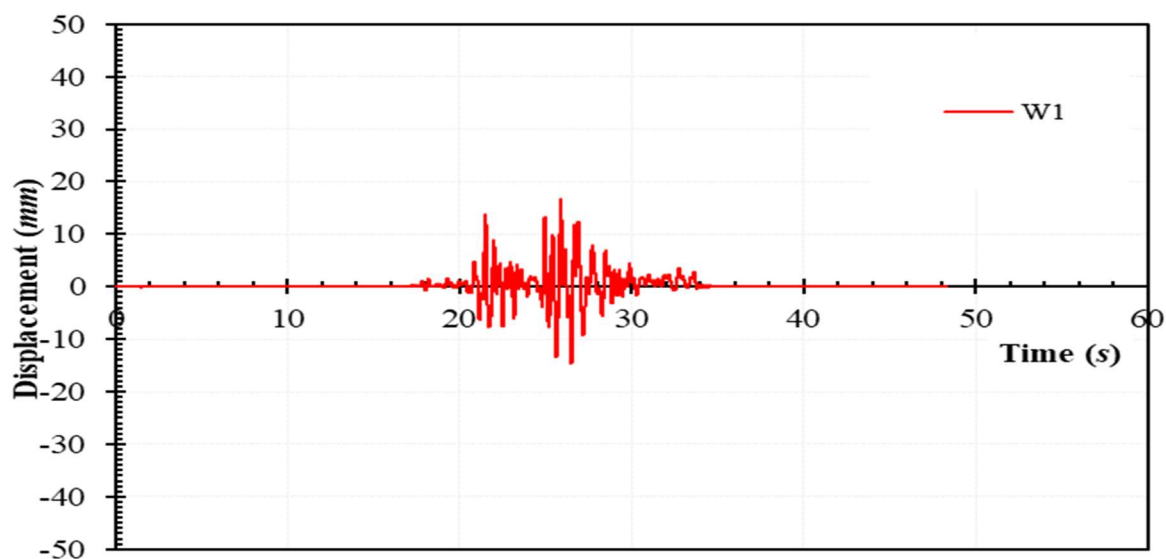


(a)

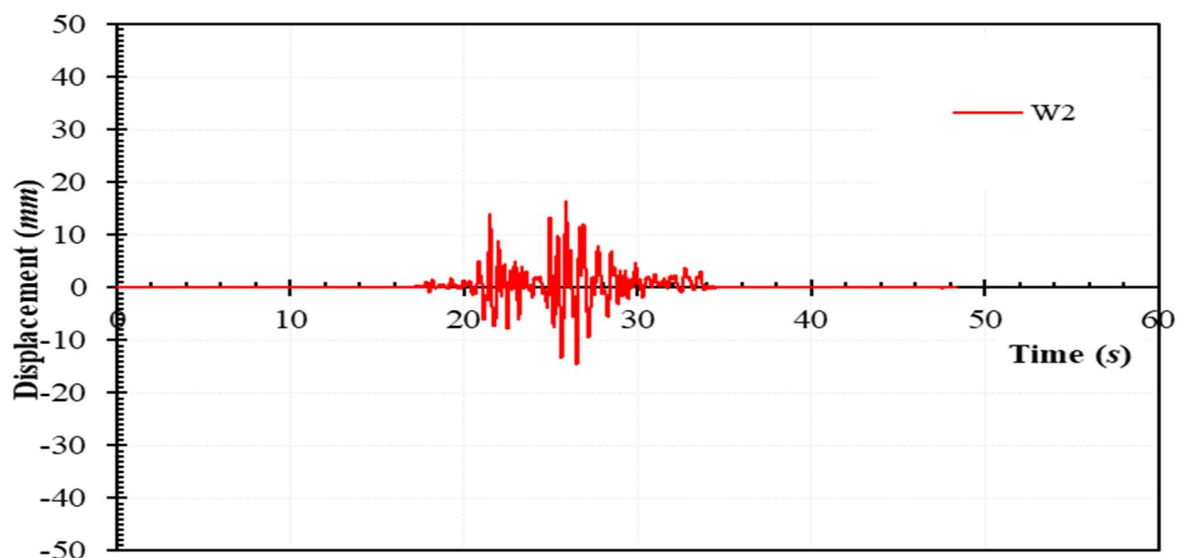


(b)

Figure 3.6.6 Characteristic results for phase A (0,5g earthquake): (a) Accelerometer 9 (b) Accelerometer 12



(a)



(b)

Figure 3.6.7 Characteristic results for phase A (0,5g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2

Figure 3.6.7 shows draw wire sensors W1 and W2. More specifically, draw wire sensor W1 is located on the slab, on the left side and draw wire sensor W2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor W1 is 16,75 mm while the minimum is -14,60 mm. The maximum movement detected by draw wire sensor W2 is 16,33 mm while the minimum is -14,60 mm.

W 1

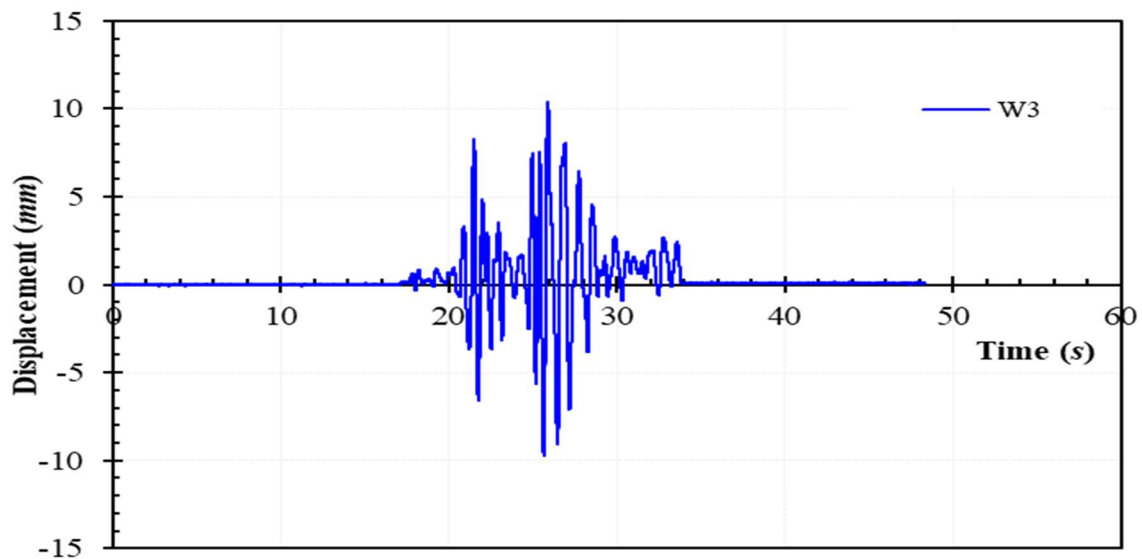
Max: 16,75 mm

Min: -14,60 mm

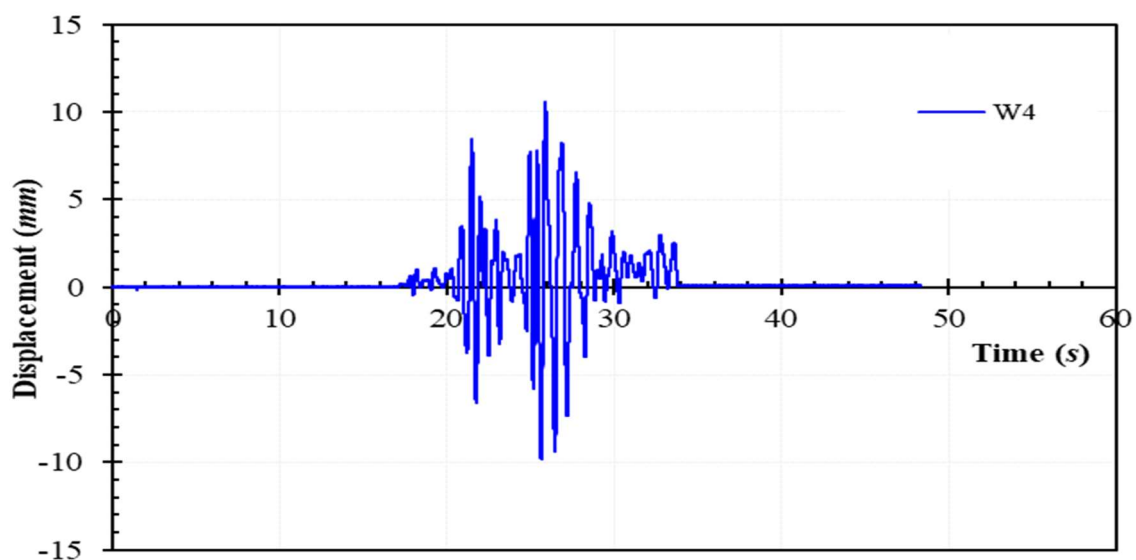
W 2

Max: 16,33 mm

Min: -14,60 mm



(a)



(b)

Figure 3.6.8 Characteristic results for phase A (0,5g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor 4

Figure 3.6.8 shows draw wire sensors W3 and W4. More specifically, draw wire sensor 3 is located on the foundation, on the left side and draw wire sensor W4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor W3 is 10,40 mm while the minimum is -9,76 mm. The maximum movement detected by draw wire sensor W2 is 10,58 mm while the minimum is -9,82 mm.

W 3

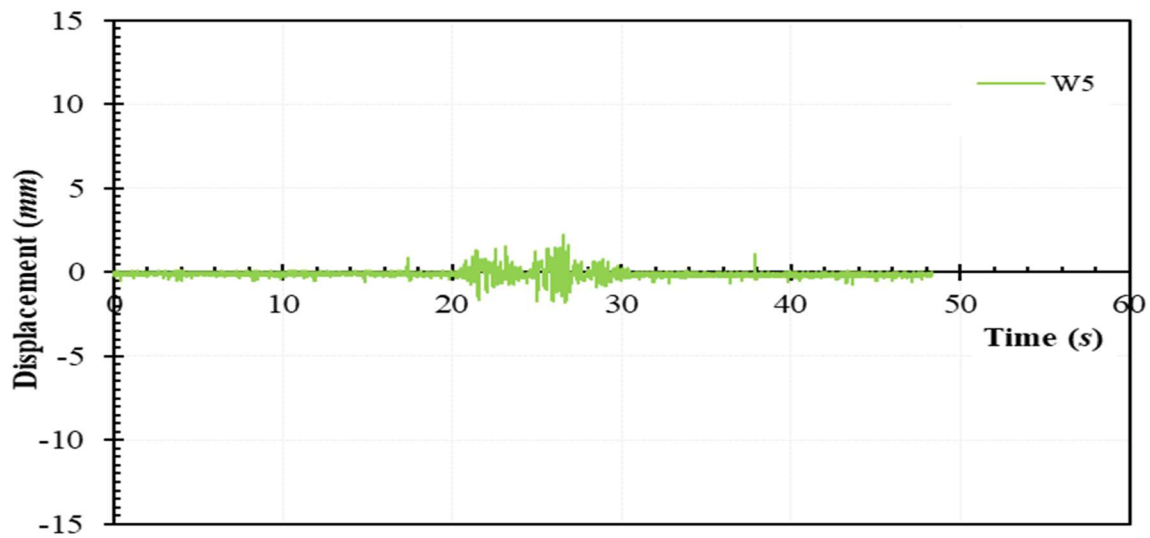
Max: 10,40 mm

Min: -9,76 mm

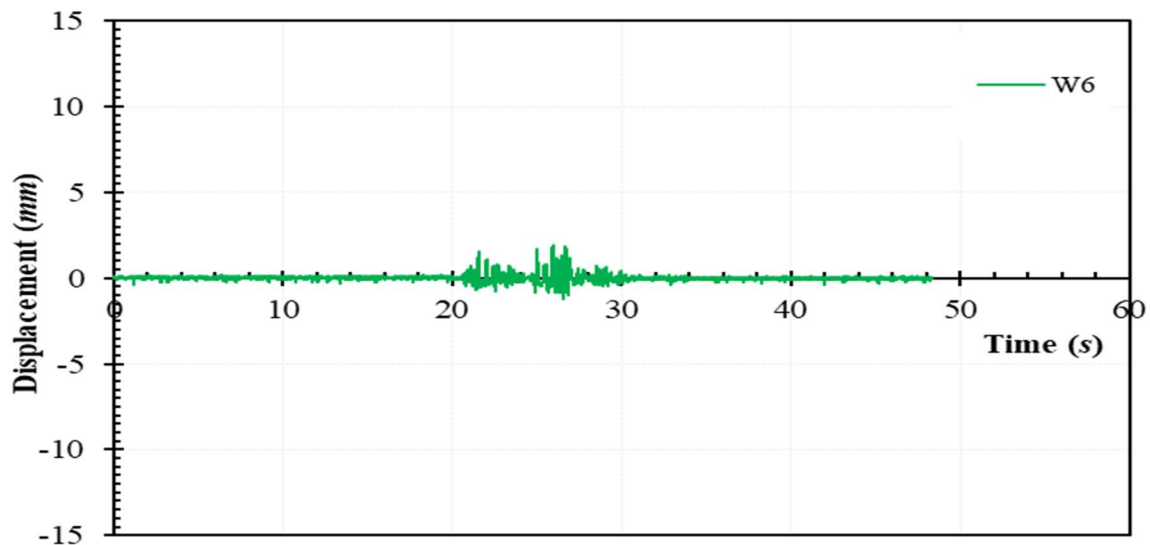
W 4

Max: 10,58 mm

Min: -9,82 mm



(a)



(b)

Figure 3.6.9 Characteristic results for phase A (0,5g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6

Figure 3.6.9 shows draw wire sensors W5 and W6. More specifically, draw wire sensor W5 is located along the partial masonry infill diagonal and draw wire sensor W6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W5 is 2,24 mm while the minimum is -1,78 mm. The maximum movement detected by draw wire sensor W6 is 1,98 mm while the minimum is -1,18 mm.

W 5

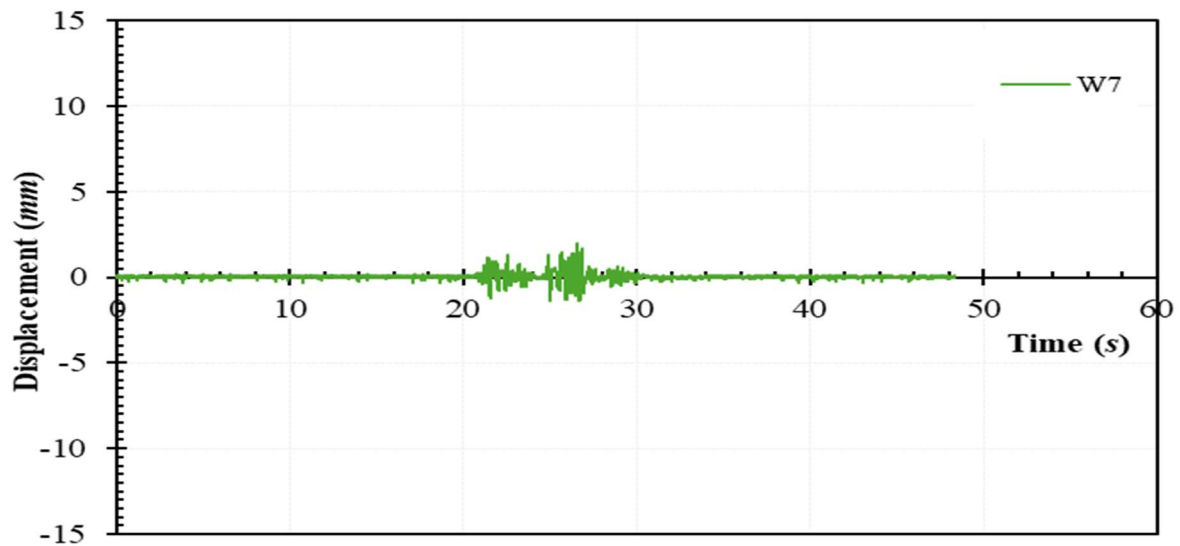
Max: 2,24 mm

Min: -1,78 mm

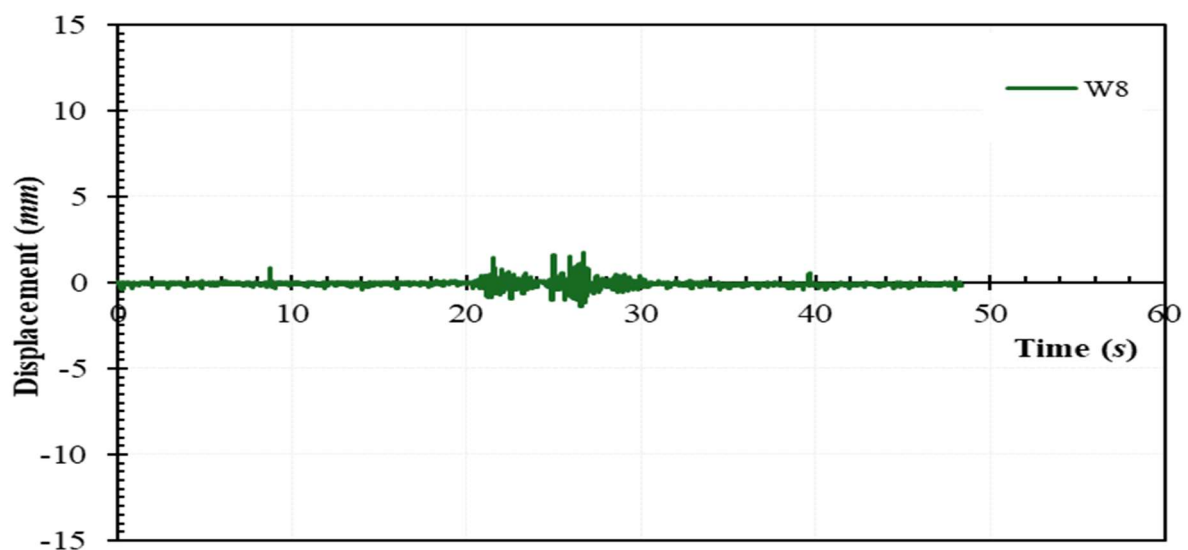
W 6

Max: 1,98 mm

Min: -1,18 mm



(a)



(b)

Figure 3.6.10 Characteristic results for phase A (0,5g earthquake): (a) Draw wire sensor 7 and (b) Draw wire sensor 8

Figure 3.6.10 shows draw wire sensors W7 and W8. More specifically, draw wire sensor W7 is located along the partial masonry infill diagonal and draw wire sensor W8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W7 is 2,01 mm while the minimum is -1,41 mm. The maximum movement detected by draw wire sensor W8 is 1,71 mm while the minimum is -1,39 mm.

W 7

Max: 2,01 mm

Min: -1,41 mm

W 8

Max: 1,71 mm

Min: -1,39 mm

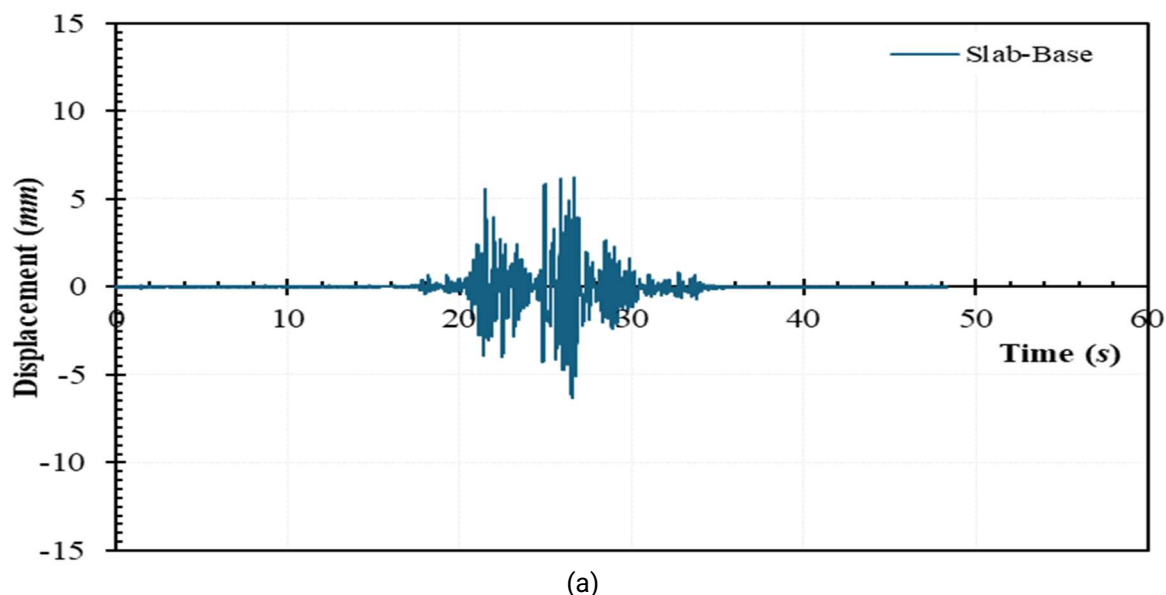


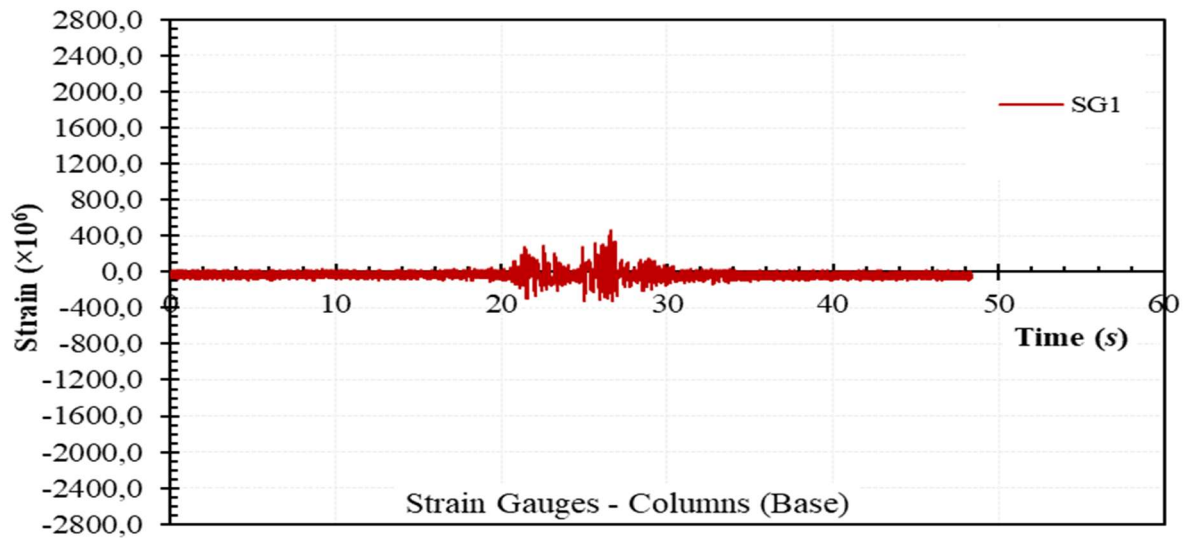
Figure 3.6.11 Characteristic results for phase A (0,5g earthquake): (a) Diagram of displacement Slab – Base

Figure 3.6.11 shows slab – base displacement. More specifically, the maximum drift detected is 5,06 ‰ while the minimum is -5,14 ‰. The residual drift is 0,01 mm.

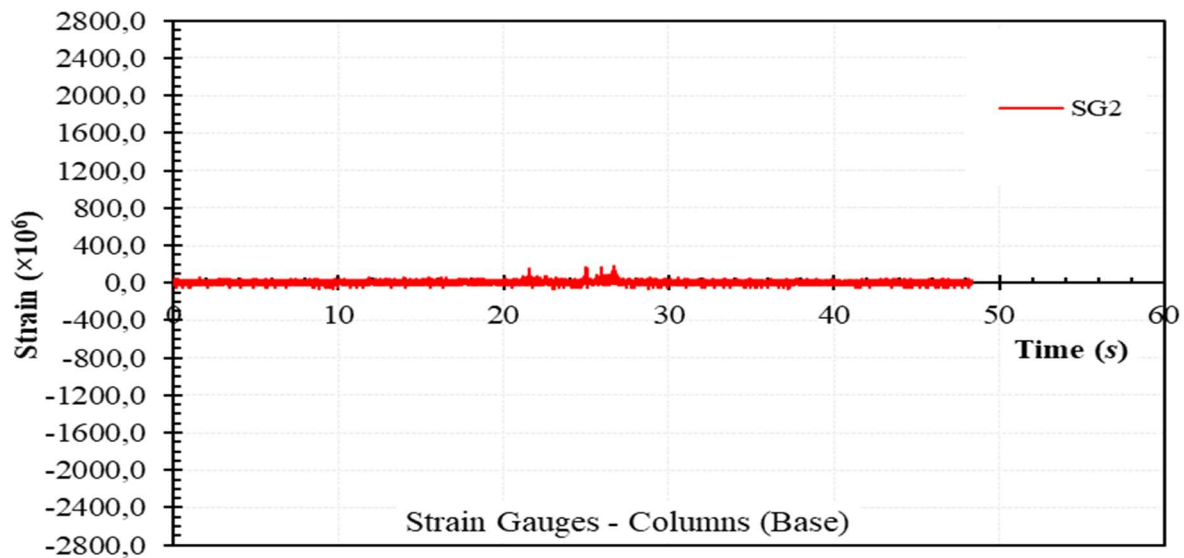
Maximum drift (‰): 5,06 (6,1985 m/1.225 m = 5,06 ‰)

Minimum drift (‰): -5,14

Residual drift: 0,01 mm



(a)



(b)

Figure 3.6.12 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 1 and (b) strain gauge 2

Strain gauges detect strain. The strain gauges shown in the figures 3.6.12, 3.6.13 and 3.6.14 are located in the longitudinal reinforcement, on the underside. More specifically, strain gauge SG1 has maximum strain $457,78\mu\text{strain}$ and minimum strain $-320,44\mu\text{strain}$. The residual strain is $-45,78\mu\text{strain}$. Strain gauge SG2 has maximum deformation $183,11\mu\text{strain}$ and minimum $-61,04\mu\text{strain}$. The residual strain is $-15,26\mu\text{strain}$. Strain gauge SG3 has $152,59\mu\text{strain}$ and $-76,30\mu\text{strain}$ maximum and minimum strain respectively. The residual strain is $0\mu\text{strain}$. Strain gauge SG4 as we can see in figure 3.6.13 has maximum $534,07\mu\text{strain}$ and minimum $-228,89\mu\text{strain}$ deformation. The residual strain is $15,26\mu\text{strain}$. Finally in figure 3.6.14 see strain gauge SG7 and SG8. Strain gauge SG7 has maximum strain $198,37\mu\text{strain}$ and SG8 has maximum strain $610,37\mu\text{strain}$. Strain gauge SG7 has $-45,78\mu\text{strain}$ minimum deformation and SG8 has $-305,19\mu\text{strain}$. The residual strain for strain gauge SG7 and SG8 is $-15,26$.

Sg 1

Max: $457,78\mu\text{strain}$

Min: $-320,44\mu\text{strain}$

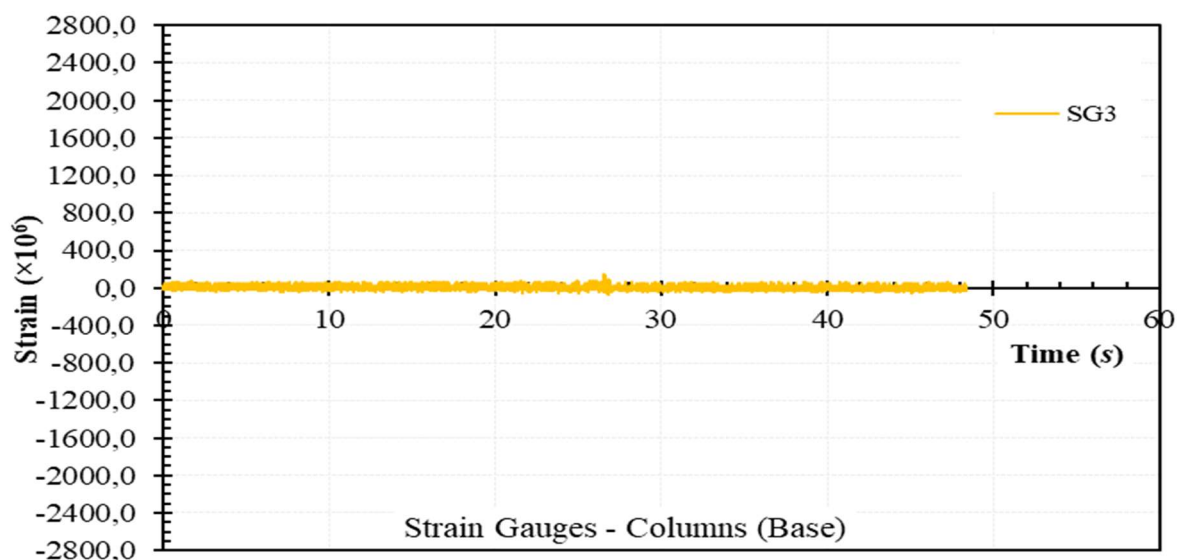
Residual: -45,78 μ strain

Sg 2

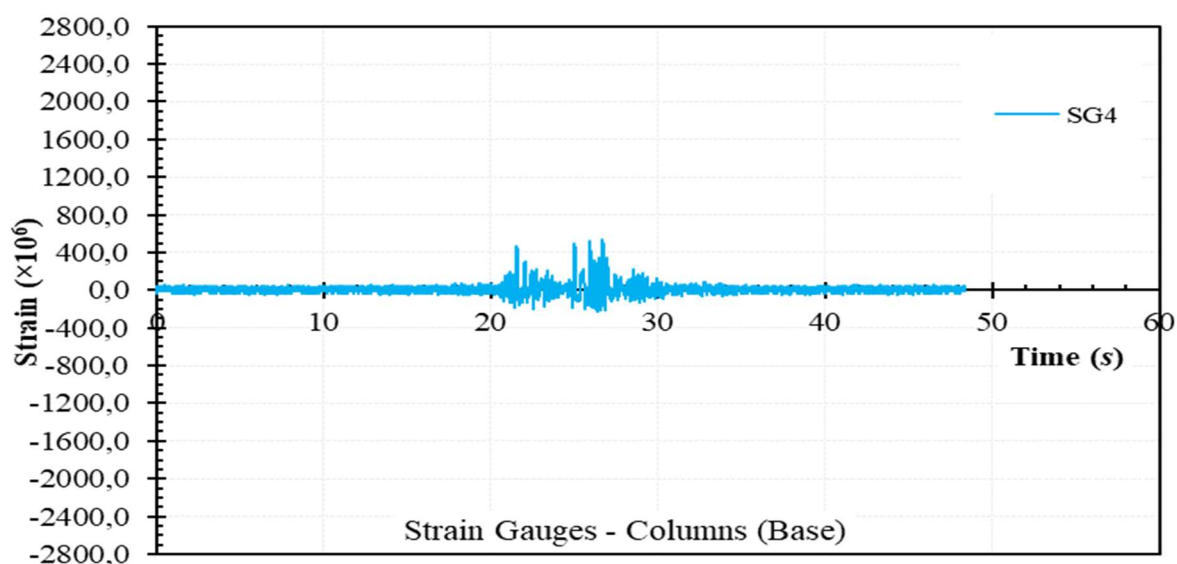
Max: 183,11 μ strain

Min: -61,04 μ strain

Residual: -15,26 μ strain



(a)



(b)

Figure 3.6.13 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 3 and (b) strain gauge 4

Sg 3

Max: 152,59 μ strain

Min: -76,30 μ strain

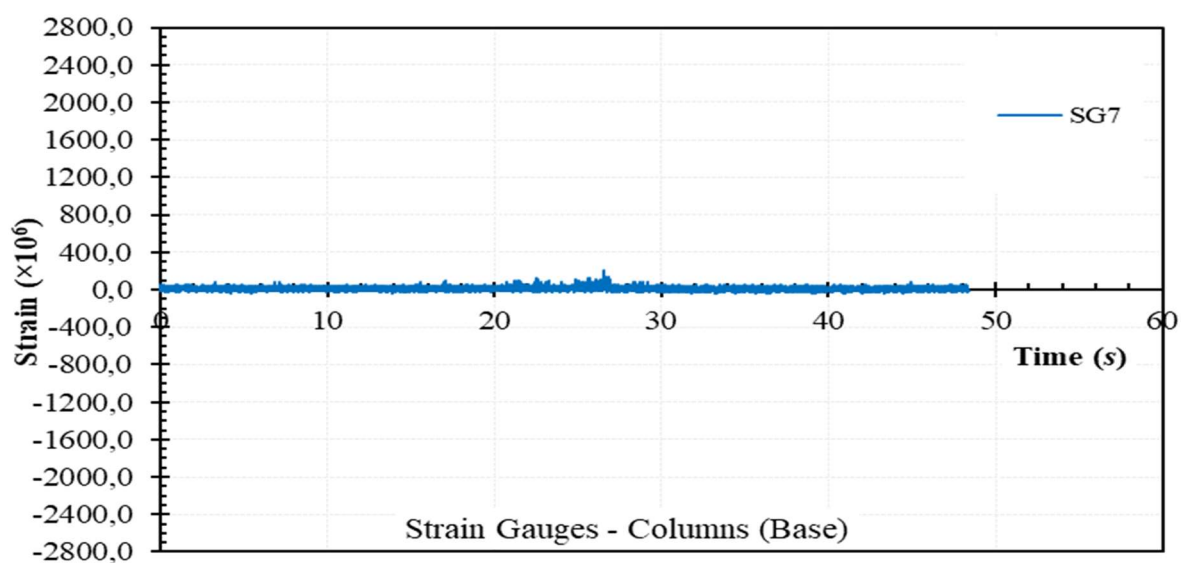
Residual: 0 μ strain

Sg 4

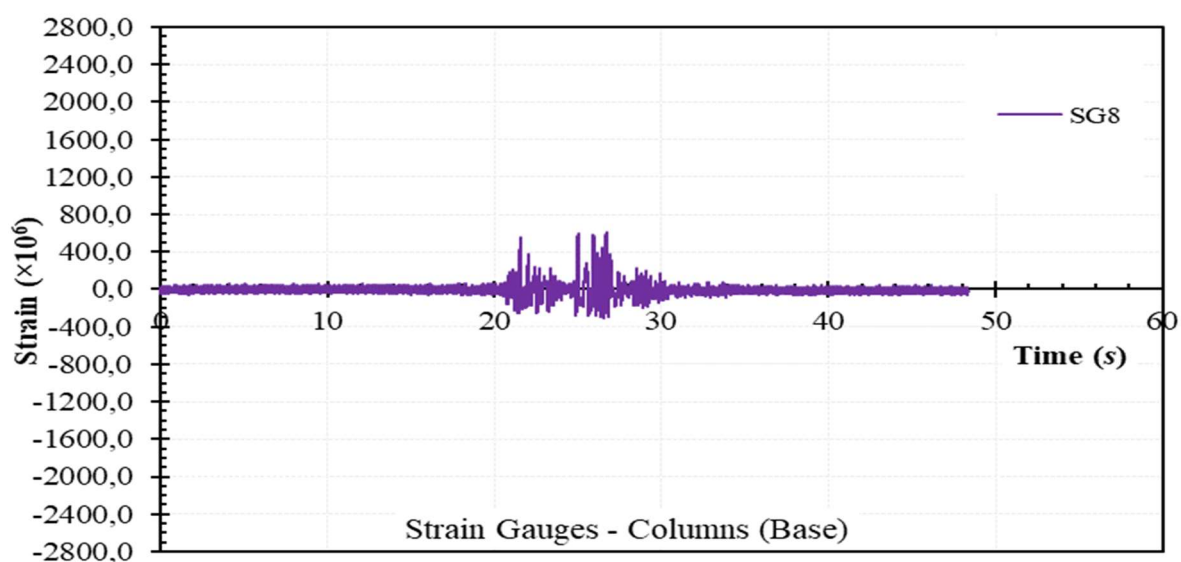
Max: 534,07 μ strain

Min: -228,89 μ strain

Residual: 15,26 μ strain



(a)



(b)

Figure 3.6.14 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 7 and (b) strain gauge 8

Sg 7

Max: 198,37 μ strain

Min: -45,78 μ strain

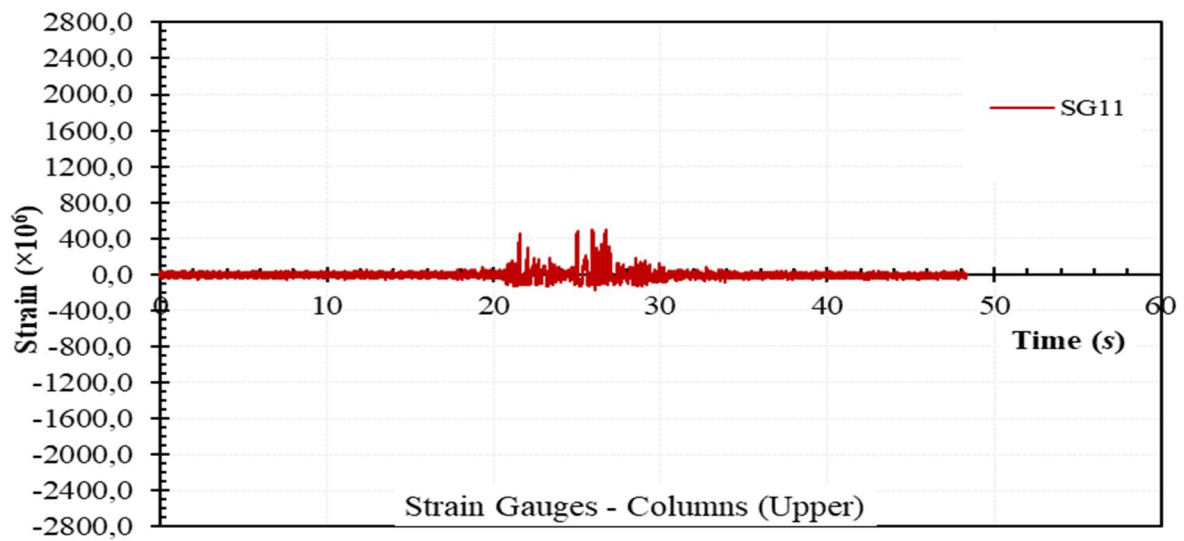
Residual: -15,26 μ strain

Sg 8

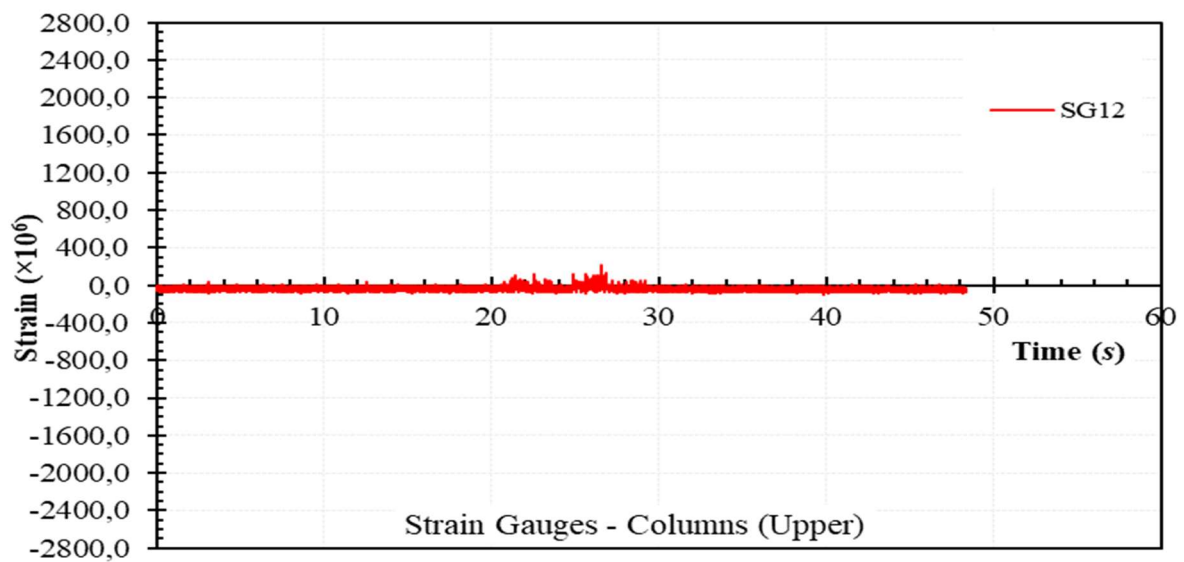
Max: 610,37 μ strain

Min: -305,19 μ strain

Residual: -15,26 μ strain



(a)



(b)

Figure 3.6.15 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 11 and (b) strain gauge 12

Sg 11

Max: 503,56 μ strain

Min: -167,85 μ strain

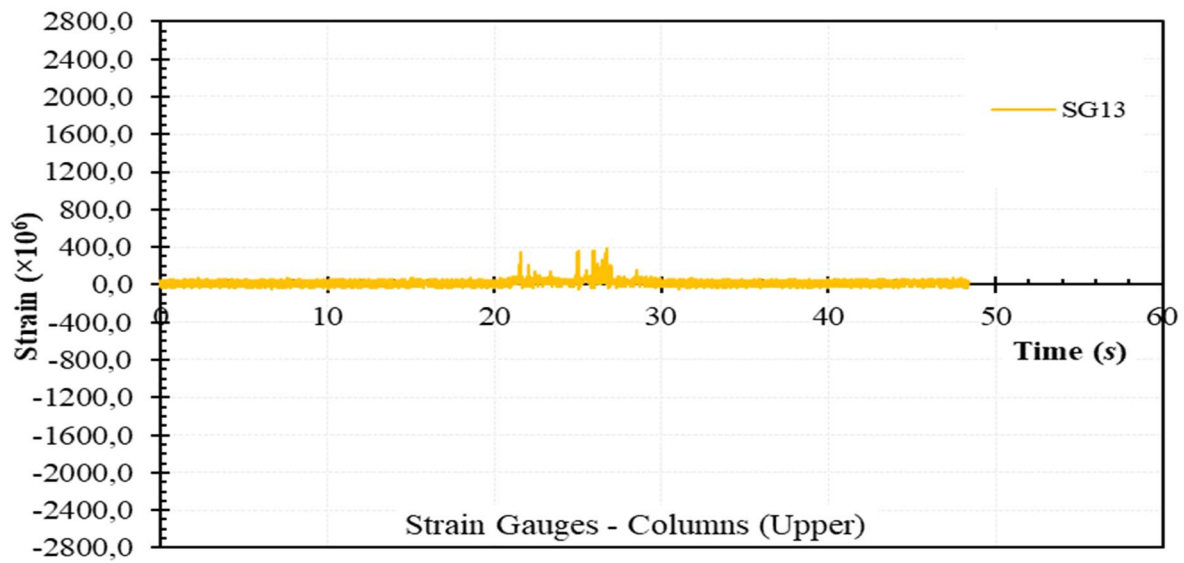
Residual: 0 μ strain

Sg 12

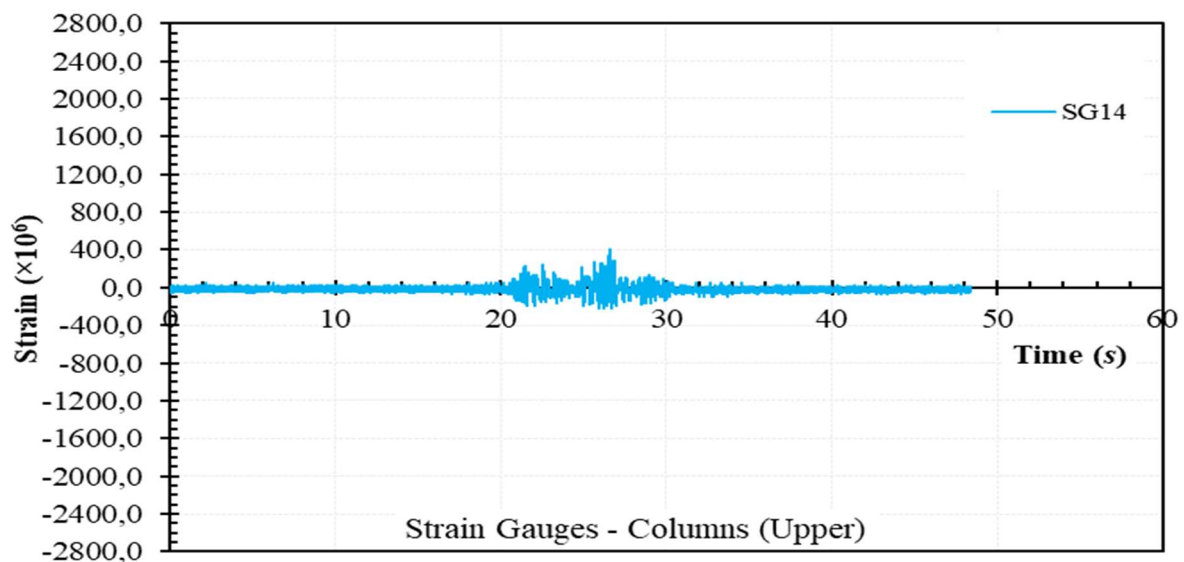
Max: 213,63 μ strain

Min: -106,81 μ strain

Residual: -61,04 μ strain



(a)



(b)

Figure 3.6.16 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 13 and (b) strain gauge 14

Sg 13

Max: 381,48 μ strain

Min: -45,78 μ strain

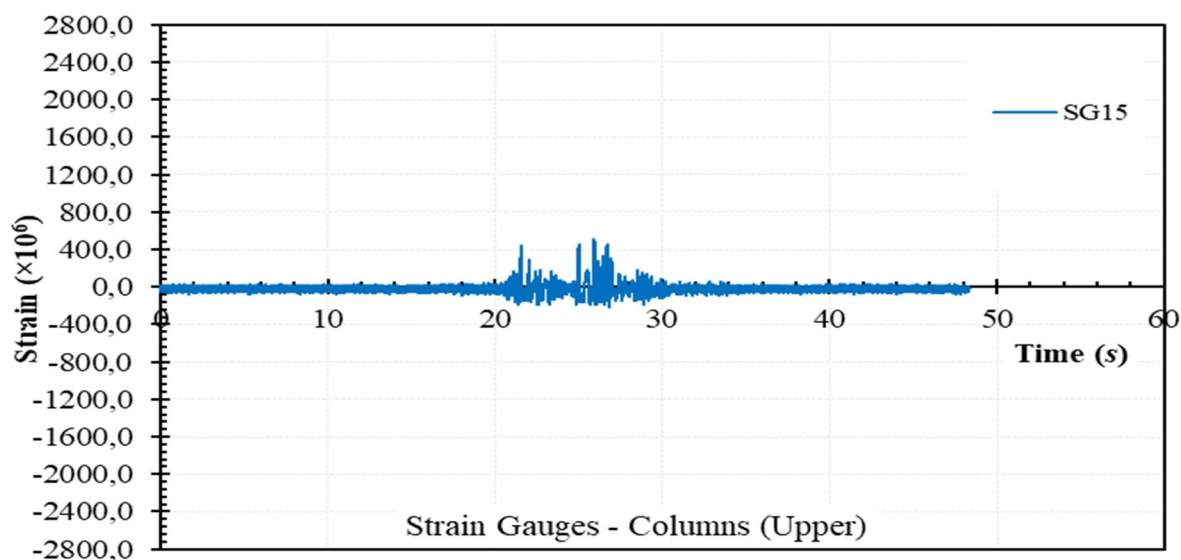
Residual: 30,52 μ strain

Sg 14

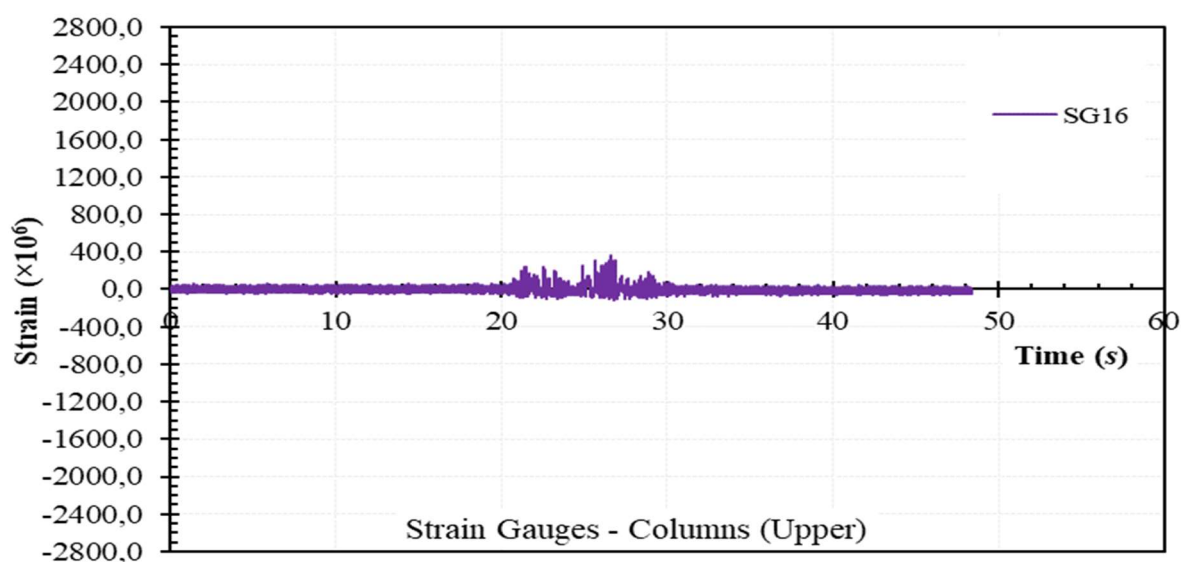
Max: 412,00 μ strain

Min: -213,63 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.6.17 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 15 and (b) strain gauge 16

Sg 15

Max: 30,52 μ strain

Min: -213,63 μ strain

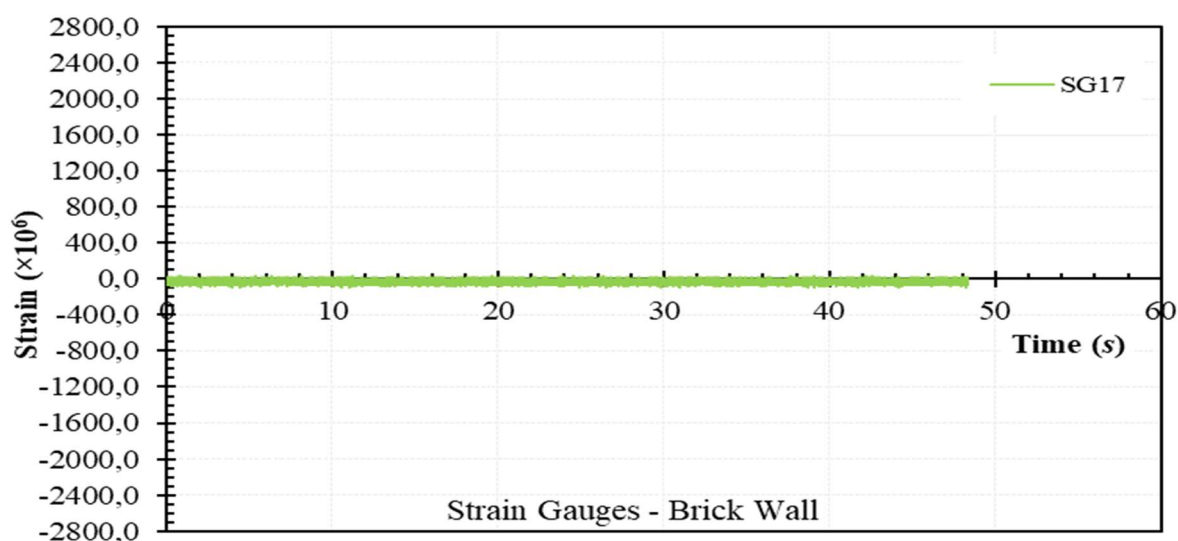
Residual: -15,26 μ strain

Sg 16

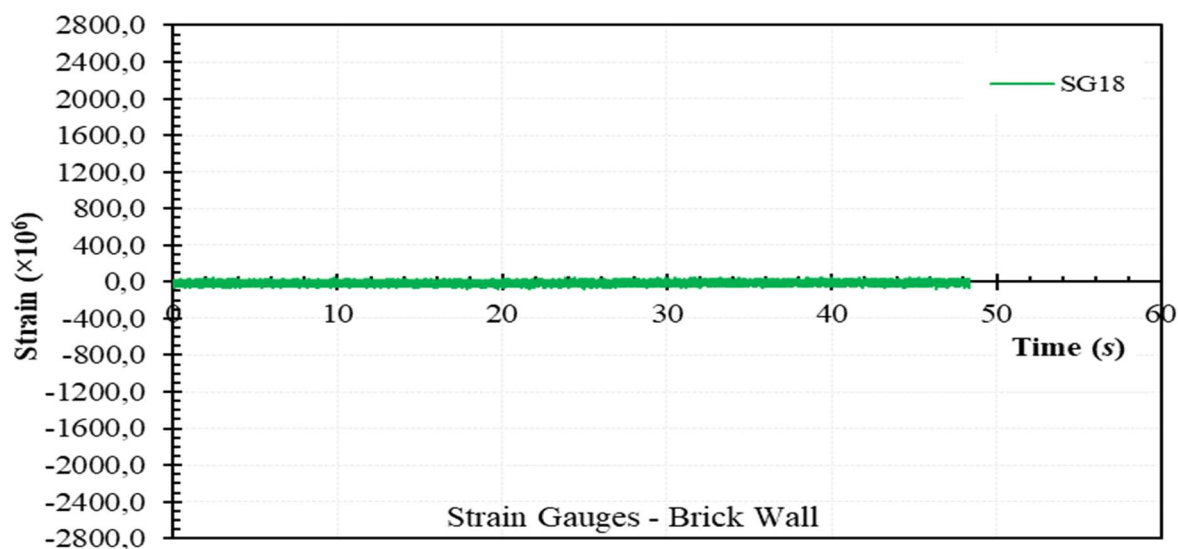
Max: 366,22 μ strain

Min: -122,07 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.6.18 Characteristic results for phase A (0,5g earthquake) (a) strain gauge 17 and (b) strain gauge 18

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauges SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge SG17 has 30,52 μ strain maximum strain. Strain gauge SG17 has minimum deformation -91,56 μ strain and strain gauge 18 -76,30 μ strain. Strain gauge SG18 has maximum strain 45,78 μ strain. Finally strain gauge SG17 presents 0 μ strain residual. Strain gauge SG18 presents -30,52 μ strain residual.

Sg 17

Max: 30,52 μ strain

Min: -91,56 μ strain

Residual: 0 μ strain

Sg 18

Max: 45,78 μ strain

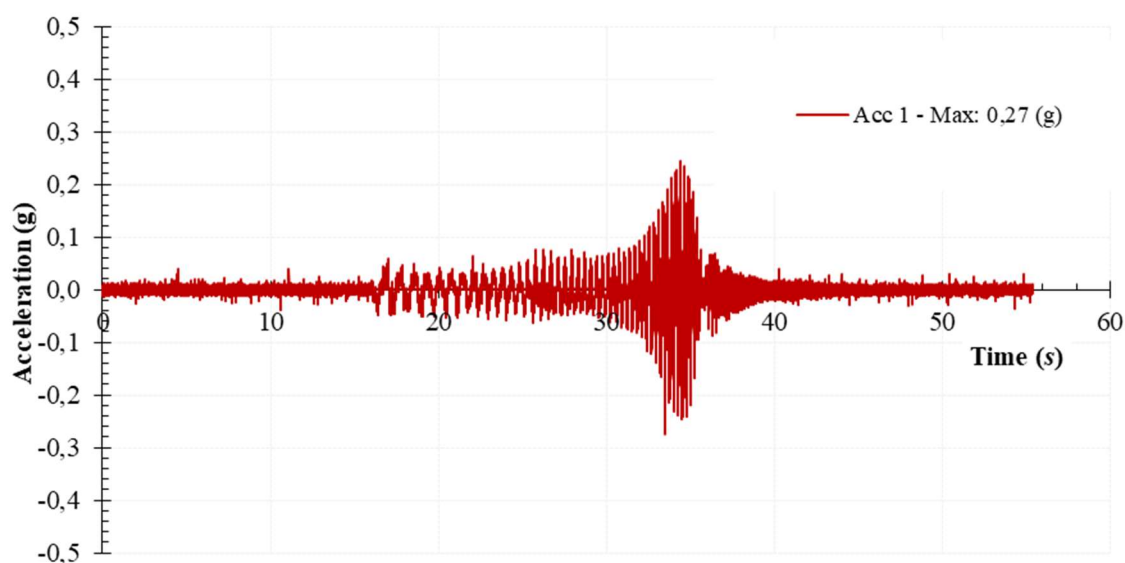
Min: -76,30 μ strain

Residual: -30,52 μ strain

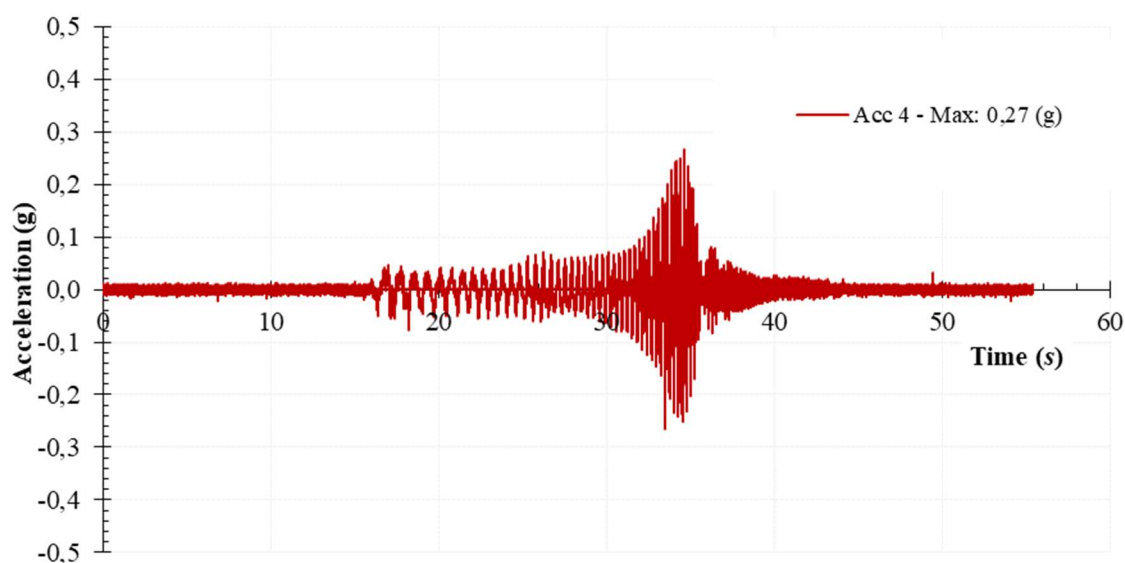
3.7) White noise test before EQ0,8g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for white noise before EQ0,8g. The max acceleration at the slab level on the accelerometer acc 1 and acc4 is 0,27g for both. The max acceleration at the foundation level on the accelerometer acc10 is 0,08g.

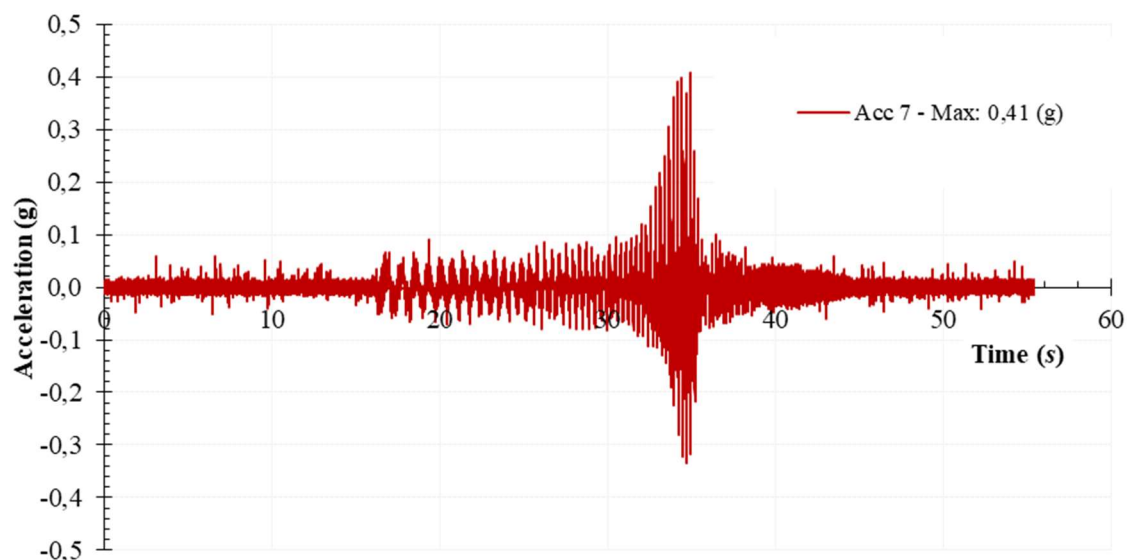


(a)

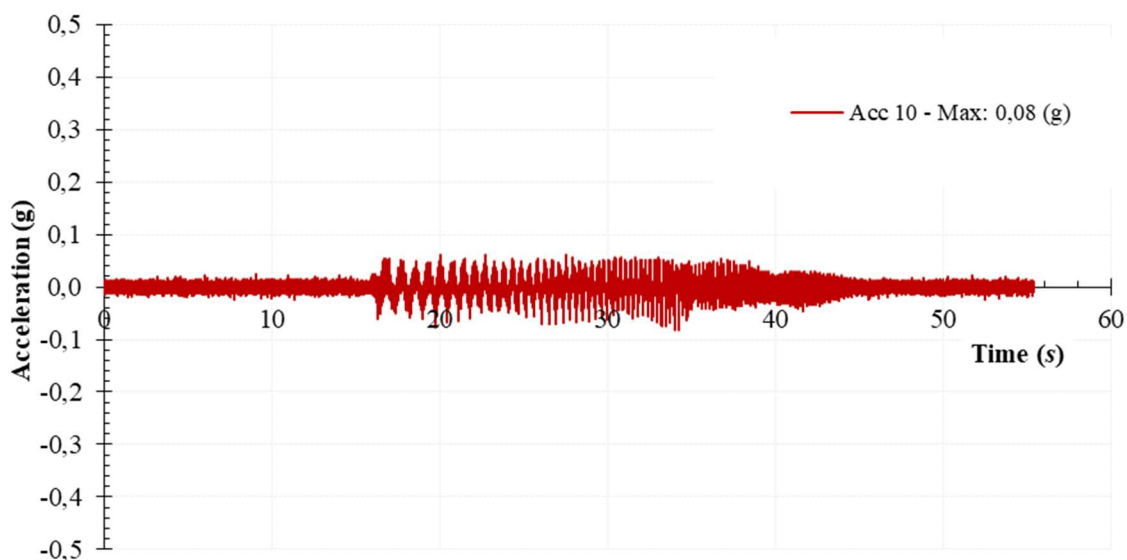


(b)

Figure 3.7.1 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 1 (b) Accelerometer 4

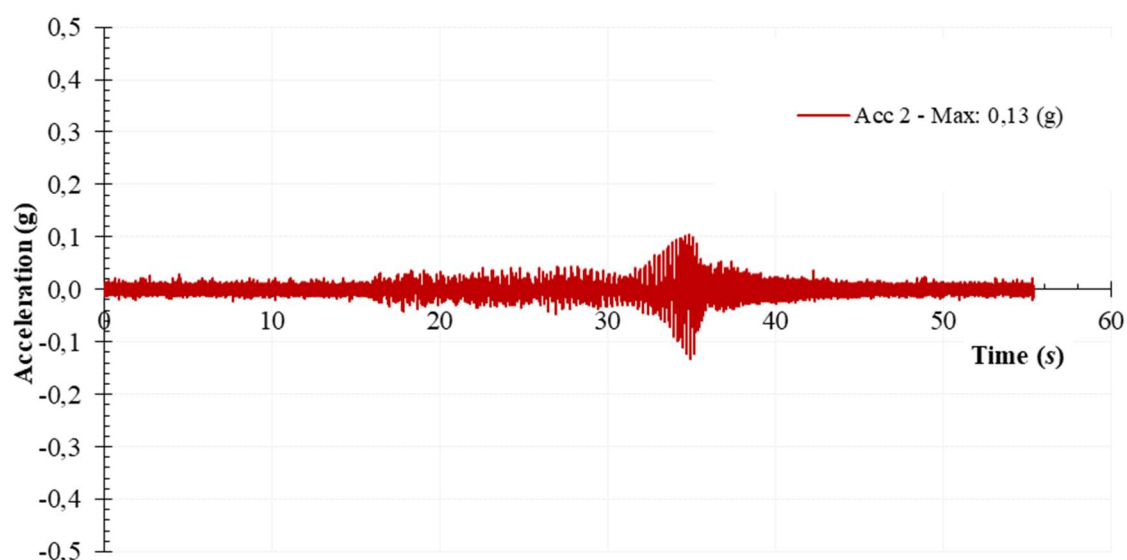


(a)

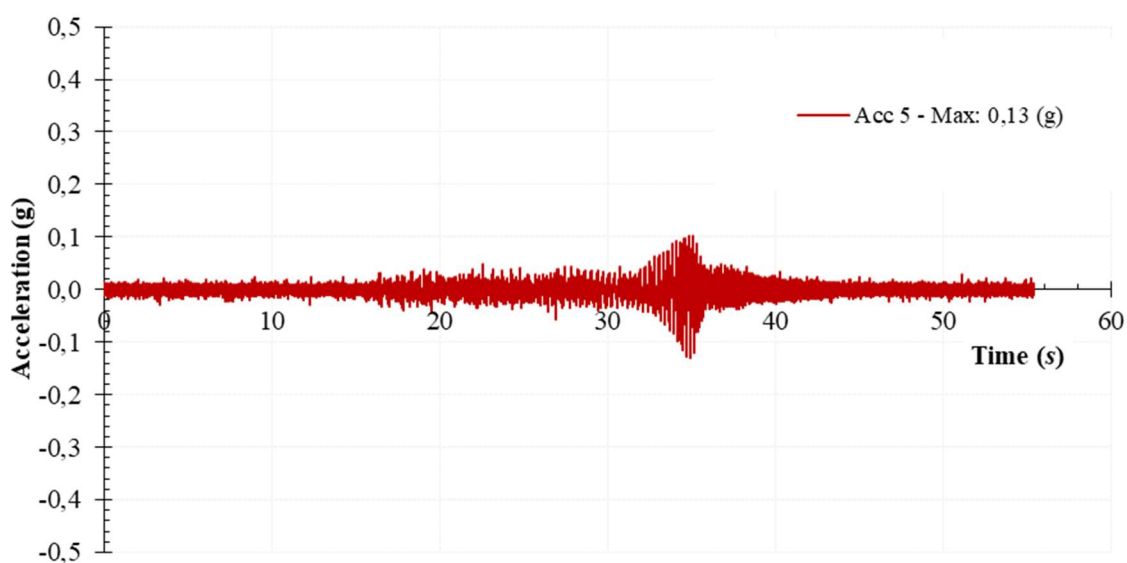


(b)

Figure 3.7.2 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

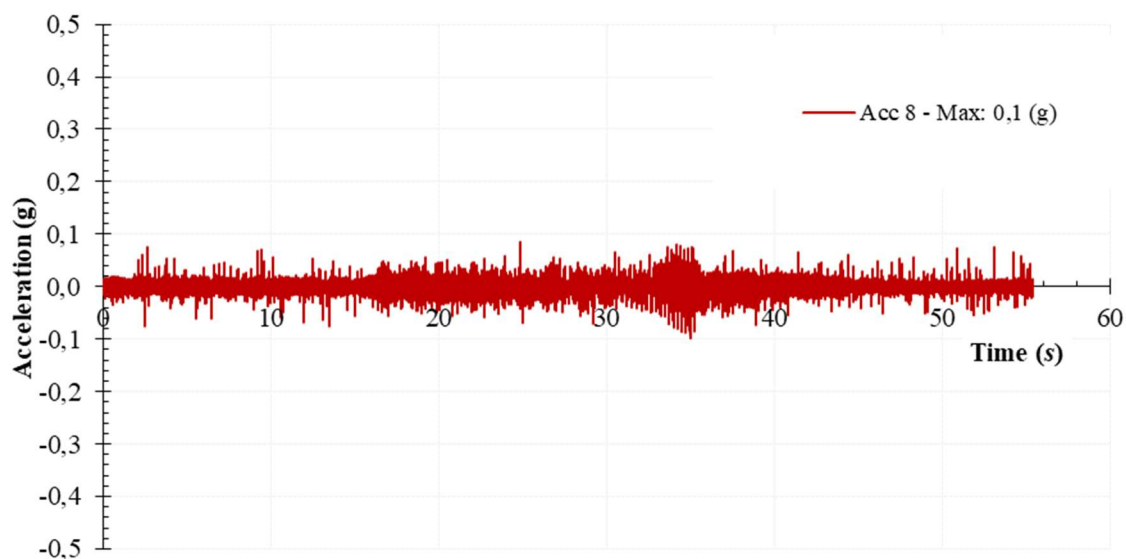


(a)

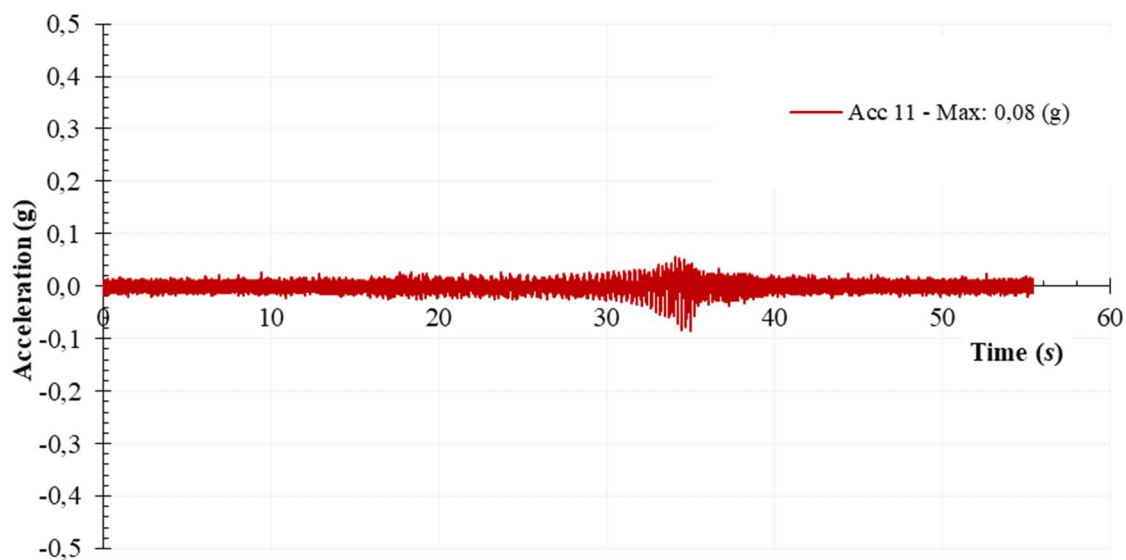


(b)

Figure 3.7.3 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

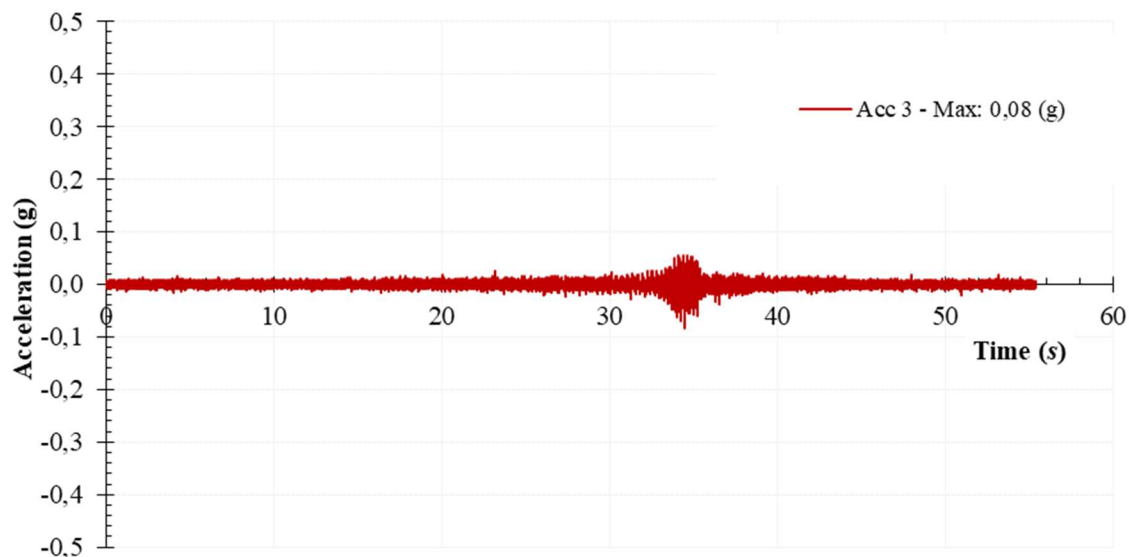


(a)

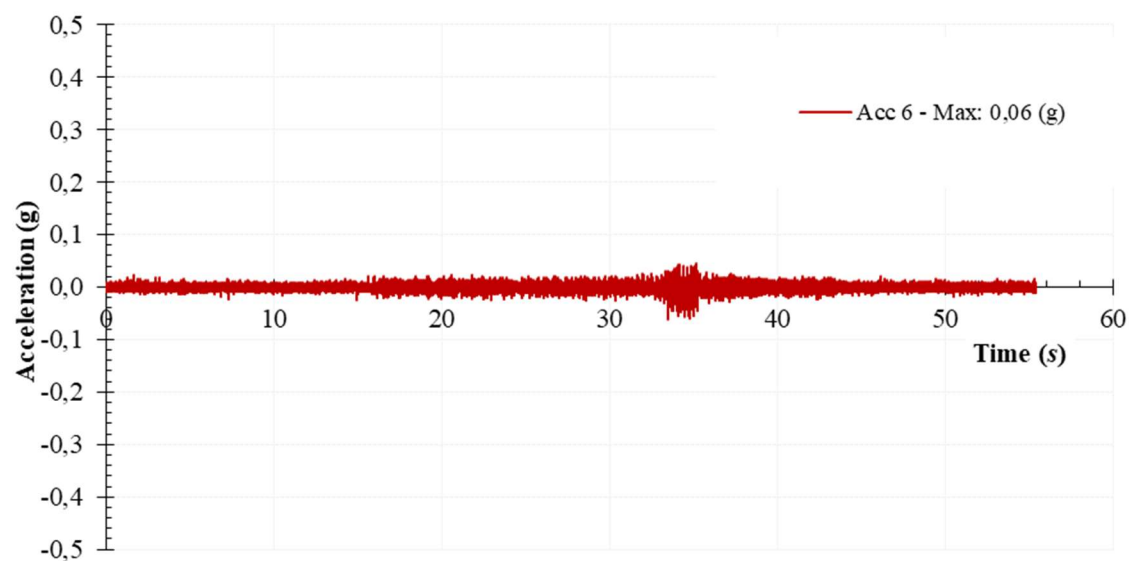


(b)

Figure 3.7.4 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 8 (b) Accelerometer 11

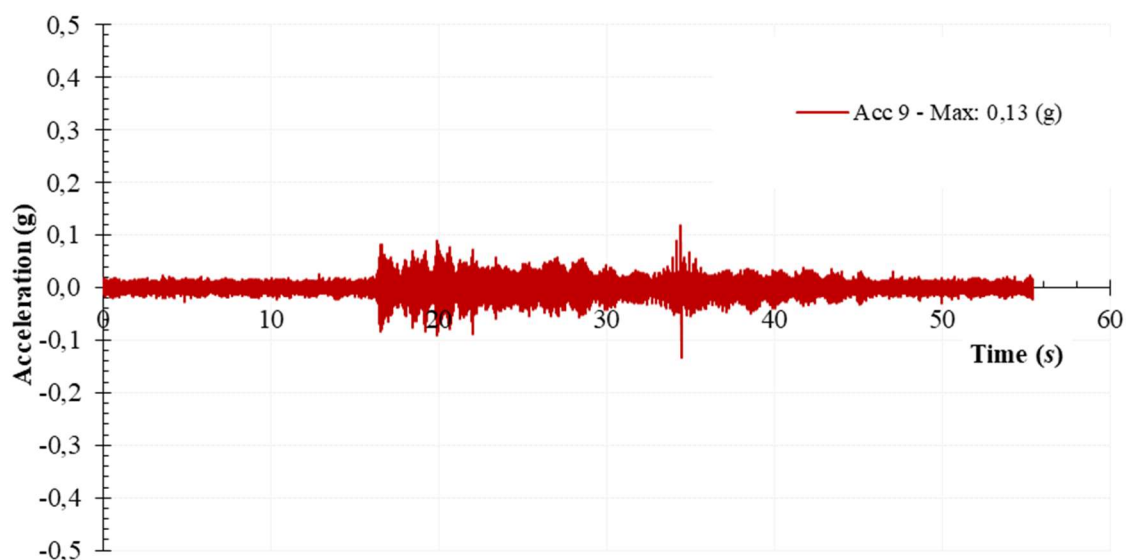


(a)

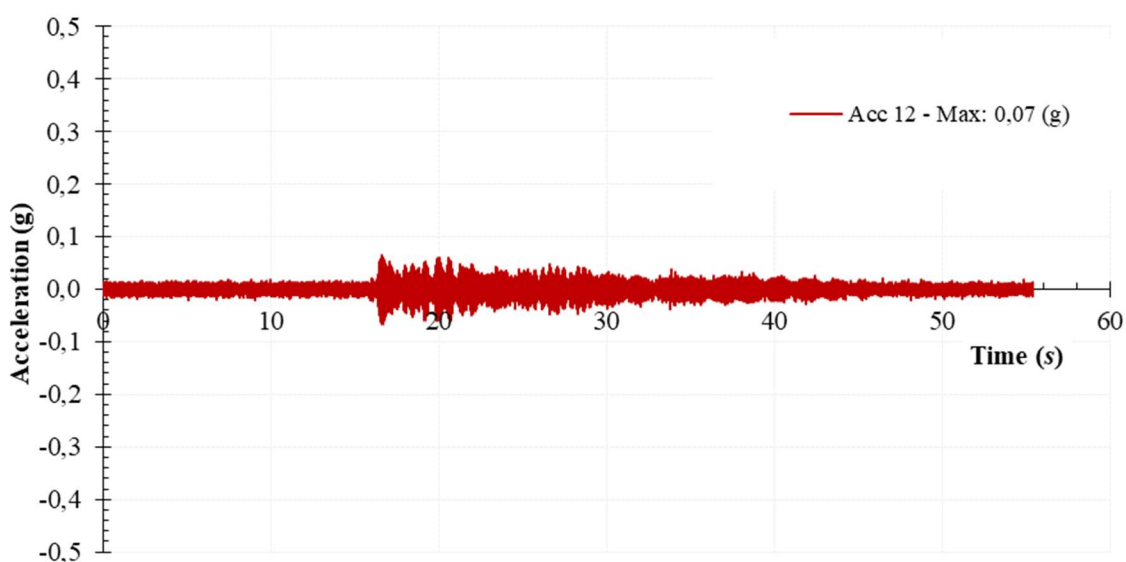


(b)

Figure 3.7.5 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 3 (b) Accelerometer 6

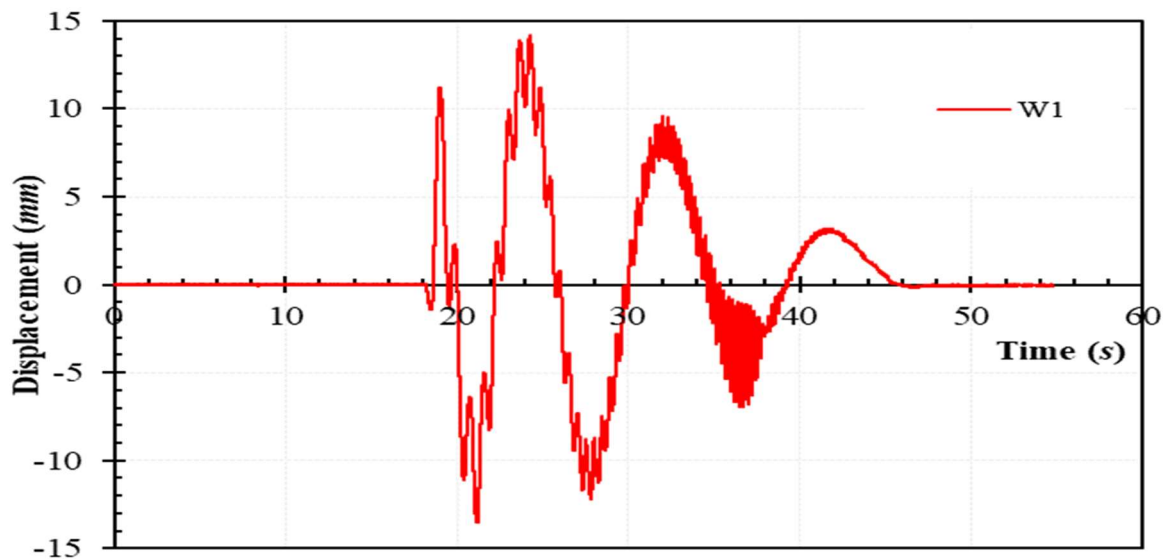


(a)

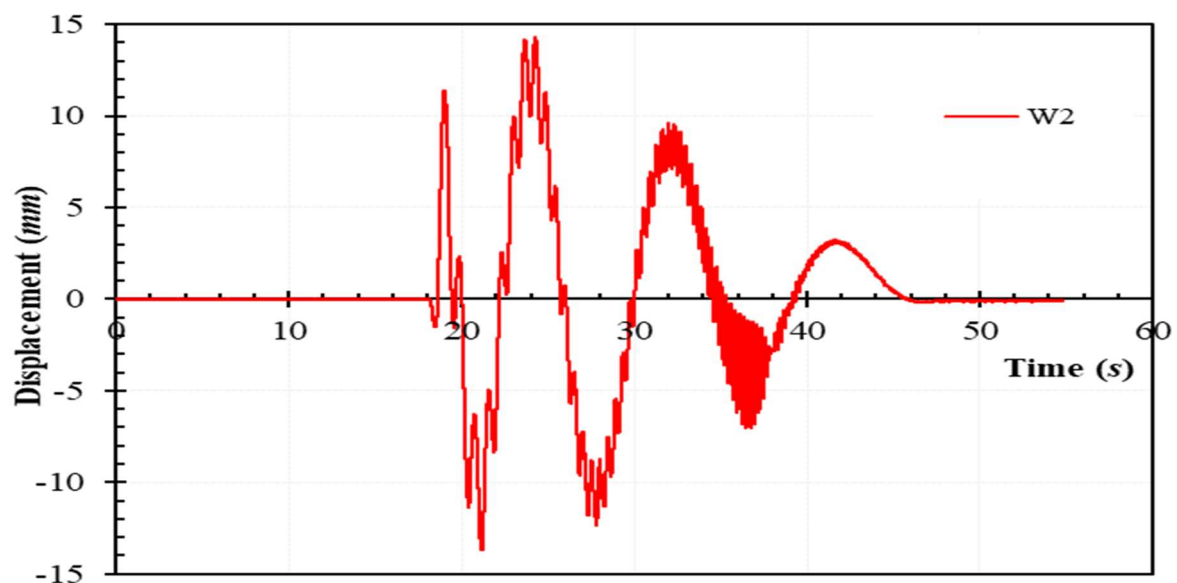


(b)

Figure 3.7.6 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Accelerometer 9 (b) Accelerometer 12



(a)



(b)

Figure 3.7.7 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Draw wire sensor 1 and (b) Draw wire sensor 2

Figure 3.7.7 shows draw wire sensors W1 and W2. More specifically, draw wire sensor W1 is located on the slab, on the left side and draw wire sensor W2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor W1 is 14,22 mm while the minimum is -13,54 mm. The maximum movement detected by draw wire sensor W2 is 14,30 mm while the minimum is -13,72 mm.

W 1

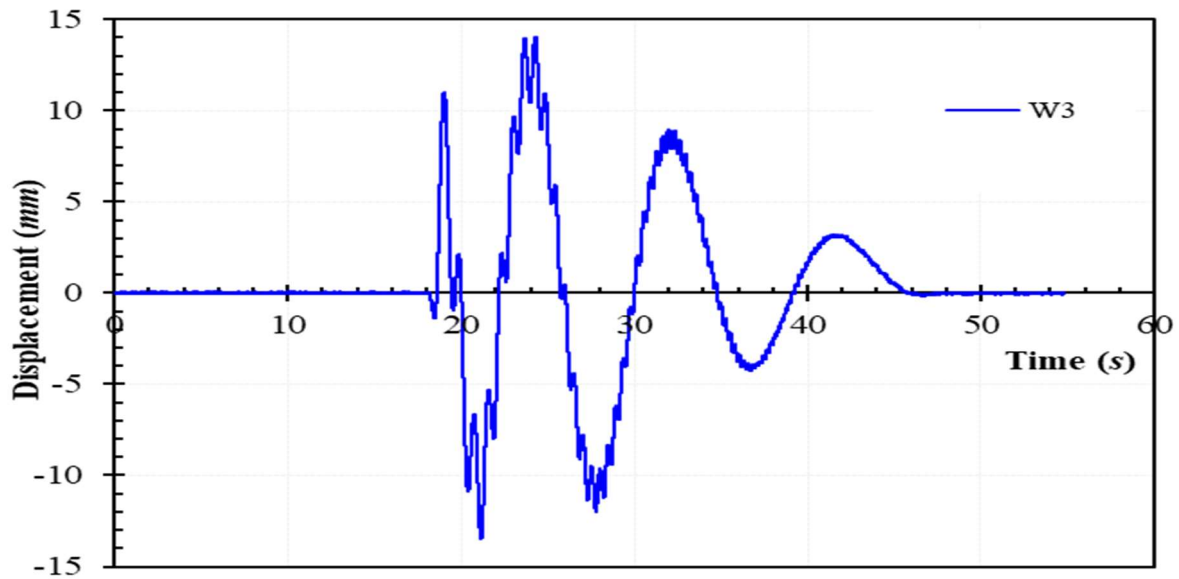
Max: 14,22 mm

Min: -13,54 mm

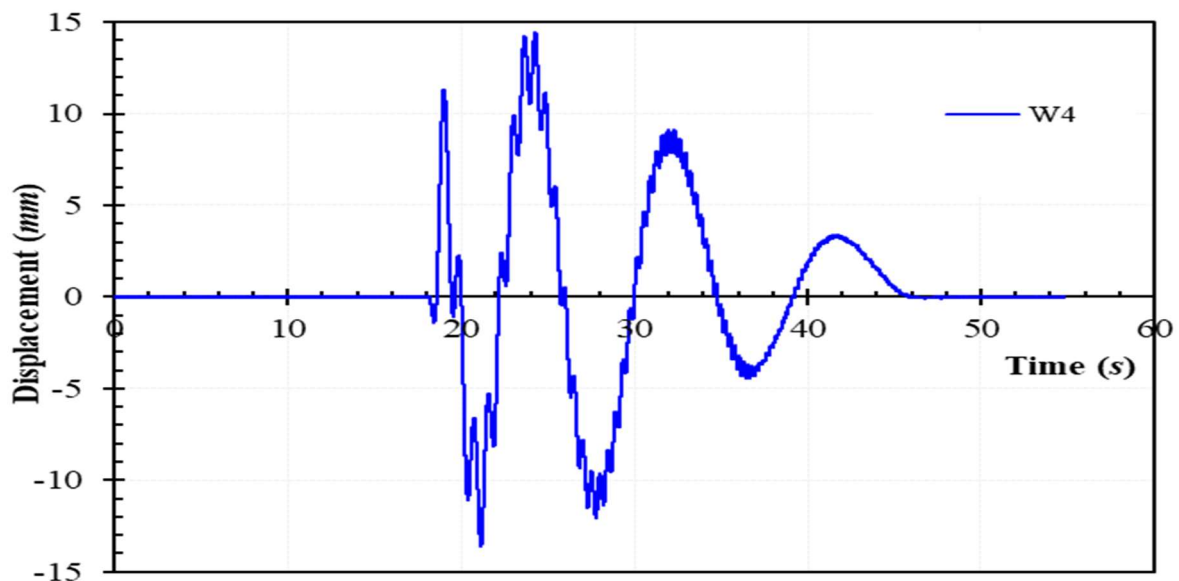
W 2

Max: 14,30 mm

Min: -13,72 mm



(a)



(b)

Figure 3.7.8 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Draw wire sensor 3 and (b) Draw wire sensor 4

Figure 3.7.8 shows draw wire sensors W3 and W4. More specifically, draw wire sensor W3 is located on the foundation, on the left side and draw wire sensor W4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor W3 is 14,22 mm while the minimum is -13,54 mm. The maximum movement detected by draw wire sensor W4 is 14,30 mm while the minimum is -13,72 mm.

W 3

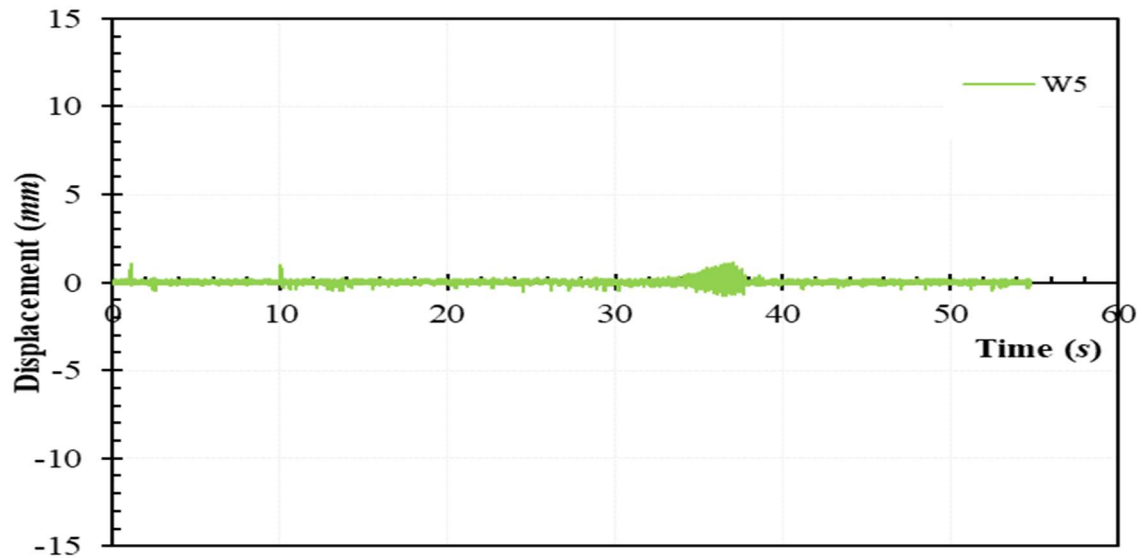
Max: 14,22 mm

Min: -13,54 mm

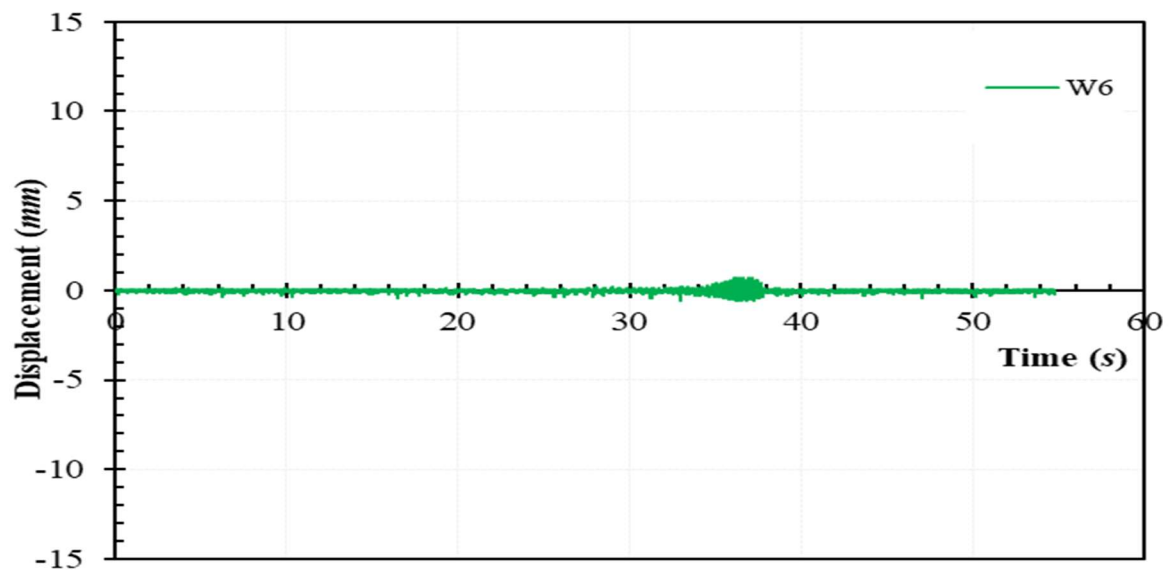
W 4

Max: 14,30 mm

Min: -13,72 mm



(a)



(b)

Figure 3.7.9 Characteristic results for phase A (white noise before 0,8g earthquake) : (a) Draw wire sensor 5 and (b) Draw wire sensor 6

Figure 3.7.9 shows draw wire sensors W5 and W6. More specifically, draw wire sensor W5 is located along the partial masonry infill diagonal and draw wire sensor W6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor 5 is 1,10 mm while the minimum is -0,77 mm. The maximum movement detected by draw wire sensor W6 is 0,72 mm while the minimum is -0,61 mm.

W 5

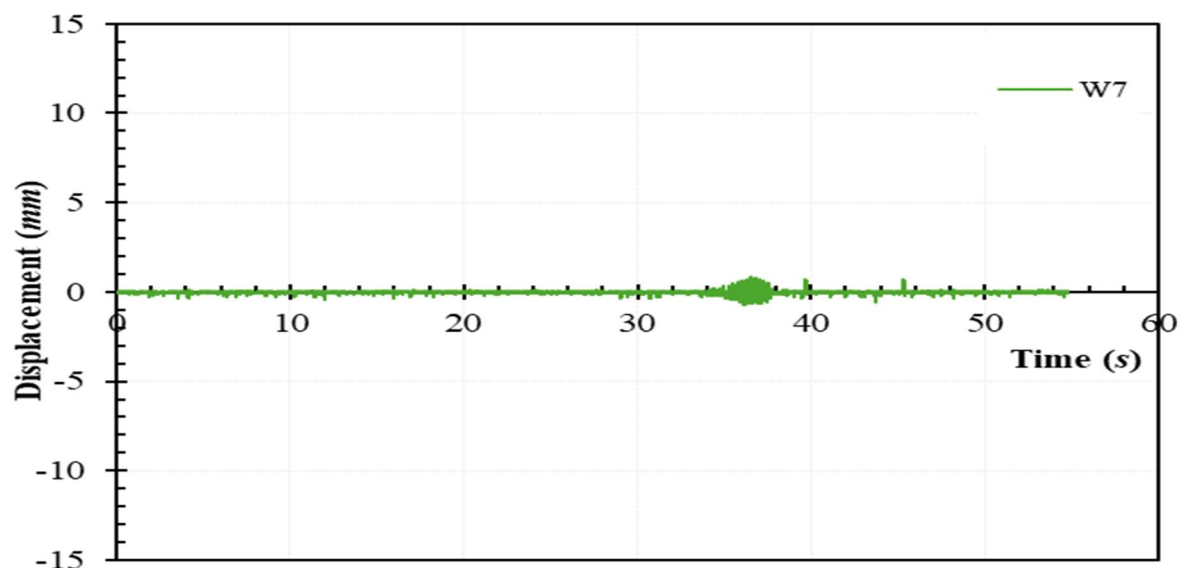
Max: 1,10 mm

Min: -0,77 mm

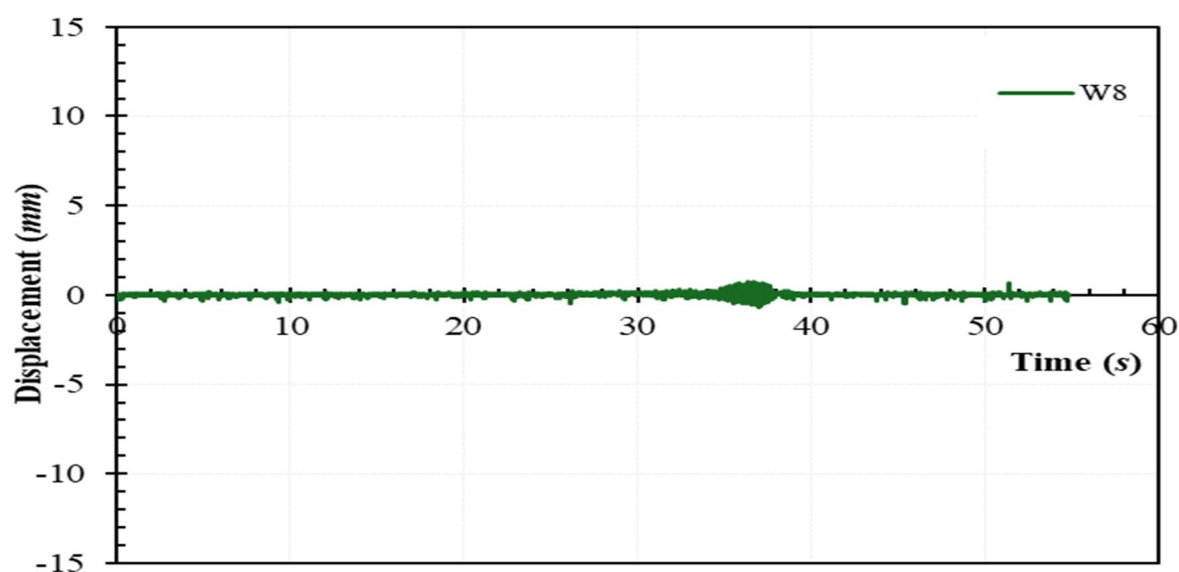
W 6

Max: 0,72 mm

Min: -0,61mm



(a)



(b)

Figure 3.7.10 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Draw wire sensor 7 and (b) Draw wire sensor 8

Figure 3.7.10 shows draw wire sensors WW7 and 8. More specifically, draw wire sensor W7 is located along the partial masonry infill diagonal and draw wire sensor W8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W7 is 0,83 mm while the minimum is -0,75 mm. The maximum movement detected by draw wire sensor W8 is 0,74 mm while the minimum is -0,71 mm.

W 7

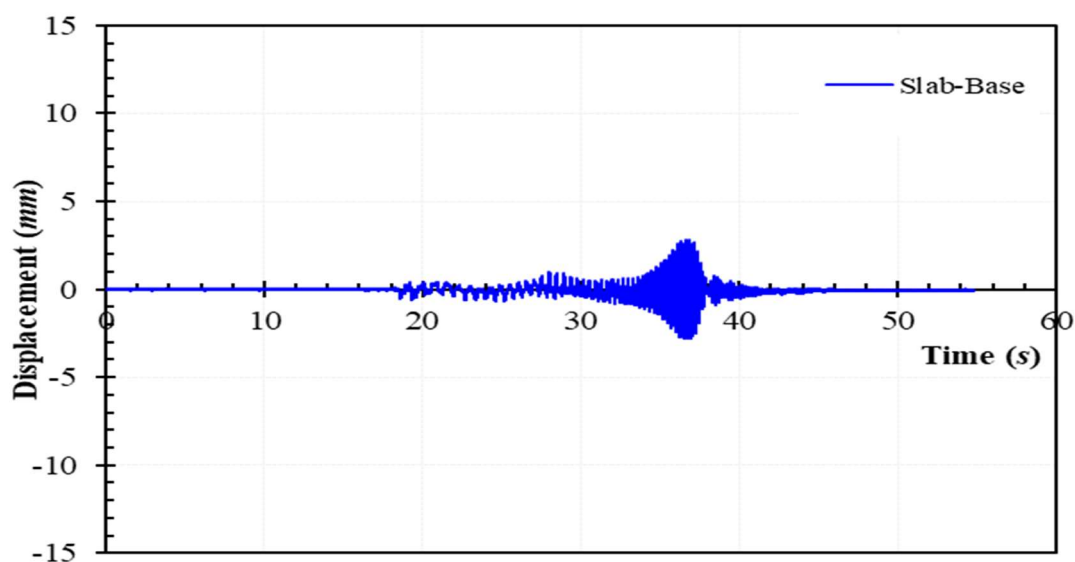
Max: 0,83 mm

Min: -0,75 mm

W 8

Max: 0,74 mm

Min: -0,71 mm



(a)

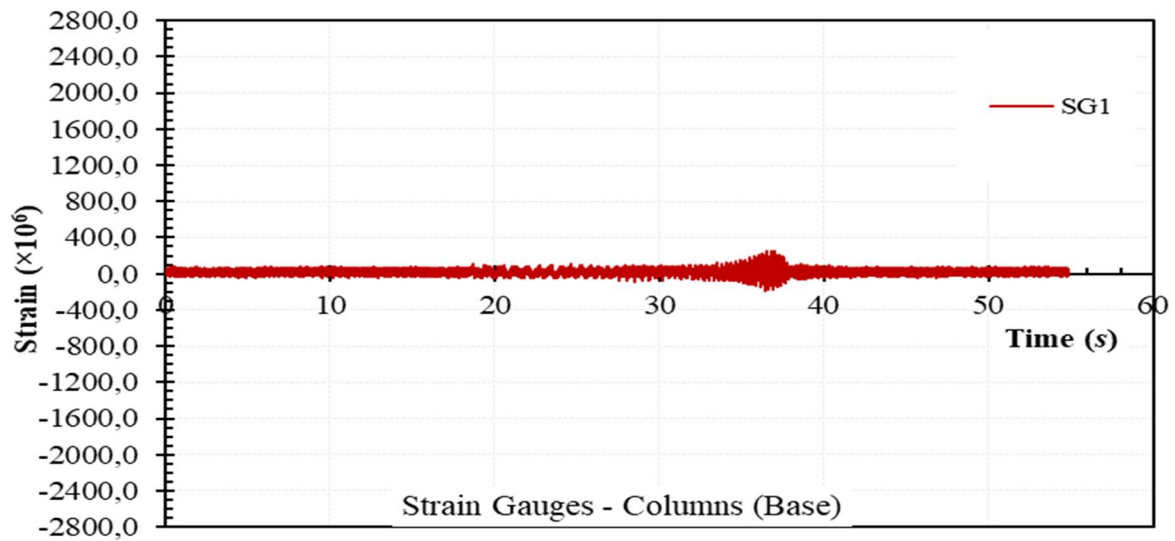
Figure 3.7.11 Characteristic results for phase A (white noise before 0,8g earthquake): (a) Diagram of displacement Slab – Base

Figure 3.7.11 shows slab – base displacement. More specifically, the maximum drift detected is 2,29 ‰ while the minimum is -2,32 ‰. The residual drift is -0,06 mm.

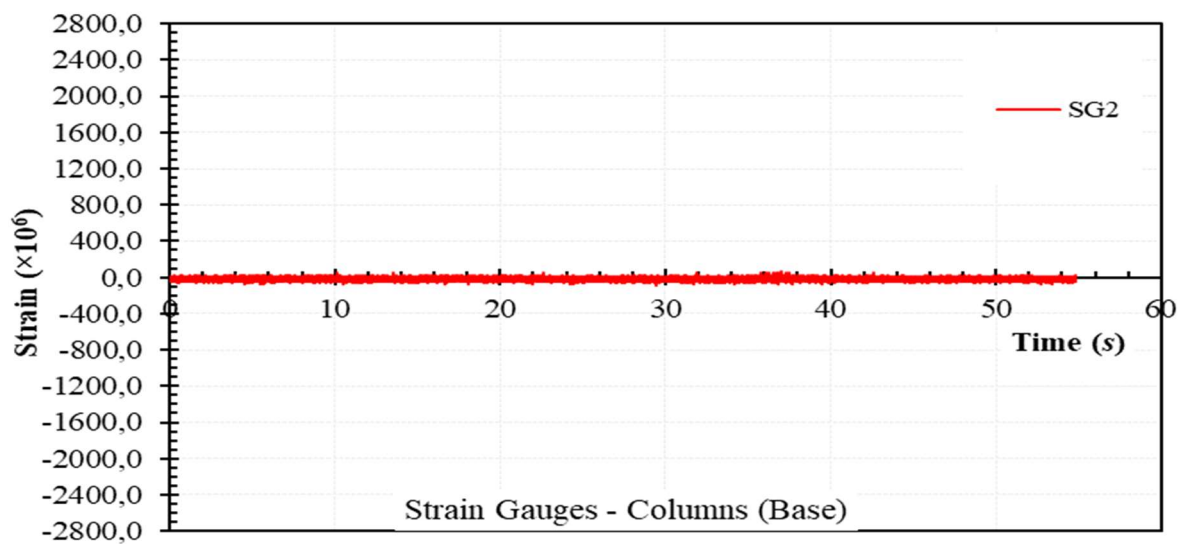
Maximum drift (‰): 2,29 (2,80525m/1,225m=2,29‰)

Minimum drift (‰): -2,32

Residual drift: -0,06 mm



(a)



(b)

Figure 3.7.12 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 1 and (b) strain gauge 2

Strain gauges detect strain. The strain gauges shown in the figures 3.7.12, 3.7.13, 3.7.14 and 3.7.19 are located in the longitudinal reinforcement, on the underside. More specifically, strain gauge SG1 has maximum strain 244,15 μ strain and minimum strain -183,11 μ strain. The residual strain is 0 μ strain. Strain gauge SG2 has maximum deformation 61,04 μ strain and minimum -91,56 μ strain. The residual strain is -30,52 μ strain. Strain gauge SG3 has 106,81 μ strain and -30,52 μ strain maximum and minimum strain respectively. The residual strain is 45,78 μ strain. Strain gauge SG4 as we can see in figure 3.7.13 has maximum 228,89 μ strain and minimum -45,78 μ strain deformation. The residual strain is -0,15 μ strain. Figure 3.7.19 shows strain gauges SG5 and SG6. Strain gauge 5 has 380,05 μ strain and -467,52 μ strain maximum and minimum strain respectively. Strain gauge SG5 presents 1,63 μ strain residual strain. Strain gauge SG6 has 56,11 μ strain maximum strain, -96,13 μ strain minimum strain and 0 μ strain residual. Finally in figure 3.7.14 see strain gauge SG7 and SG8. Strain gauge SG7 has maximum strain 106,81 μ strain and SG8 has maximum strain 305,19 μ strain. Strain gauge SG7 has -45,78 μ strain

minimum deformation and SG8 has $-183,11 \mu\text{strain}$. The residual strain for strain gauge SG7 and SG8 is 15,26, 0,46 respectively.

Sg 1

Max: $244,15 \mu\text{strain}$

Min: $-183,11 \mu\text{strain}$

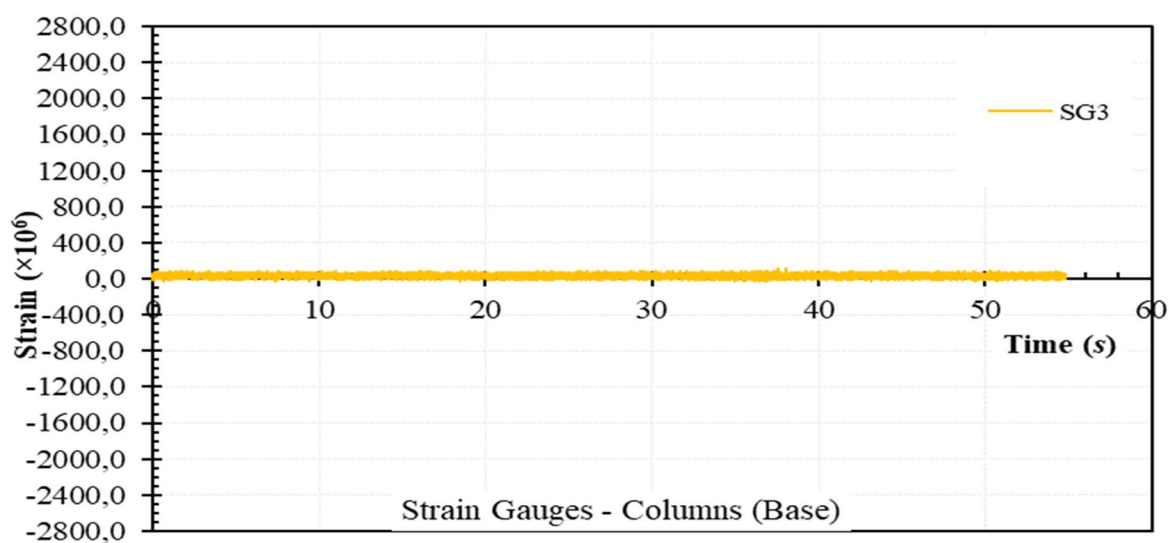
Residual: $0 \mu\text{strain}$

Sg 2

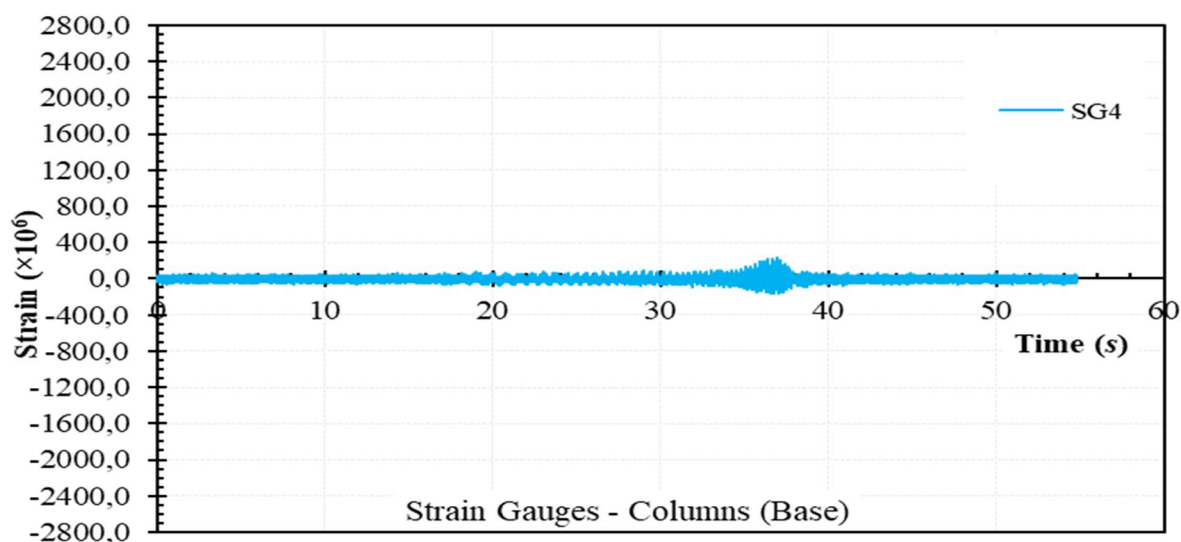
Max: $61,04 \mu\text{strain}$

Min: $-91,56 \mu\text{strain}$

Residual: $-30,52 \mu\text{strain}$



(a)



(b)

Figure 3.7.13 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 3 and (b) strain gauge 4

Sg 3

Max: $106,81 \mu\text{strain}$

Min: -30,52 μ strain

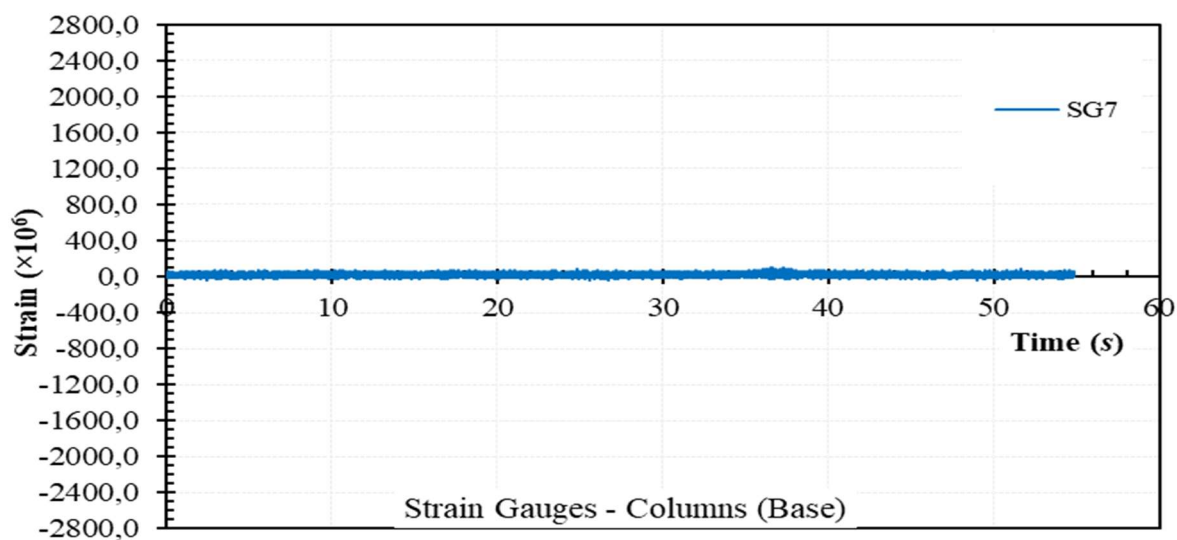
Residual: 45,78 μ strain

Sg 4

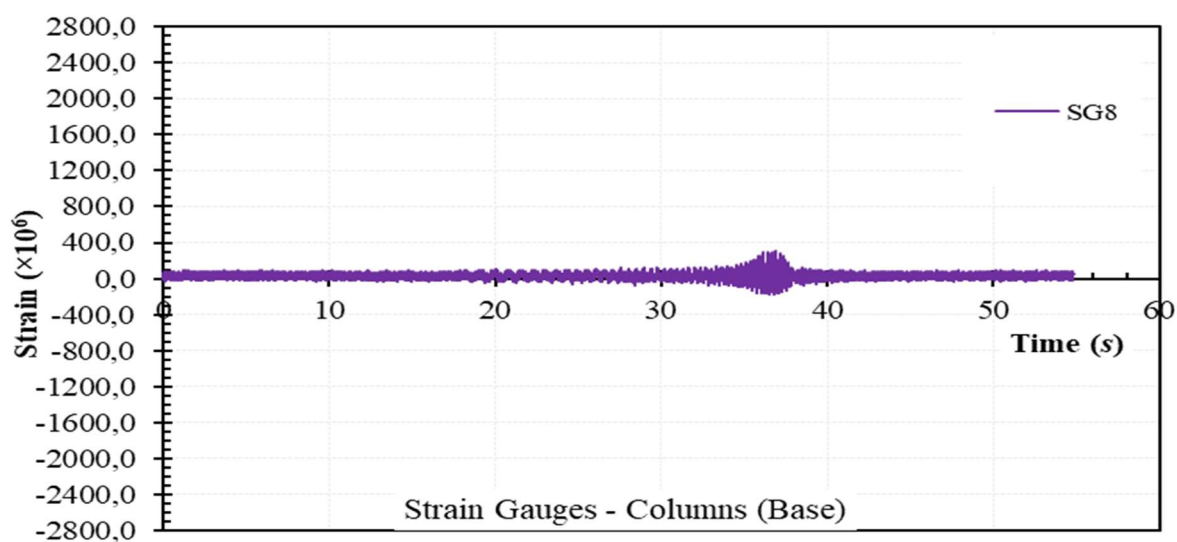
Max: 228,89 μ strain

Min: -45,78 μ strain

Residual: -0,15 μ strain



(a)



(b)

Figure 3.7.14 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 7 and (b) strain gauge 8

Sg 7

Max: 106,81 μ strain

Min: -45,78 μ strain

Residual: 15,26 μ strain

Sg 8

Max: 305,19 μ strain

Min: -183,11 μ strain

Residual: 0,46 μ strain

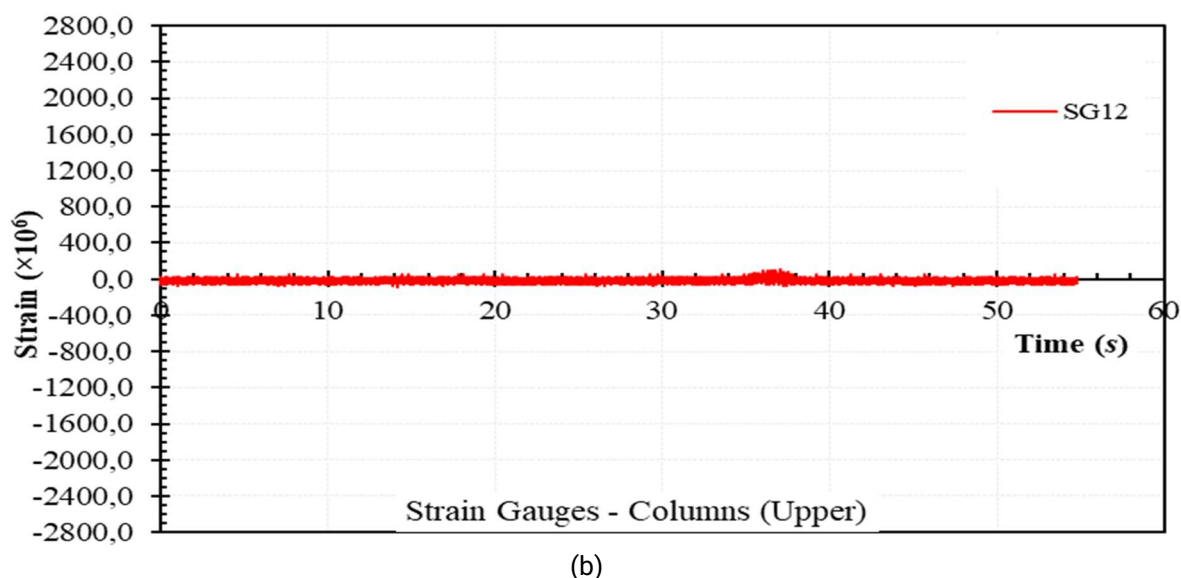
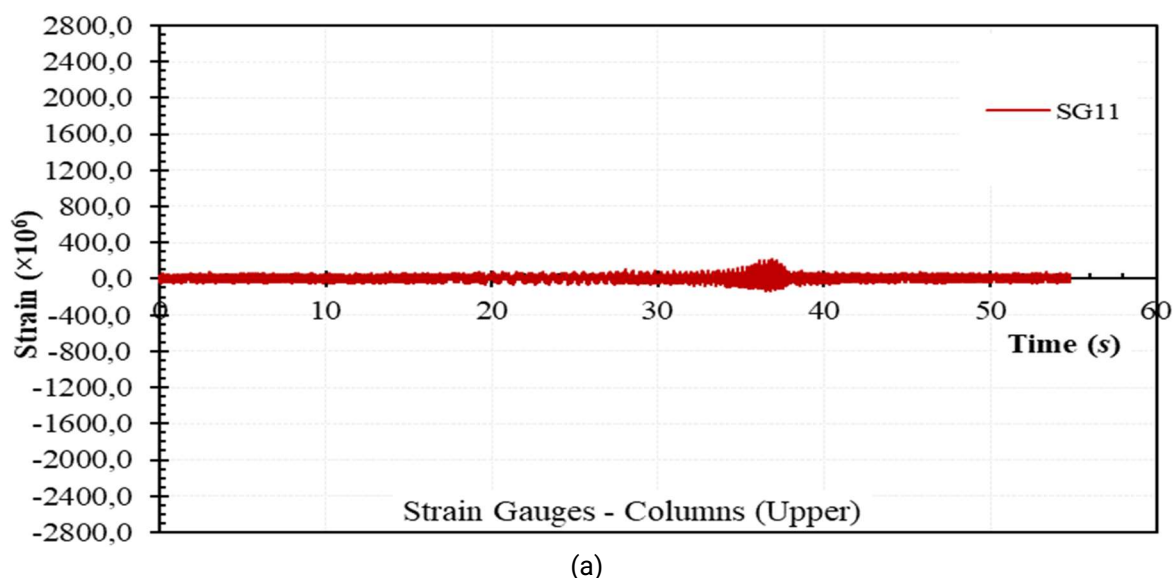


Figure 3.7.15 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 11 and (b) strain gauge 12

The strain gauges shown in the figures 3.7.15, 3.7.16 and 3.7.17 are located in the longitudinal reinforcement, on the upper side. More specifically, strain gauge SG11 has maximum strain 213,63 μ strain and minimum -137,33 μ strain deformation. The residual strain is 0 μ strain for strain gauge SG11. Strain gauge SG12 has maximum strain 106,81 μ strain and minimum strain -91,56 μ strain. The residual value is -30,52 μ strain. Strain gauge SG13 has maximum strain 137,33 μ strain and minimum strain -61,04 μ strain. The residual is 30,52 μ strain. Strain gauge SG14 has maximum strain 198,37 μ strain and minimum strain -137,33 μ strain. The residual is 0,15 μ strain. Finally strain gauges SG15 has maximum strain 213,63 μ strain and minimum strain -167,85 μ strain. The residual is -15,26 μ strain. Strain

gauge SG16 has maximum strain 244,15 μ strain, minimum strain -61,04 μ strain and residual strain 30,52 μ strain.

Sg 11

Max: 213,63 μ strain

Min: -137,33 μ strain

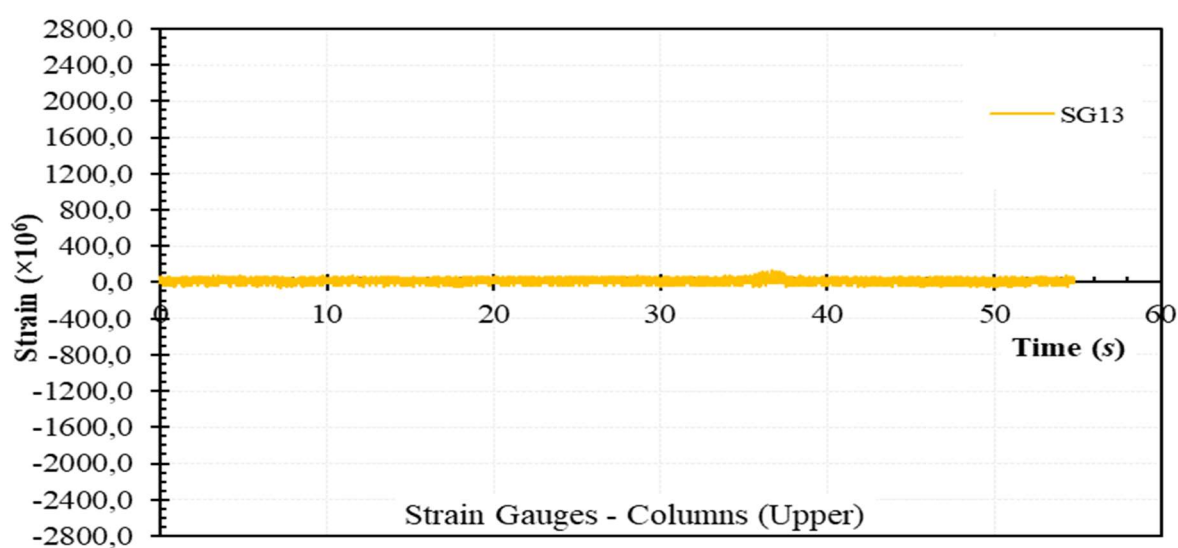
Residual: 0 μ strain

Sg 12

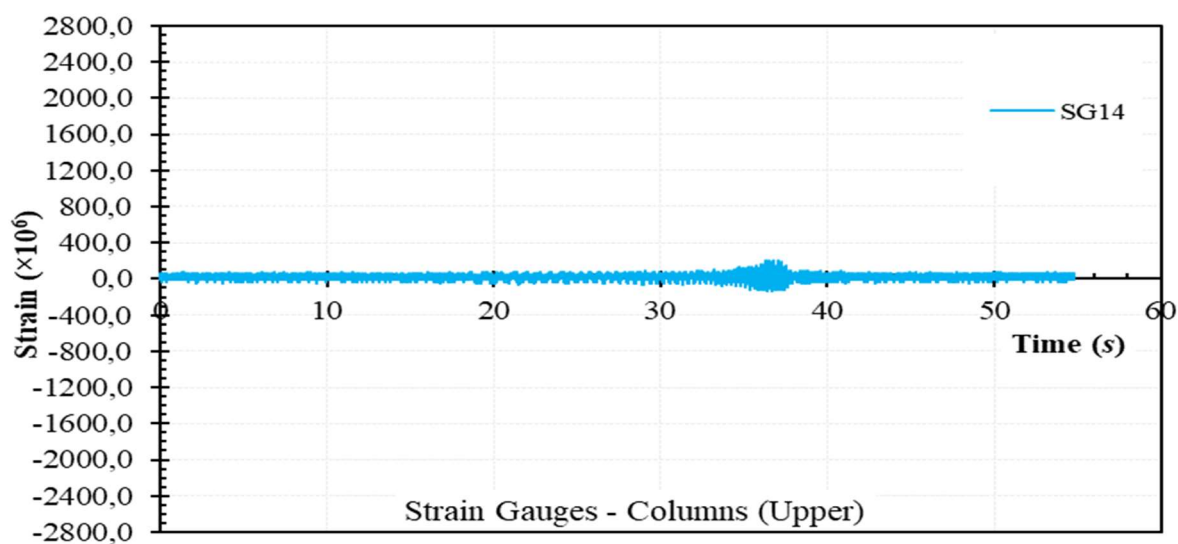
Max: 106,81 μ strain

Min: -91,56 μ strain

Residual: -30,52 μ strain



(a)



(b)

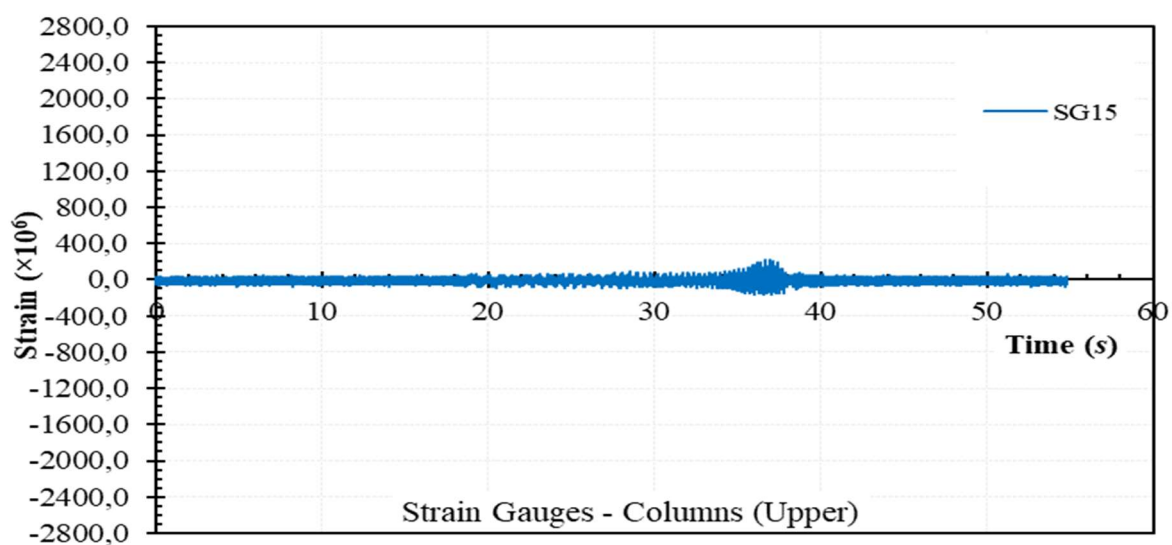
Figure 3.7.16 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 13 and (b) strain gauge 14

Sg 13

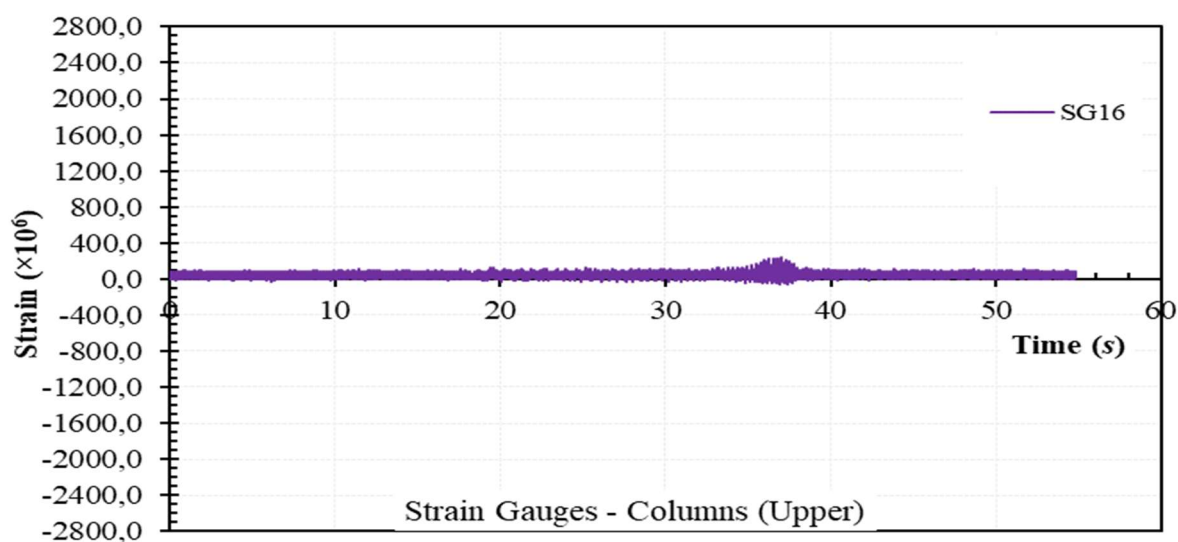
Max: 137,33 μ strain
Min: -61,04 μ strain
Residual: 30,52 μ strain

Sg 14

Max: 198,37 μ strain
Min: -137,33 μ strain
Residual: 0,15 μ strain



(a)



(b)

Figure 3.7.17 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 15 and (b) strain gauge 16

Sg 15

Max: 213,63 μ strain
Min: -167,85 μ strain

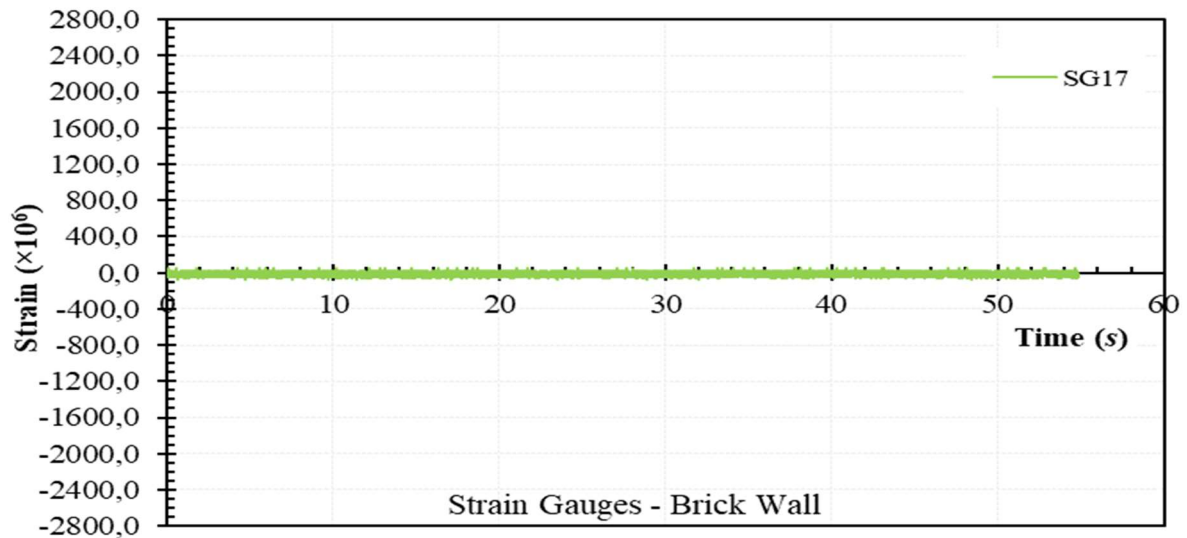
Residual: -15,26 μ strain

Sg 16

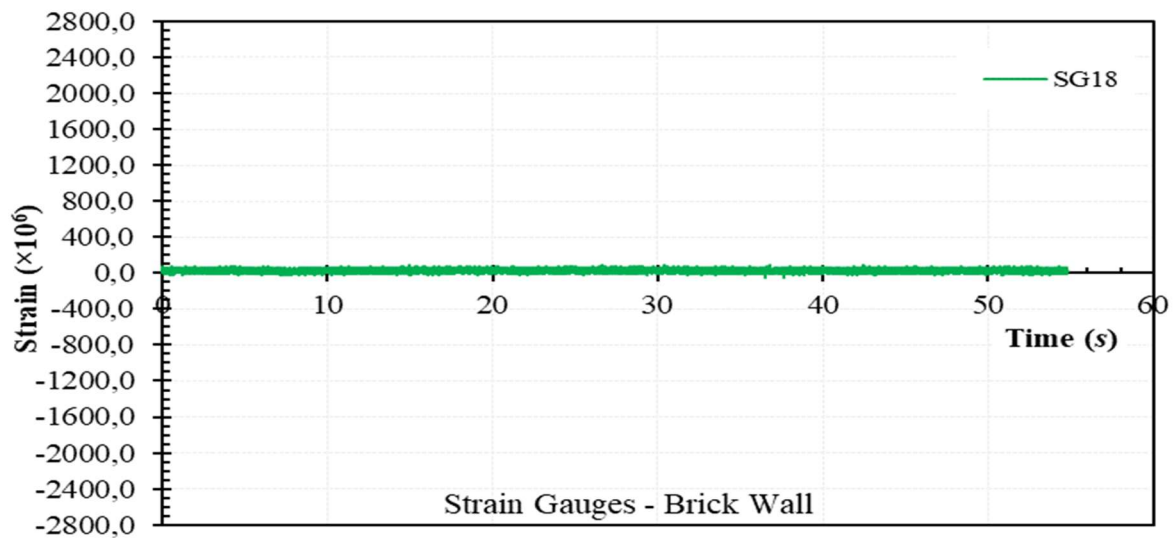
Max: 244,15 μ strain

Min: -61,04 μ strain

Residual: 30,52 μ strain



(a)

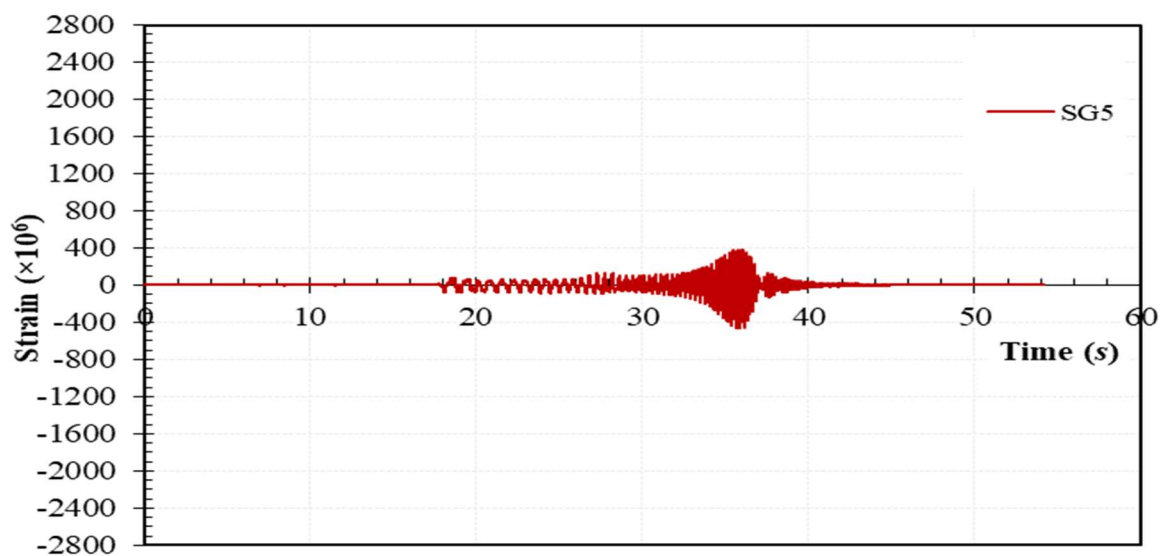


(b)

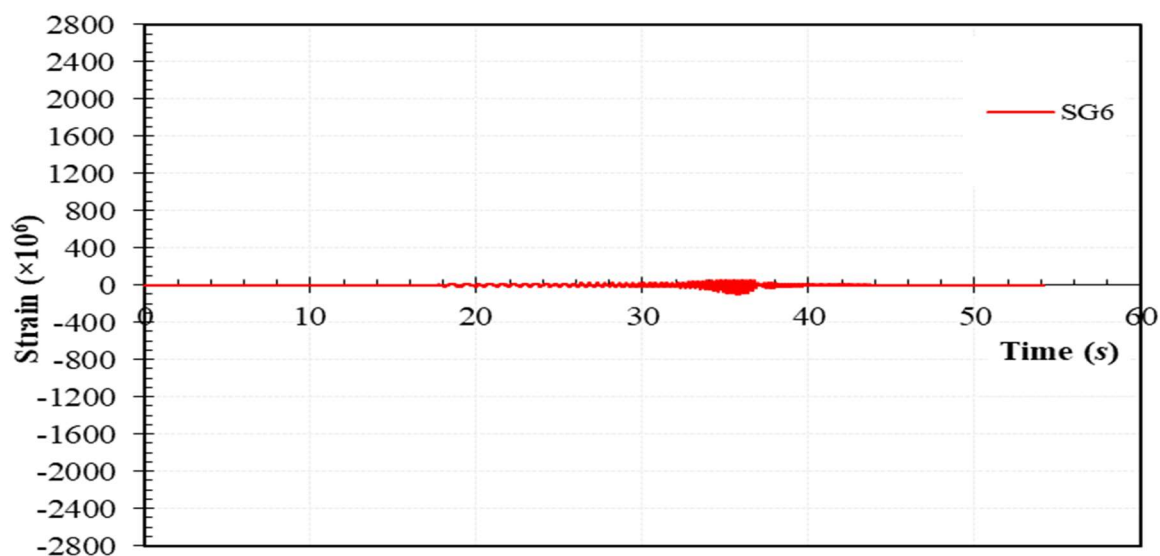
Figure 3.7.18 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 17 and (b) strain gauge 18

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauge SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge SG17 has 45,78 μ strain maximum strain. Strain gauge SG17 has minimum deformation -76,30 μ strain and strain gauge 18 -45,78 μ strain. Strain gauge SG18 has maximum strain 91,56 μ strain. Finally strain gauge SG17 presents -0,15 μ strain residual. Strain gauge SG18 presents 15,26 μ strain residual.

Sg 17Max: 45,78 μ strainMin: -76,30 μ strainResidual: -0,15 μ strain**Sg 18**Max: 91,56 μ strainMin: -45,78 μ strainResidual: 15,26 μ strain



(a)



(b)

Figure 3.7.19 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 5 and (b) strain gauge 6

Sg 5

Max: 380,05 μ strain

Min: -467,52 μ strain

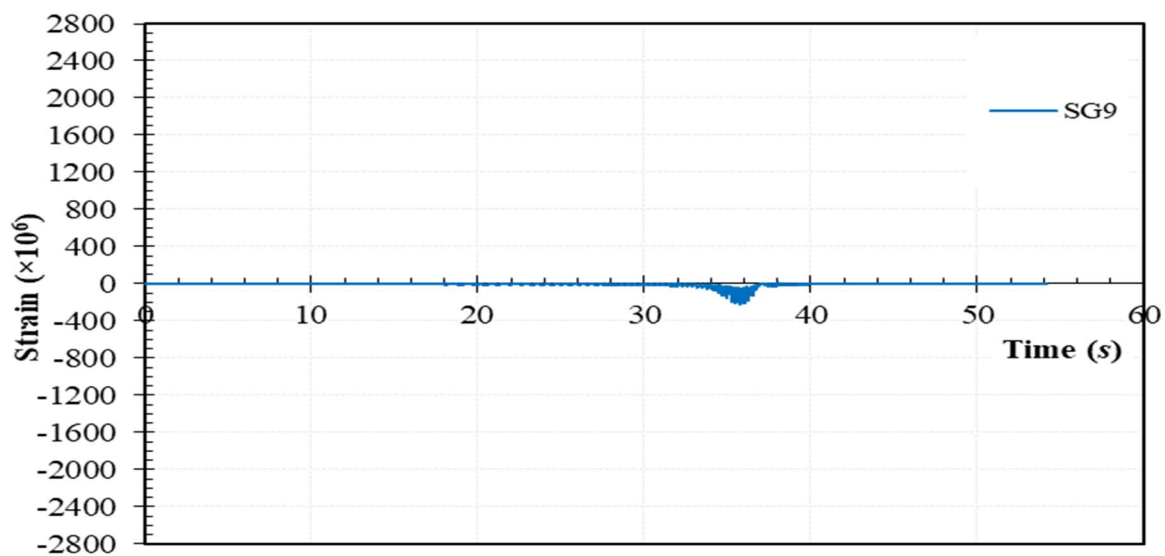
Residual: 1,63 μ strain

Sg 6

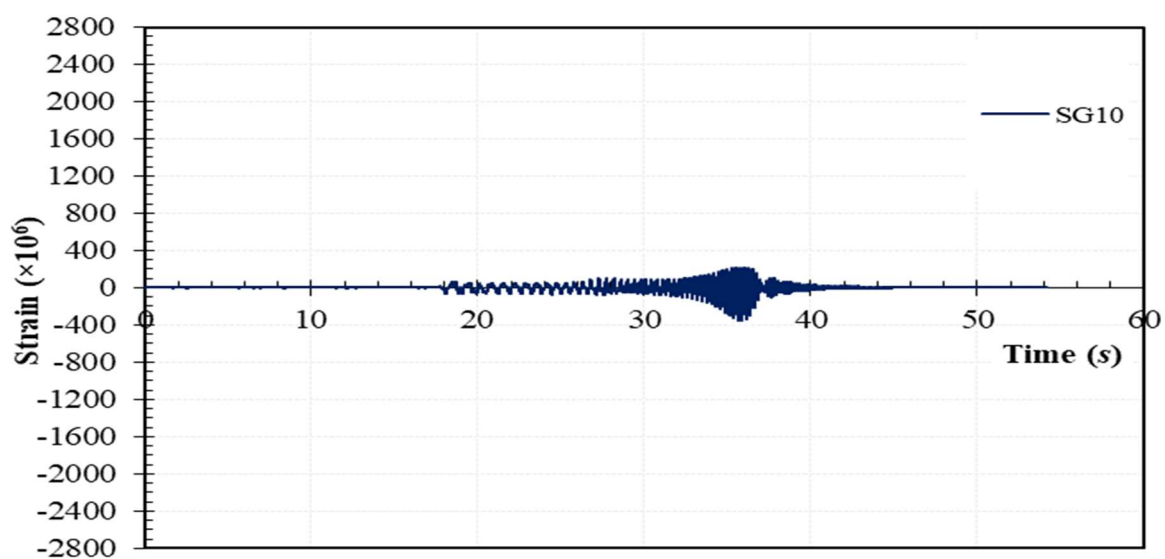
Max: 56,22 μ strain

Min: -96,13 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.7.20 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 9 and (b) strain gauge 10

Sg 9

Max: 6,51 μ strain

Min: -216,24 μ strain

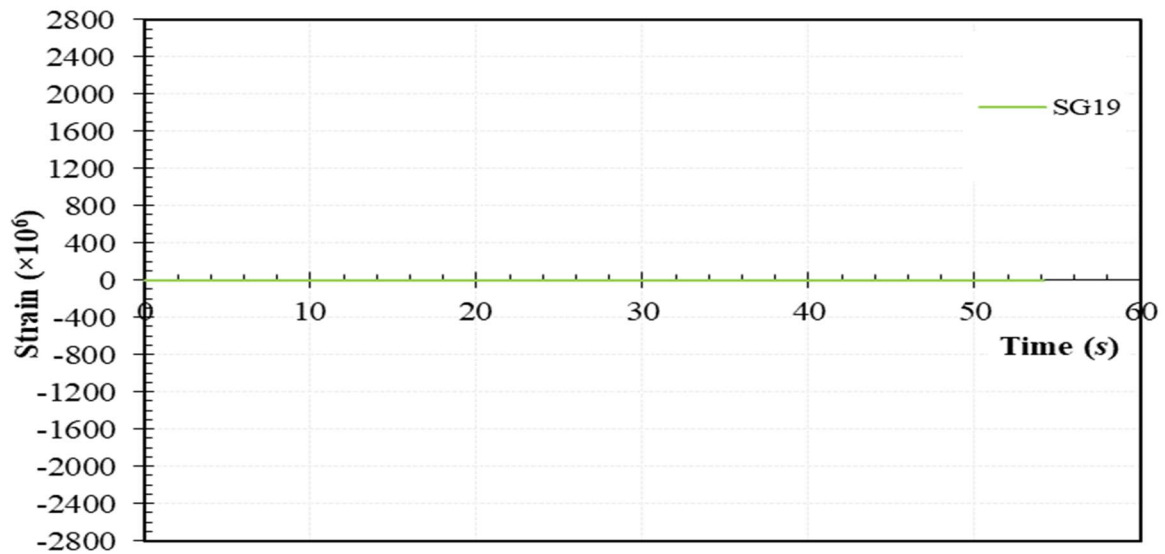
Residual: 0 μ strain

Sg 10

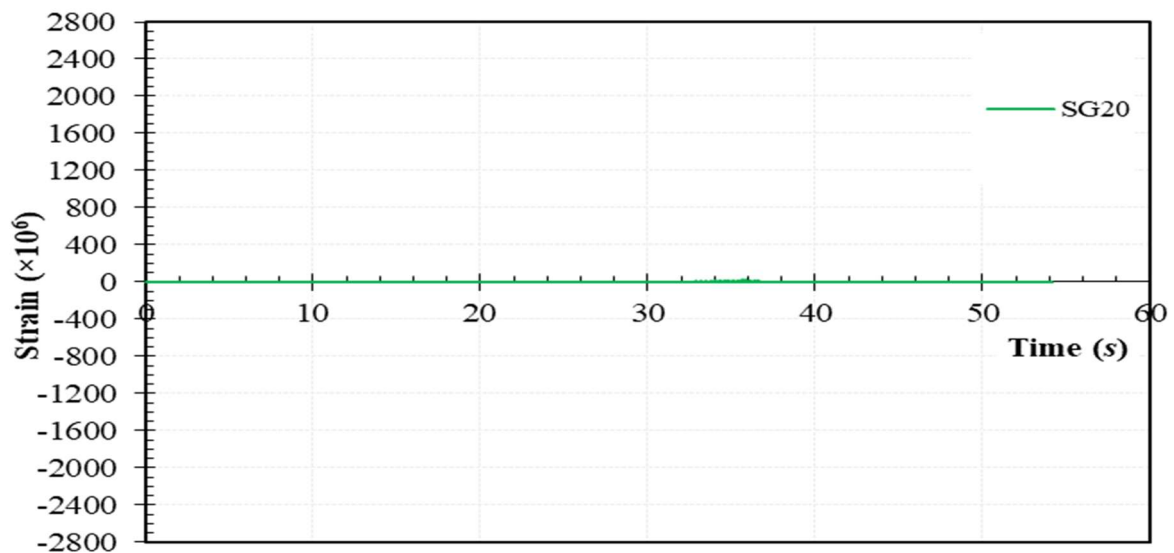
Max: 218,17 μ strain

Min: -351,97 μ strain

Residual: 0,82 μ strain



(a)



(b)

Figure 3.7.21 Characteristic results for phase A (white noise before 0,8g earthquake) (a) strain gauge 19 and (b) strain gauge 20

Strain gauge 19 is located on the centre of partial masonry 2 along direction x. Strain gauges 20 is located on the centre of partial masonry 2 along direction x. More specifically strain gauge SG19 has maximum $2,43 \mu$ strain and minimum $-1,62 \mu$ strain. Strain gauge SG20 has maximum strain $20,33 \mu$ strain and minimum $-5,69 \mu$ strain. The residual strain for strain gauge SG19 is $-0,81 \mu$ strain and residual for strain gauge SG20 is $-0,81 \mu$ strain.

Sg 19

Max: $2,43 \mu$ strain

Min: $-1,62 \mu$ strain

Residual: $-0,81 \mu$ strain

Sg 20

Max: 20,33 μ strain

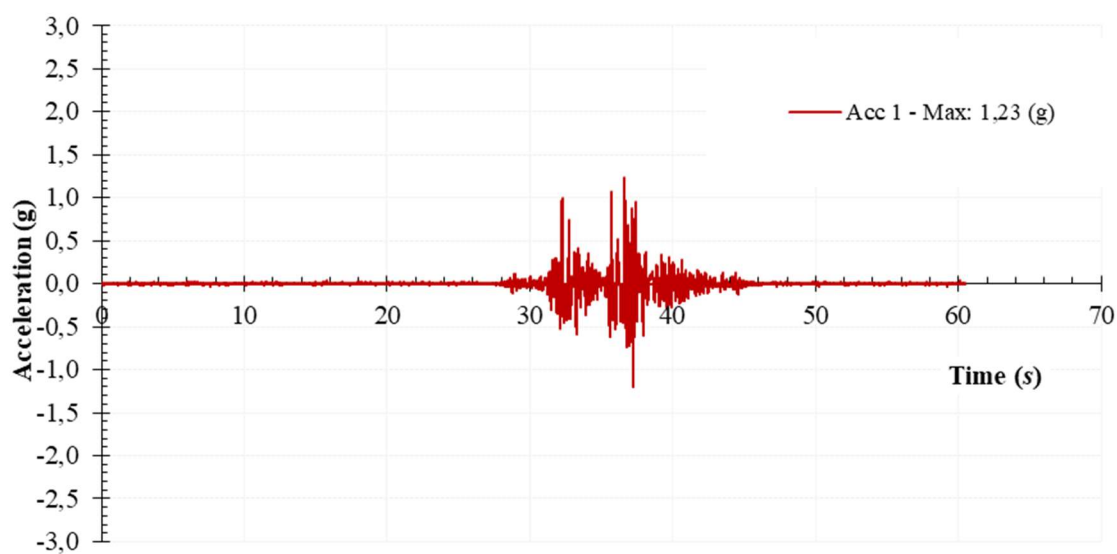
Min: -5,69 μ strain

Residual: -0,81 μ strain

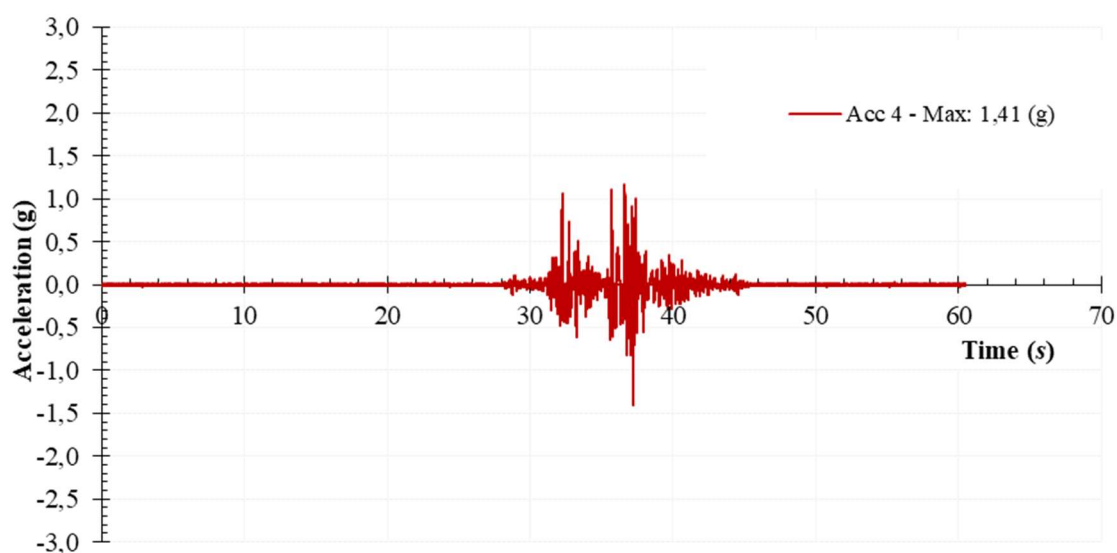
3.8) Earthquake EQ0,8g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for EQ0,8g. The max acceleration at the slab level on the accelerometer acc1 and acc4 is 1,23g and 1,41g respectively. The max acceleration at the foundation level on the accelerometer acc10 is 0,76g.

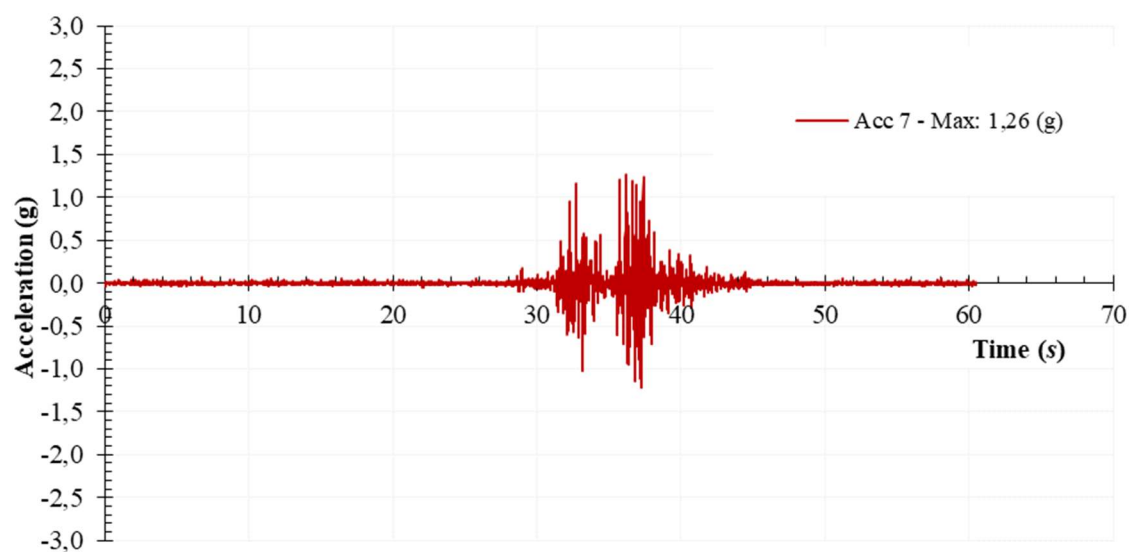


(a)

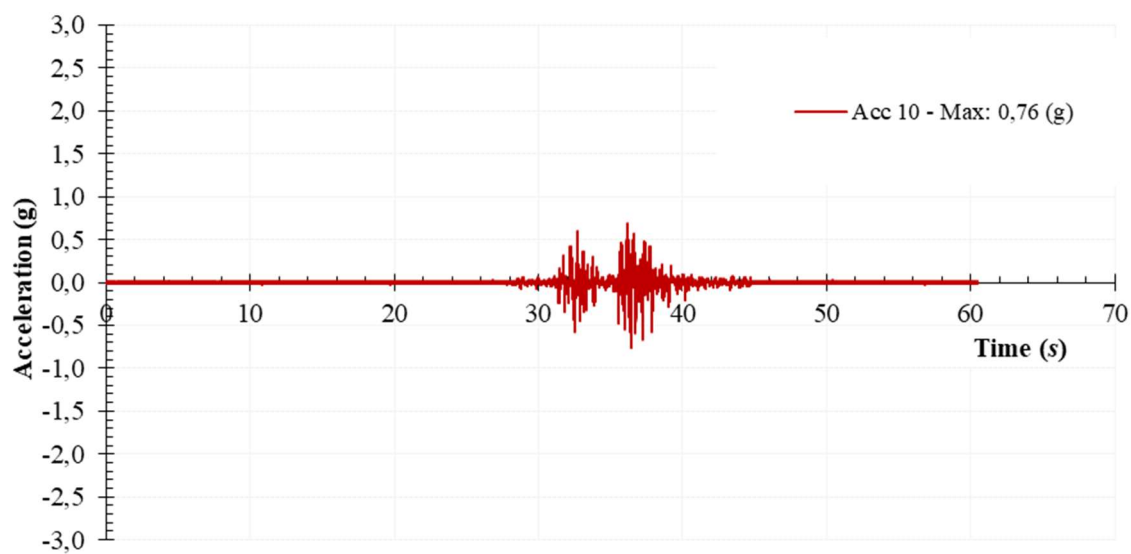


(b)

Figure 3.8.1 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 1 (b) Accelerometer 4

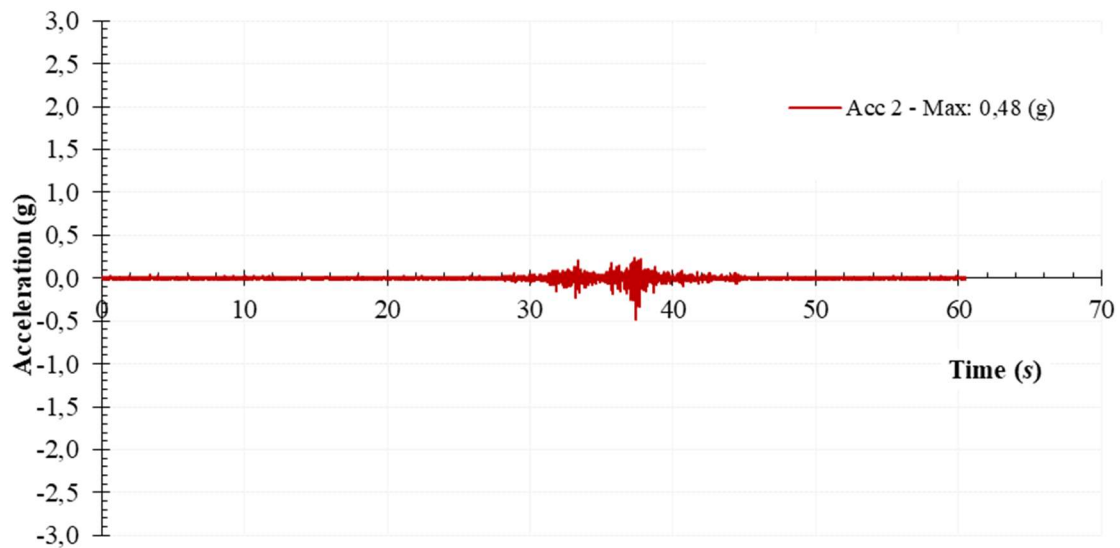


(a)

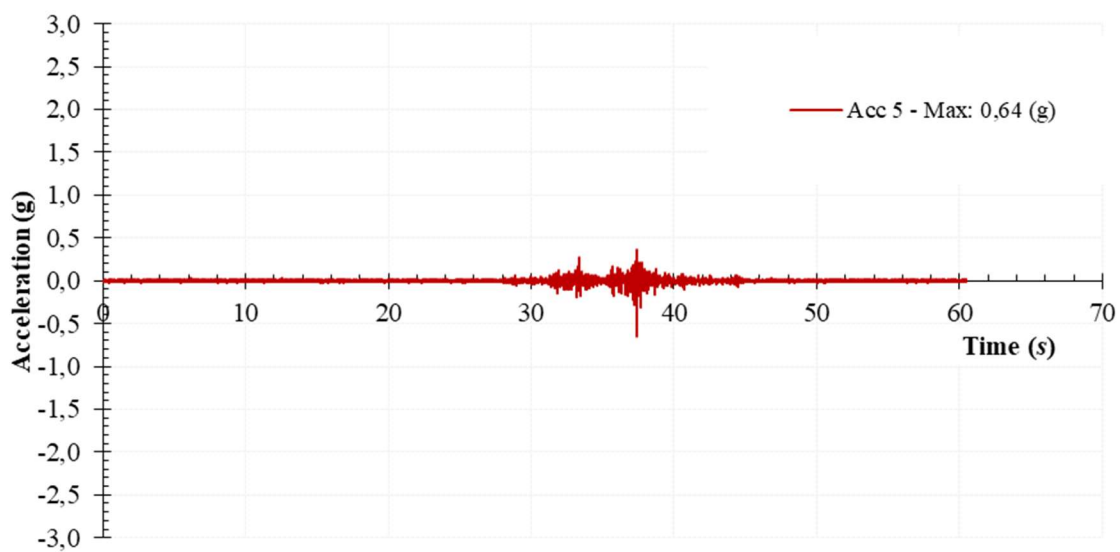


(b)

Figure 3.8.2 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

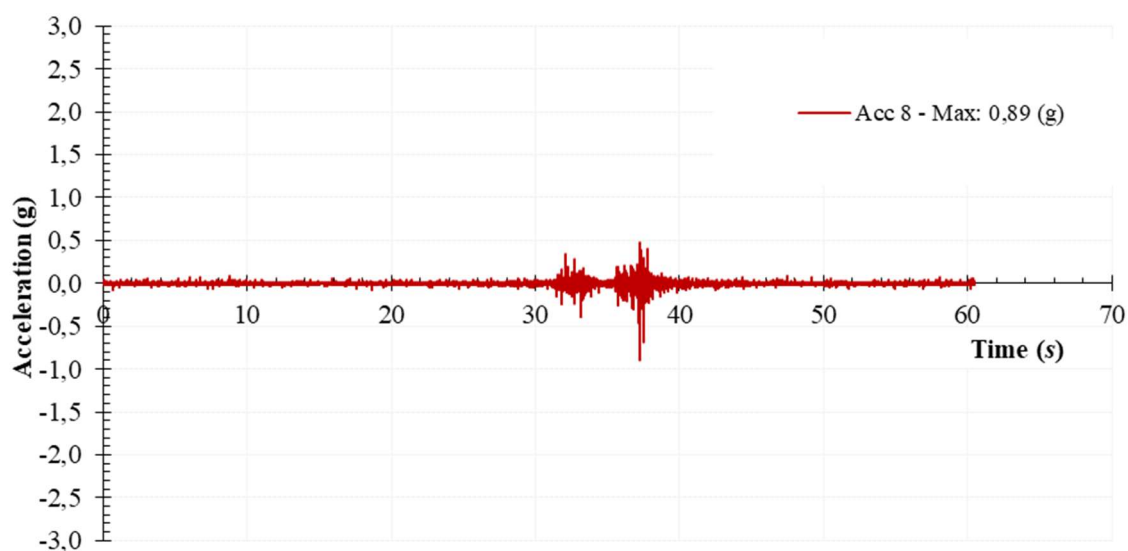


(a)

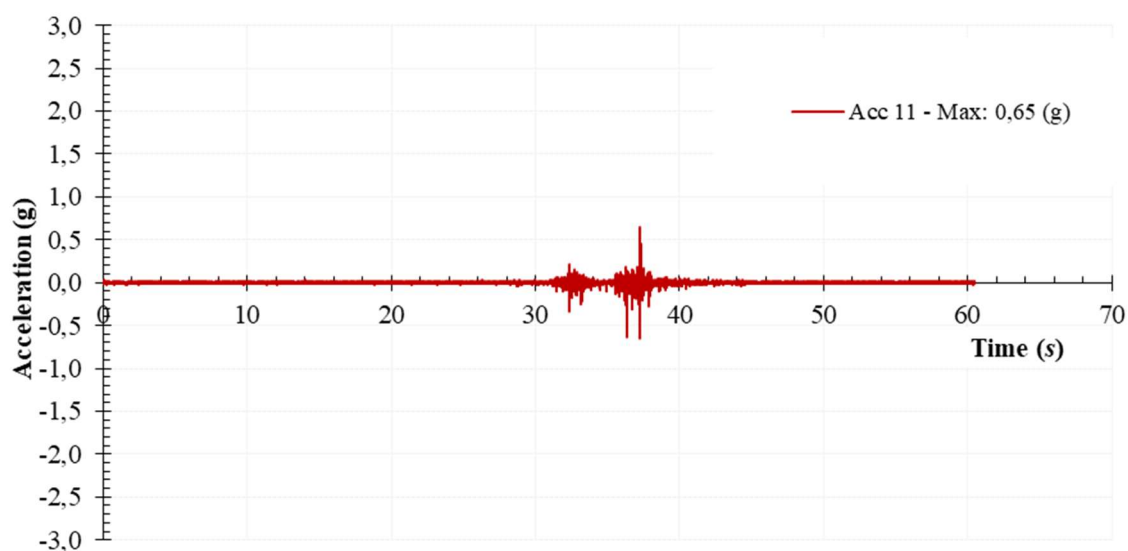


(b)

Figure 3.8.3 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

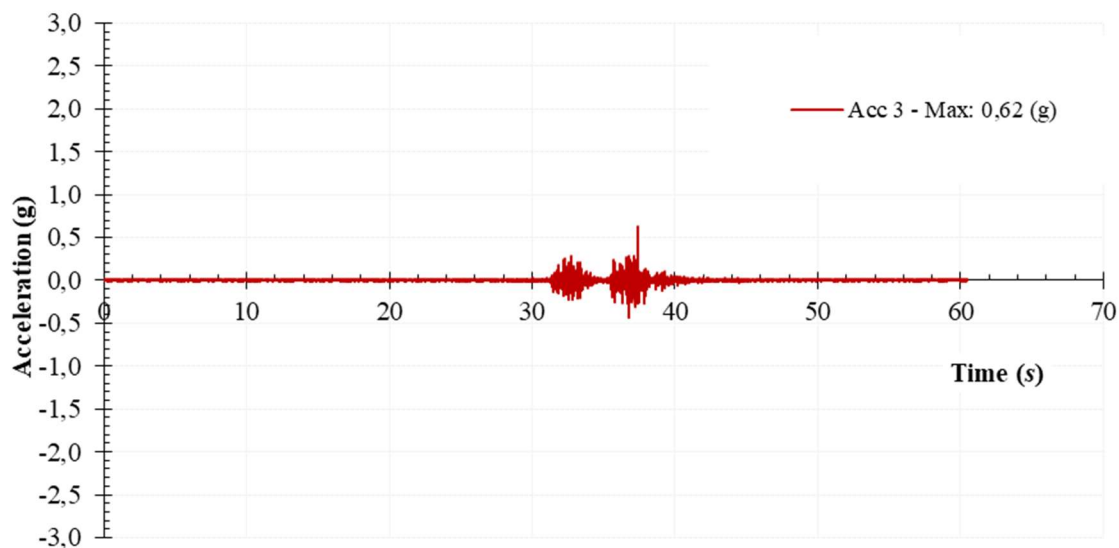


(a)

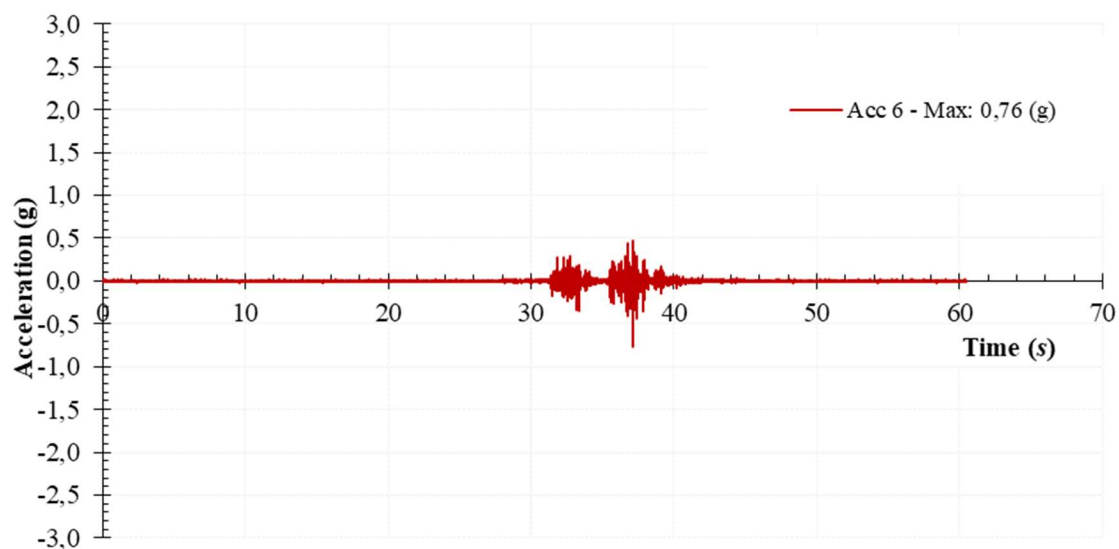


(b)

Figure 3.8.4 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 8 (b) Accelerometer 11

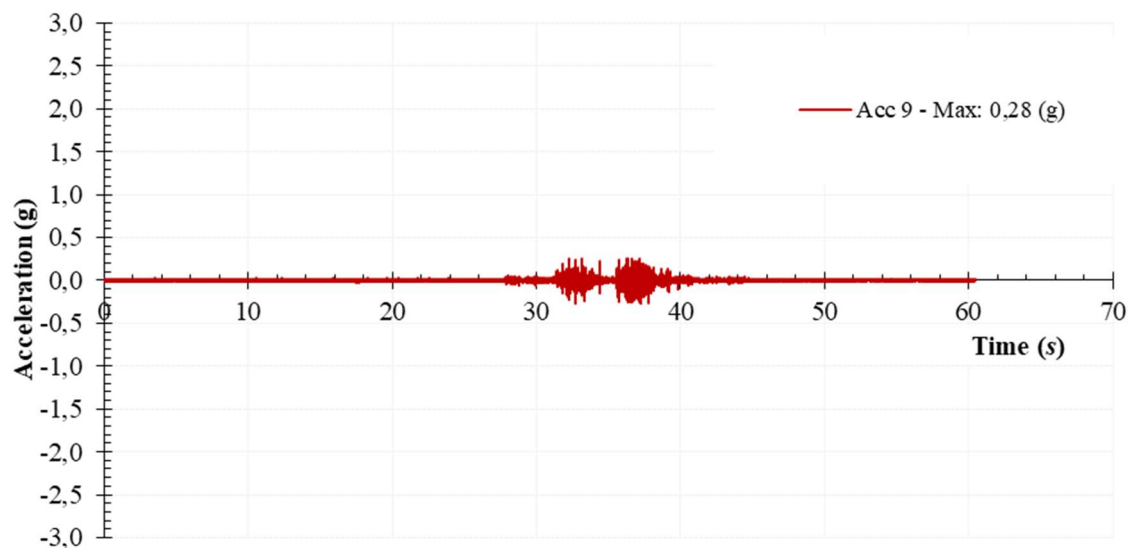


(a)

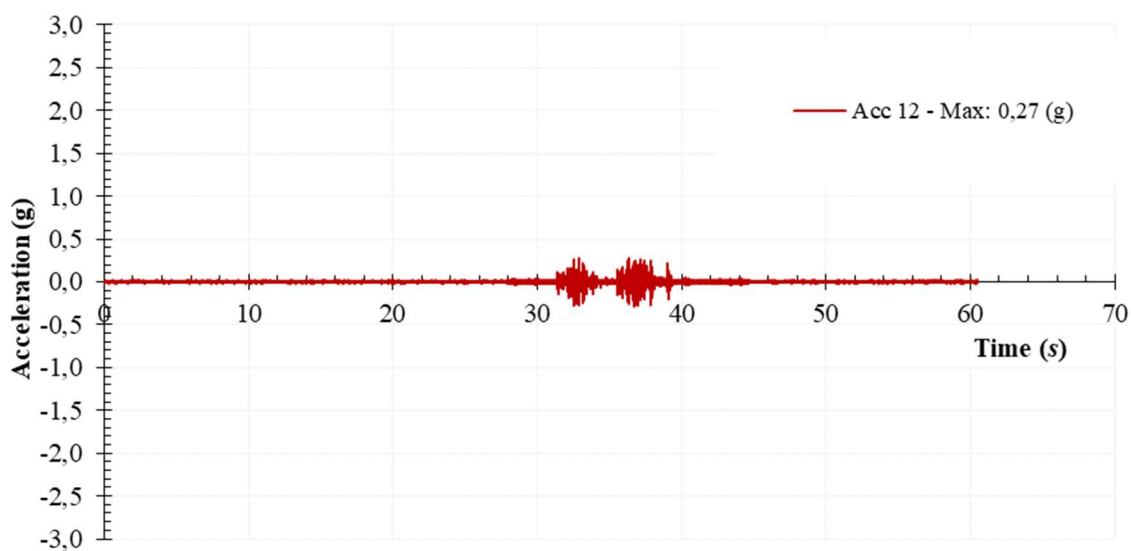


(b)

Figure 3.8.5 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 3 (b) Accelerometer 6

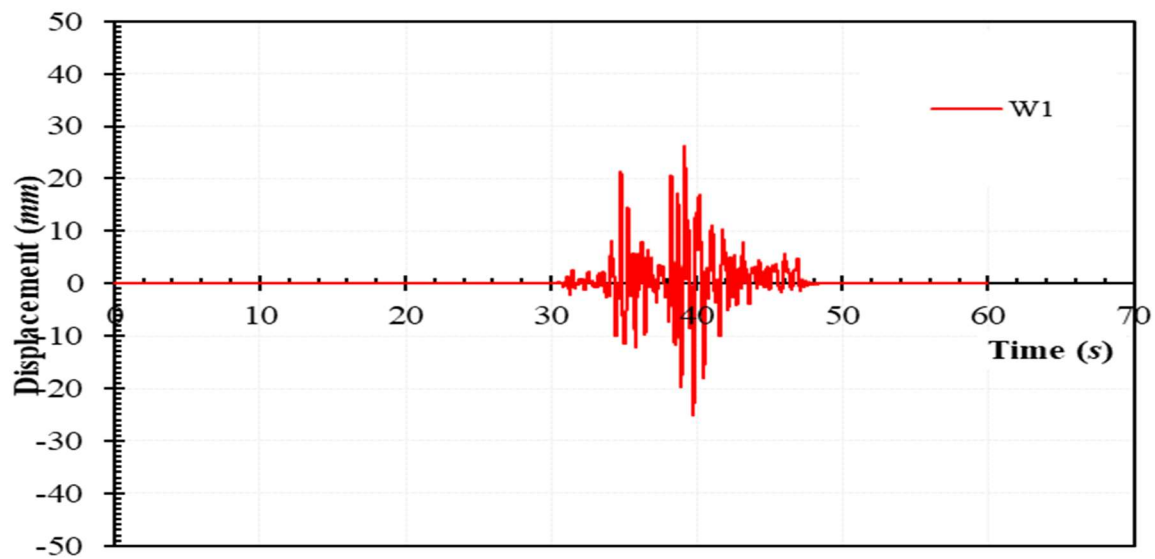


(a)

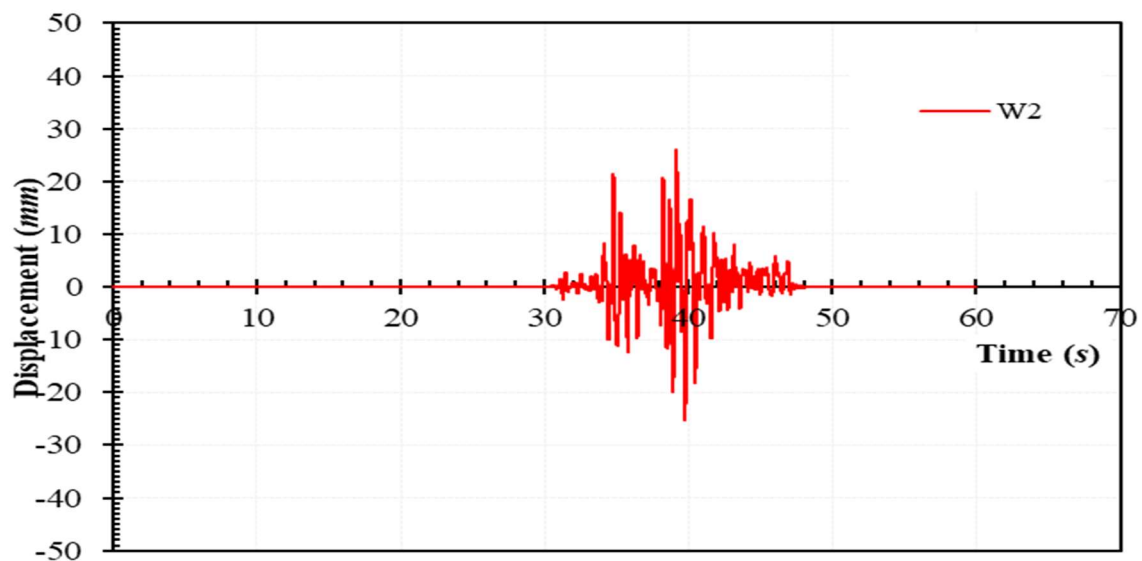


(b)

Figure 3.8.6 Characteristic results for phase A (0,8g earthquake): (a) Accelerometer 9 (b) Accelerometer 12



(a)



(b)

Figure 3.8.7 Characteristic results for phase A (0,8g earthquake): (a) Draw wire sensor W1 and (b) Draw wire sensor W2

Figure 3.8.7 shows draw wire sensors W1 and W2. More specifically, draw wire sensor W1 is located on the slab, on the left side and draw wire sensor W2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor W1 is 26,29 mm while the minimum is -25,16 mm. The maximum movement detected by draw wire sensor 2 is 25,94 mm while the minimum is -25,25 mm.

W 1

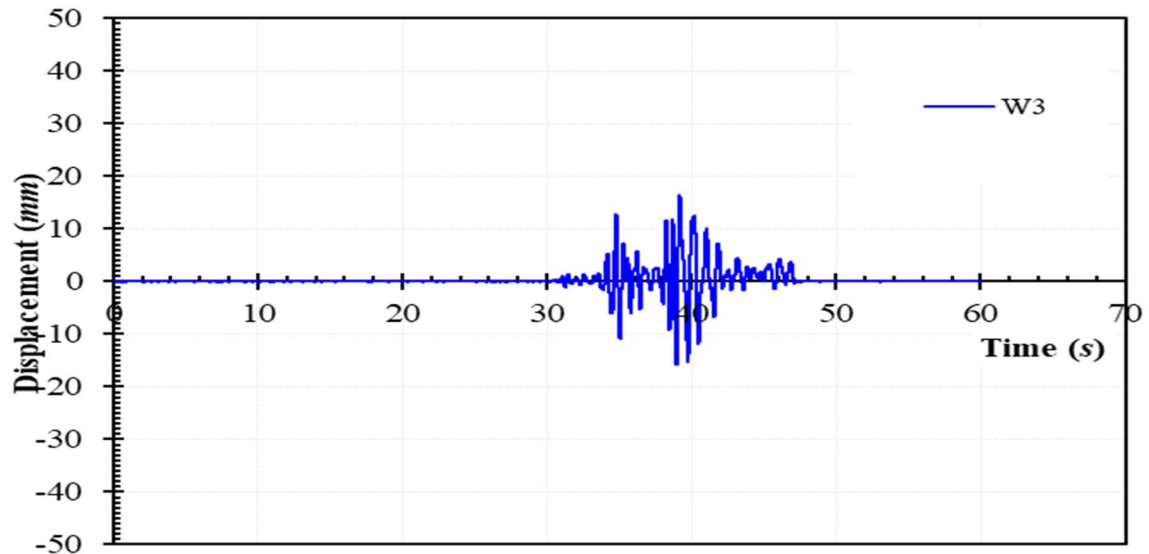
Max: 26,29 mm

Min: -25,16 mm

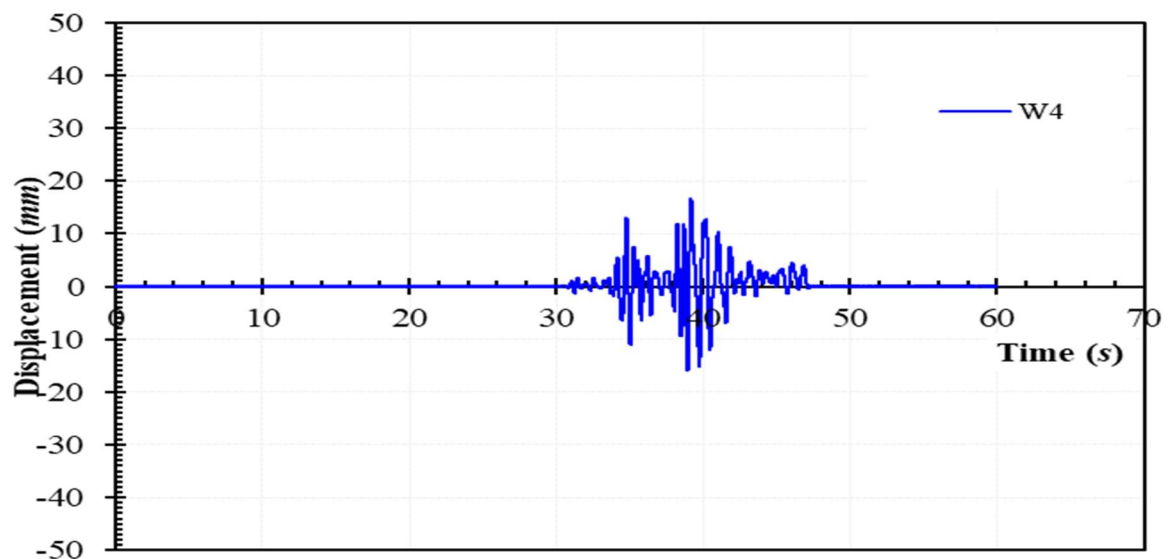
W 2

Max: 25,94 mm

Min: -25,25 mm



(a)



(b)

Figure 3.8.8 Characteristic results for phase A (0,8g earthquake): (a) Draw wire sensor W3 and (b) Draw wire sensor W4

Figure 3.8.8 shows draw wire sensors W3 and W4. More specifically, draw wire sensor W3 is located on the foundation, on the left side and draw wire sensor 4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor W3 is 16,39 mm while the minimum is -15,84 mm. The maximum movement detected by draw wire sensor W4 is 16,65 mm while the minimum is -15,80 mm.

W 3

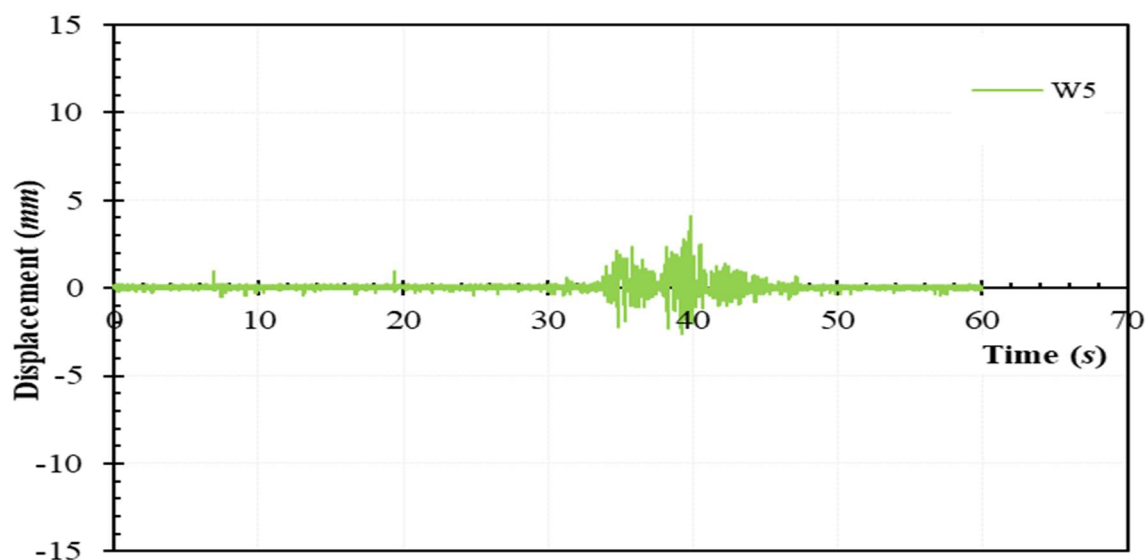
Max: 16,39 mm

Min: -15,84 mm

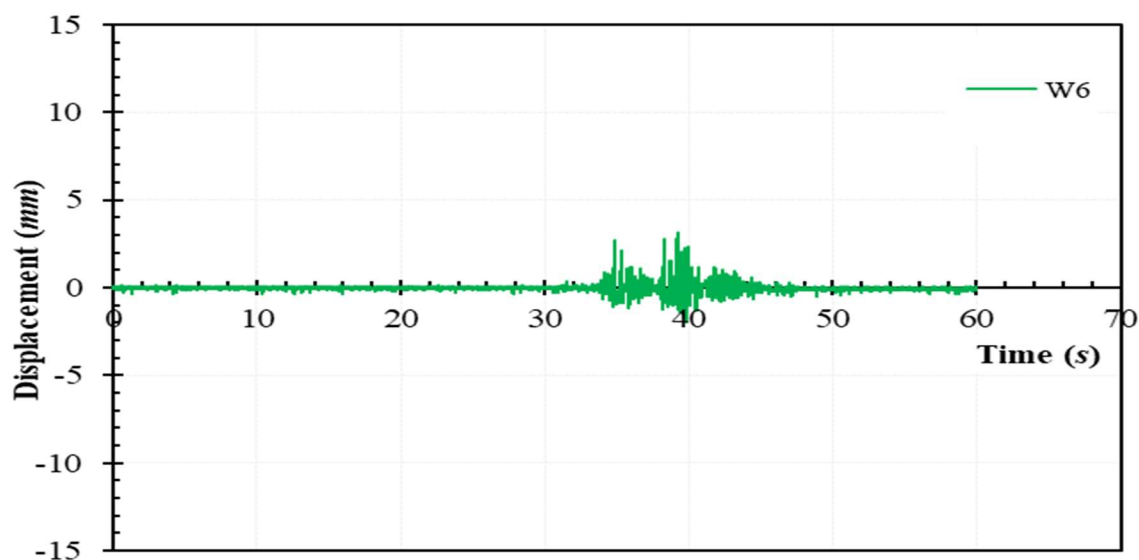
W 4

Max: 16,65 mm

Min: -15,80 mm



(a)



(b)

Figure 3.8.9 Characteristic results for phase A (0,8g earthquake): (a) Draw wire sensor 5 and (b) Draw wire sensor 6

Figure 3.8.9 shows draw wire sensors W5 and W6. More specifically, draw wire sensor W 5 is located along the partial masonry infill diagonal and draw wire sensor W6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W5 is 4,11 mm while the minimum is -2,62 mm. The maximum movement detected by draw wire sensor W6 is 3,10 mm while the minimum is -1,99 mm.

W 5

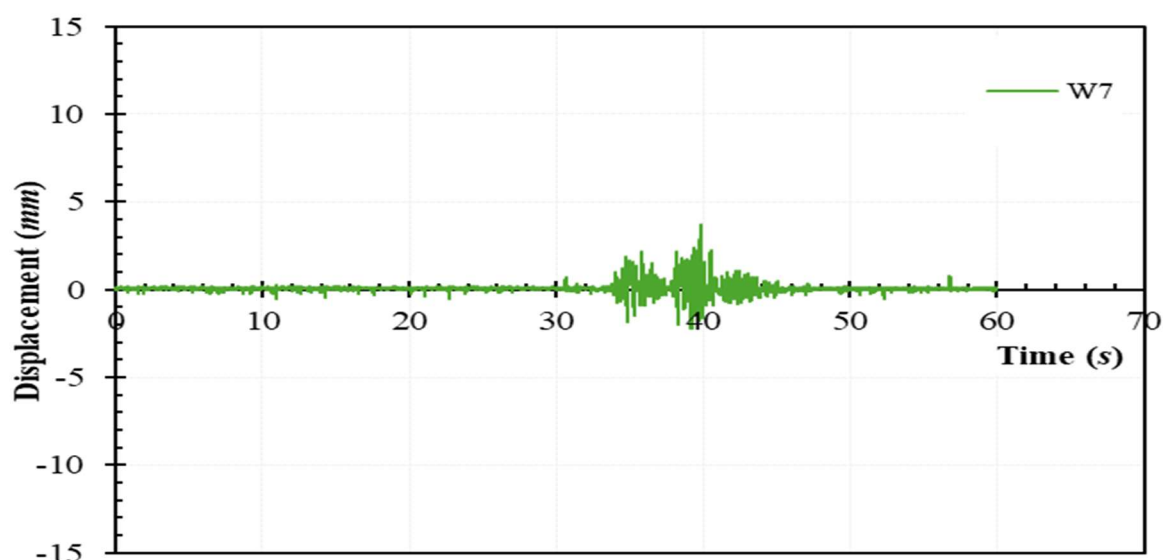
Max: 4,11 mm

Min: -2,62 mm

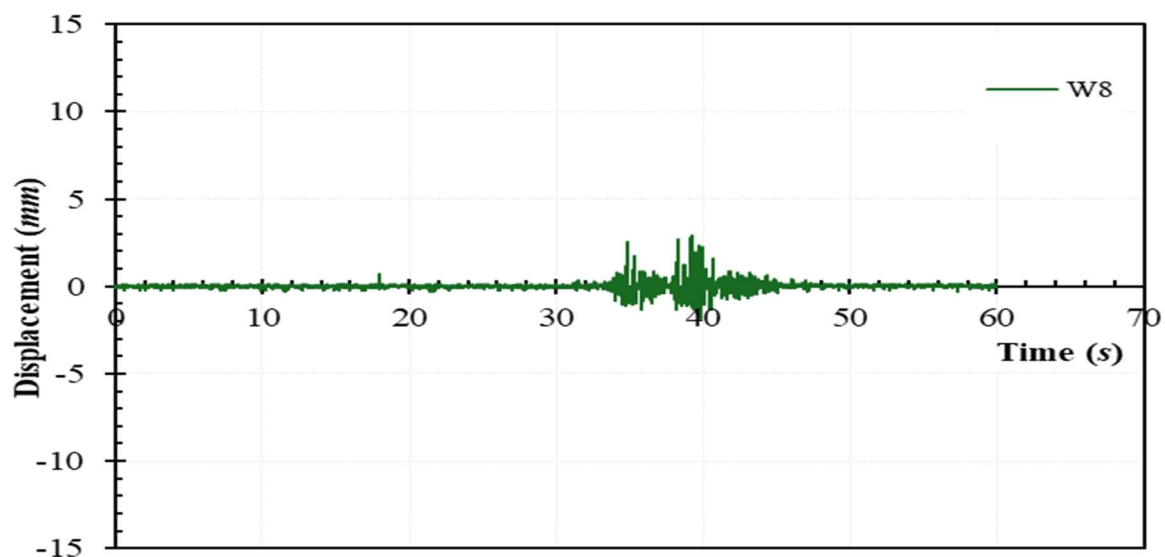
W 6

Max: 3,10 mm

Min: -1,99 mm



(a)



(b)

Figure 3.8.10 Characteristic results for phase A (0,8g earthquake): (a) Draw wire sensor 7 and (b) Draw wire sensor 8

Figure 3.8.10 shows draw wire sensors W7 and W8. More specifically, draw wire sensor W7 is located along the partial masonry infill diagonal and draw wire sensor W8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor W7 is 3,68 mm while the minimum is -2,26 mm. The maximum movement detected by draw wire sensor W8 is 2,92 mm while the minimum is -1,86 mm.

W 7

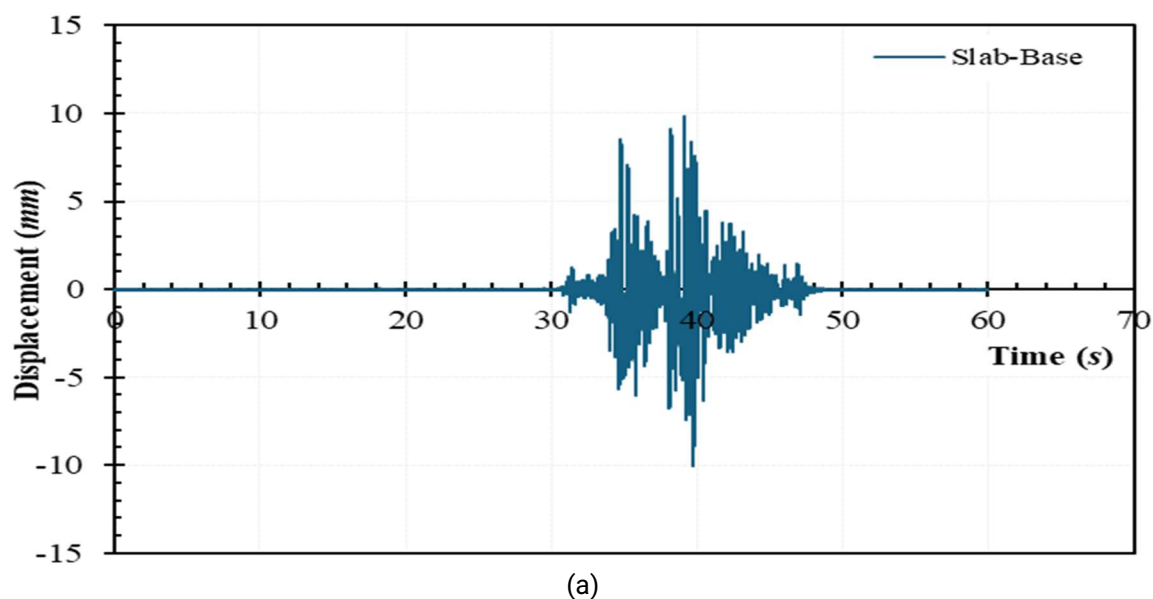
Max: 3,68 mm

Min: -2,26 mm

W 8

Max: 2,92 mm

Min: -1,86 mm



(a)

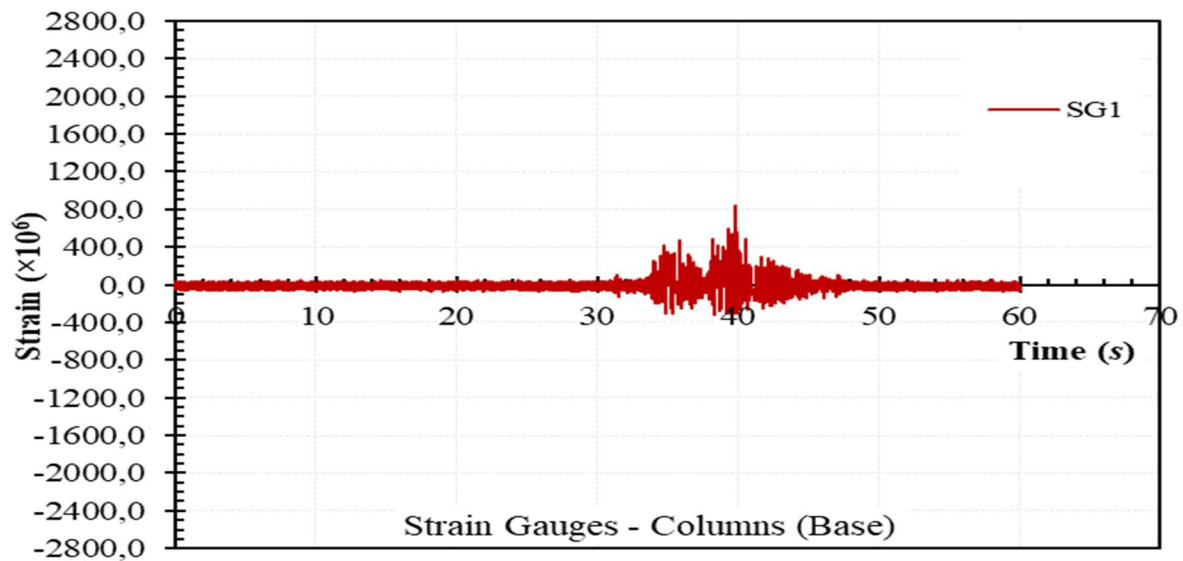
Figure 3.8.11 Characteristic results for phase A (0,8g earthquake): (a) Diagram of displacement Slab - Base

Figure 3.8.11 shows slab - base displacement. More specifically, the maximum drift detected is 8,04 ‰ while the minimum is -8,22 ‰. The residual drift is -0,03 mm.

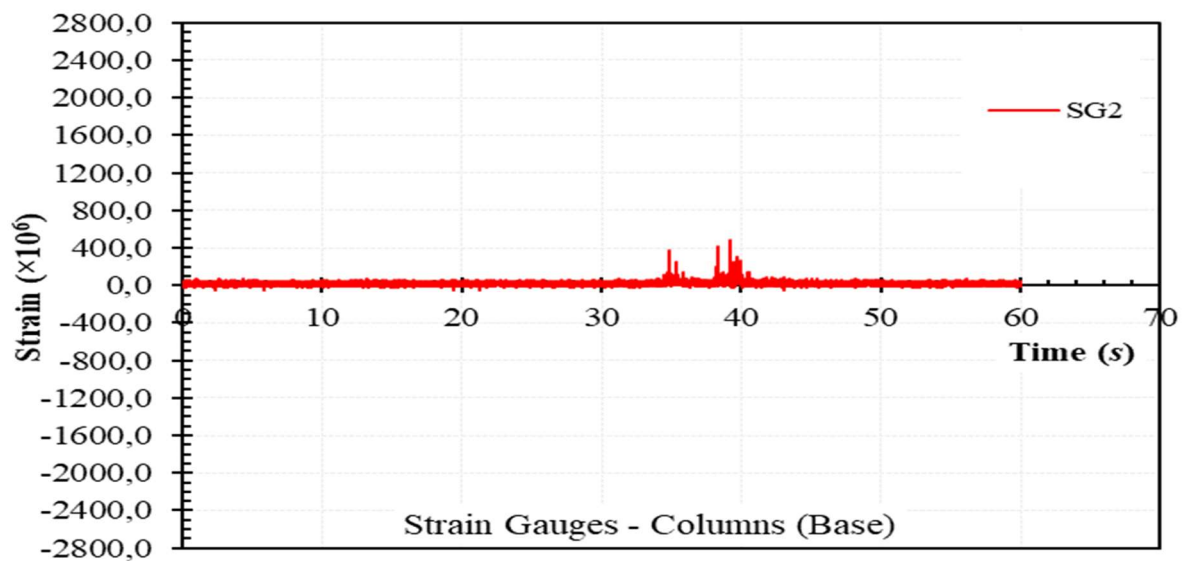
Maximum drift (‰): 8,04 ($9,849 \text{ m} / 1,225 \text{ m} = 8,04 \text{ ‰}$)

Minimum drift (‰): -8,22

Residual drift: -0,03 mm



(a)



(b)

Figure 3.8.12 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 1 and (b) strain gauge 2

Strain gauges detect strain. The strain gauges shown in the figures 3.8.12, 3.8.13, 3.8.14 and 3.8.19 are located in the longitudinal reinforcement, on the underside. More specifically, strain gauge SG1 has maximum strain $839,26\mu\text{strain}$ and minimum strain $-320,44\mu\text{strain}$. The residual strain is $-15,26\mu\text{strain}$. Strain gauge SG2 has maximum deformation $488,30\mu\text{strain}$ and minimum $-45,78\mu\text{strain}$. The residual strain is $15,26\mu\text{strain}$. Strain gauge SG3 has $381,48\mu\text{strain}$ and $-91,56\mu\text{strain}$ maximum and minimum strain respectively. The residual strain is $-15,26\mu\text{strain}$. Strain gauge SG4 as we can see in figure 3.8.13 has maximum $839,26\mu\text{strain}$ and minimum $-274,67\mu\text{strain}$ deformation. The residual strain is $0\mu\text{strain}$. Figure 3.8.19 shows strain gauges SG5 and SG6. Strain gauge 5 has $680,56\mu\text{strain}$ and $-2015,62\mu\text{strain}$ maximum and minimum strain respectively. Strain gauge SG5 presents $11,39\mu\text{strain}$ residual strain. Strain gauge 6 has $61,11\mu\text{strain}$ maximum strain, $-1003,52\mu\text{strain}$ minimum strain and $4,89\mu\text{strain}$ residual. Finally in figure 3.8.14 see strain gauge SG7 and SG8. Strain gauge SG7 has maximum strain

412 μ strain and SG8 has maximum strain 946,07 μ strain. Strain gauge SG7 has -76,30 μ strain minimum deformation and SG8 has -320,44 μ strain. The residual strain for strain gauge SG7 and SG8 is 15,26, 0 respectively.

Sg 1

Max: 839,26 μ strain

Min: -320,44 μ strain

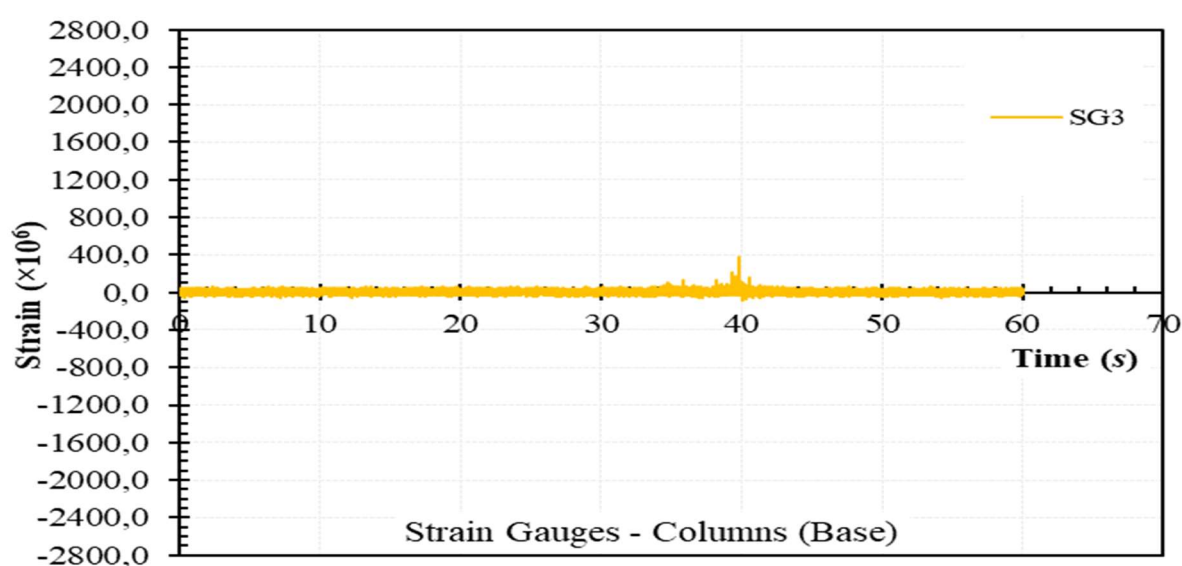
Residual: -15,26 μ strain

Sg 2

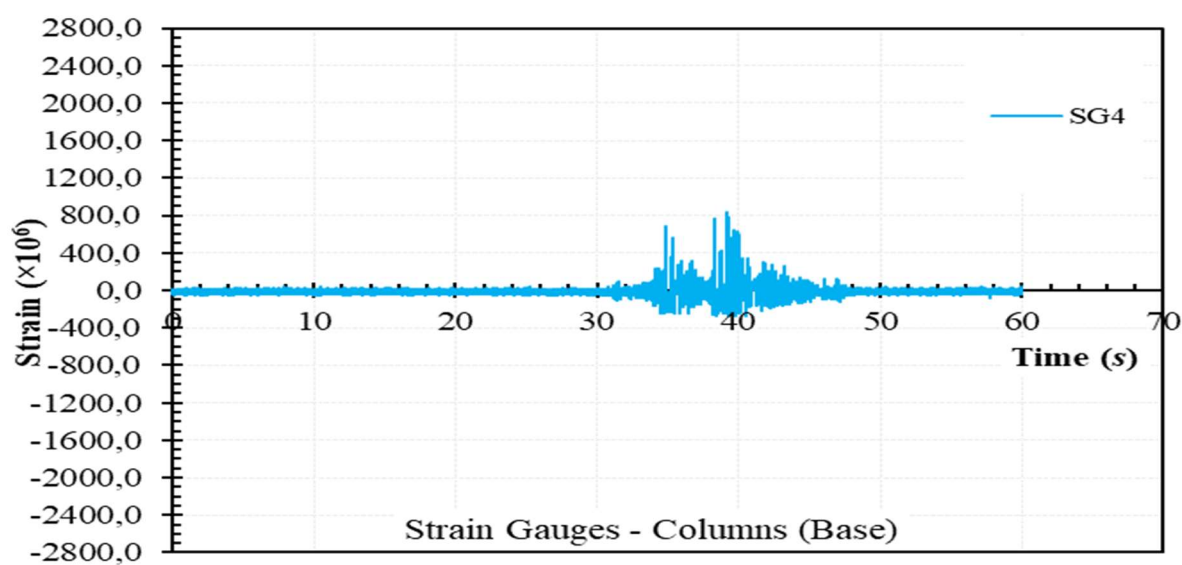
Max: 488,30 μ strain

Min: -45,78 μ strain

Residual: 15,26 μ strain



(a)



(b)

Figure 3.8.13 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 3 and (b) strain gauge 4

Sg 3

Max: 381,48 μ strain

Min: -91,56 μ strain

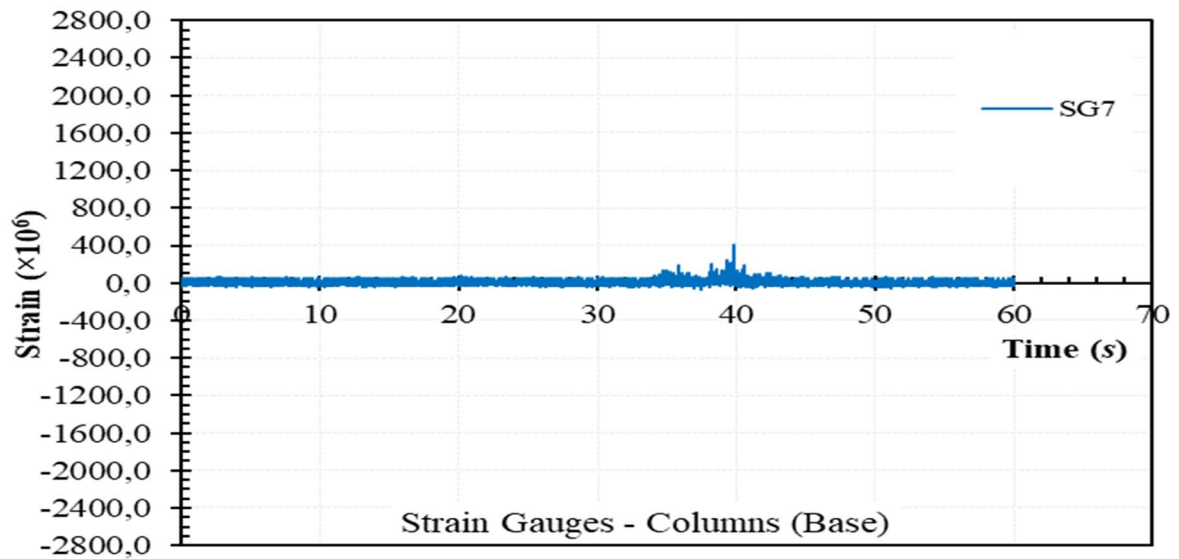
Residual: -15,26 μ strain

Sg 4

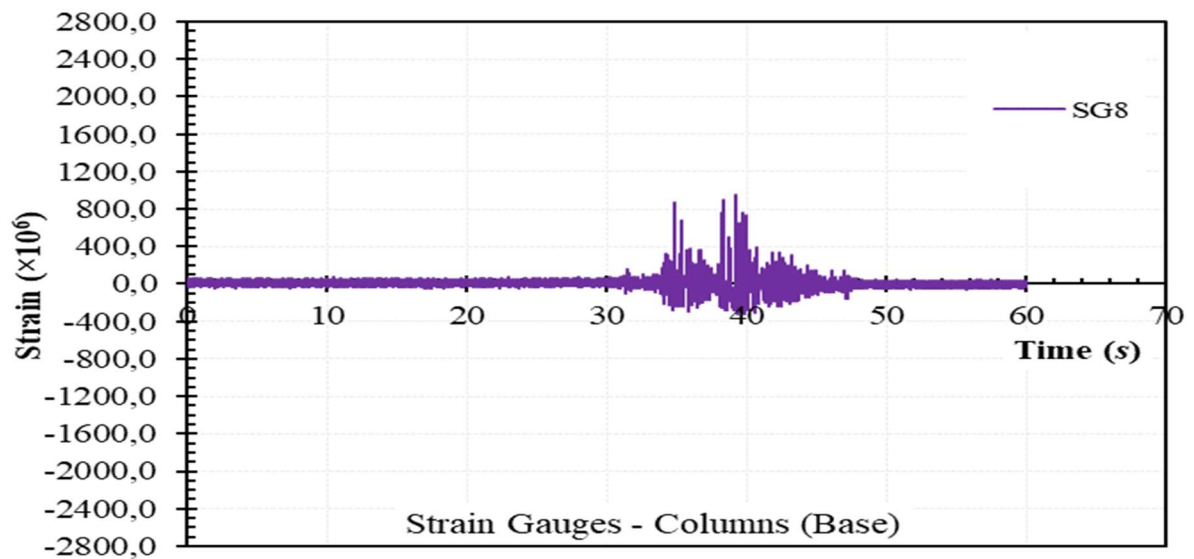
Max: 839,26 μ strain

Min: -274,67 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.8.14 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 7 and (b) strain gauge 8

Sg 7

Max: 412,00 μ strain

Min: -76,30 μ strain

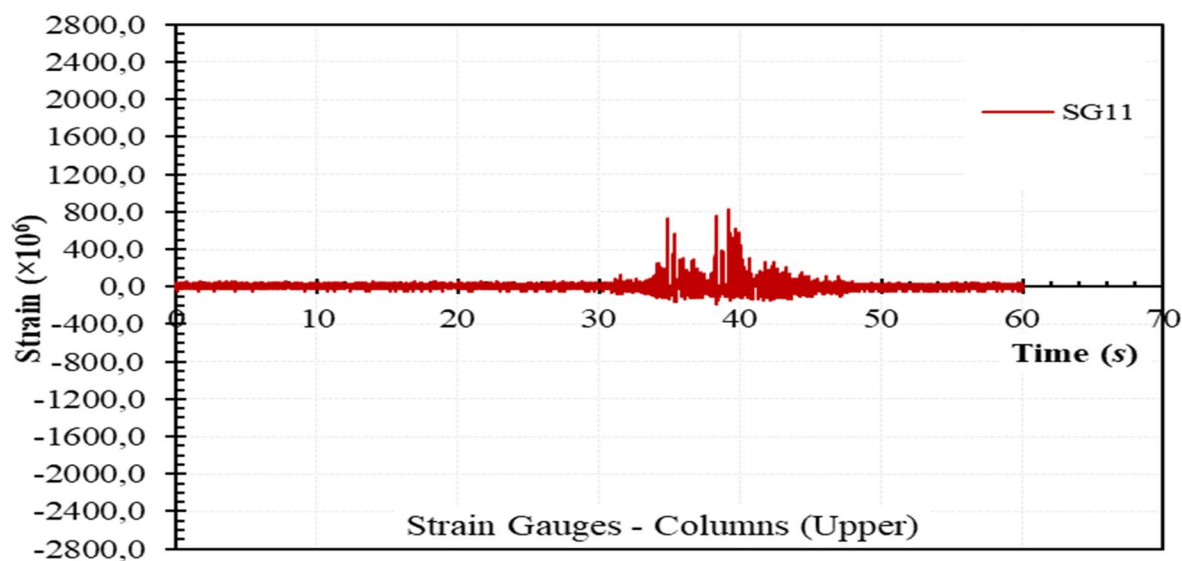
Residual: -15,26 μ strain

Sg 8

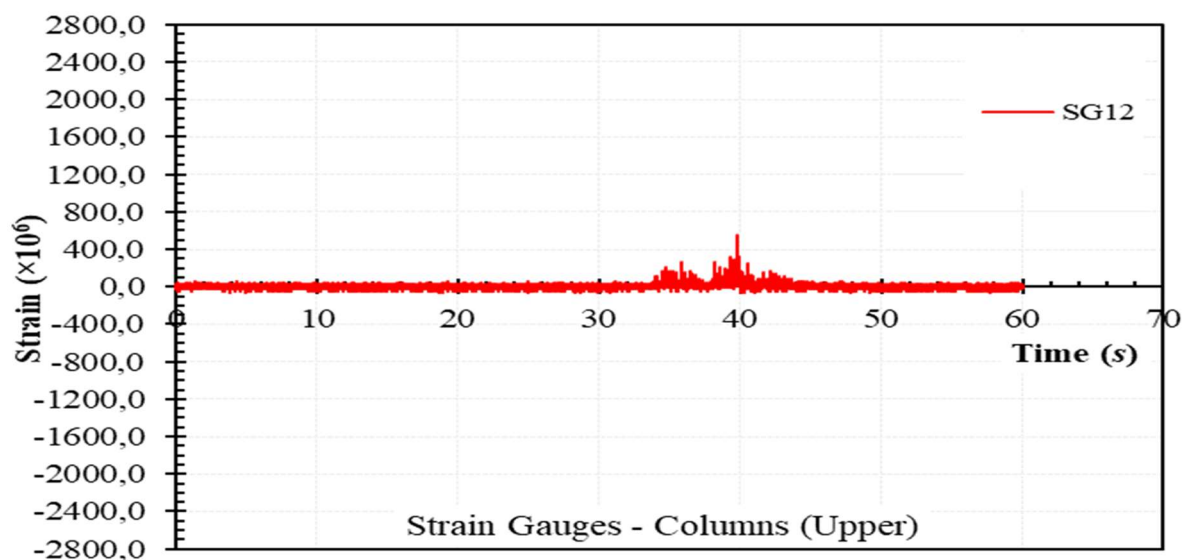
Max: 946,07 μ strain

Min: -320,44 μ strain

Residual: 0 μ strain



(a)



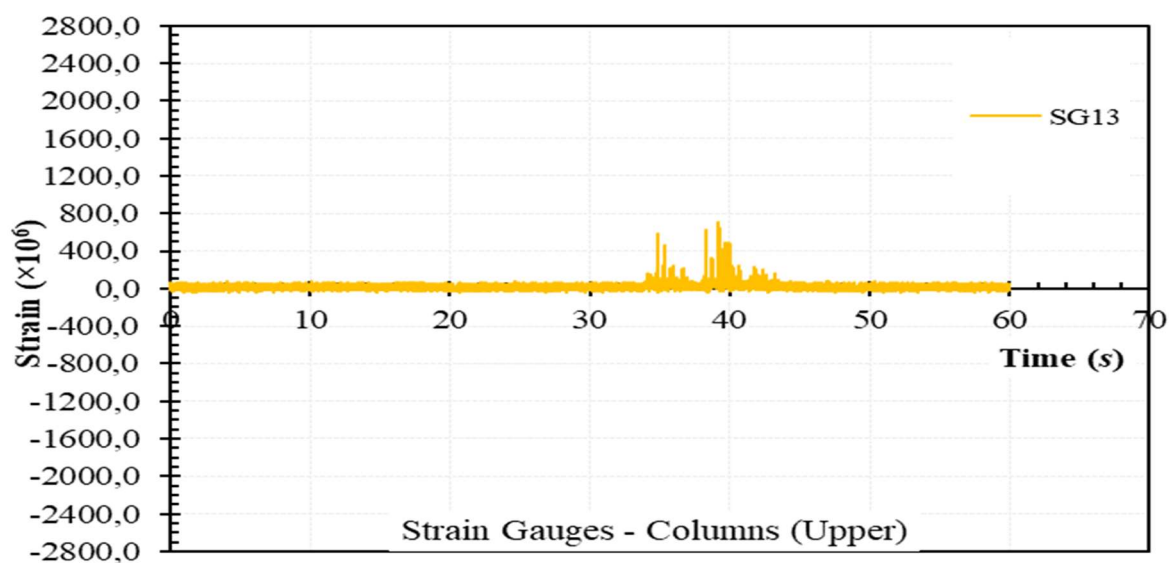
(b)

Figure 3.8.15 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 11 and (b) strain gauge 12

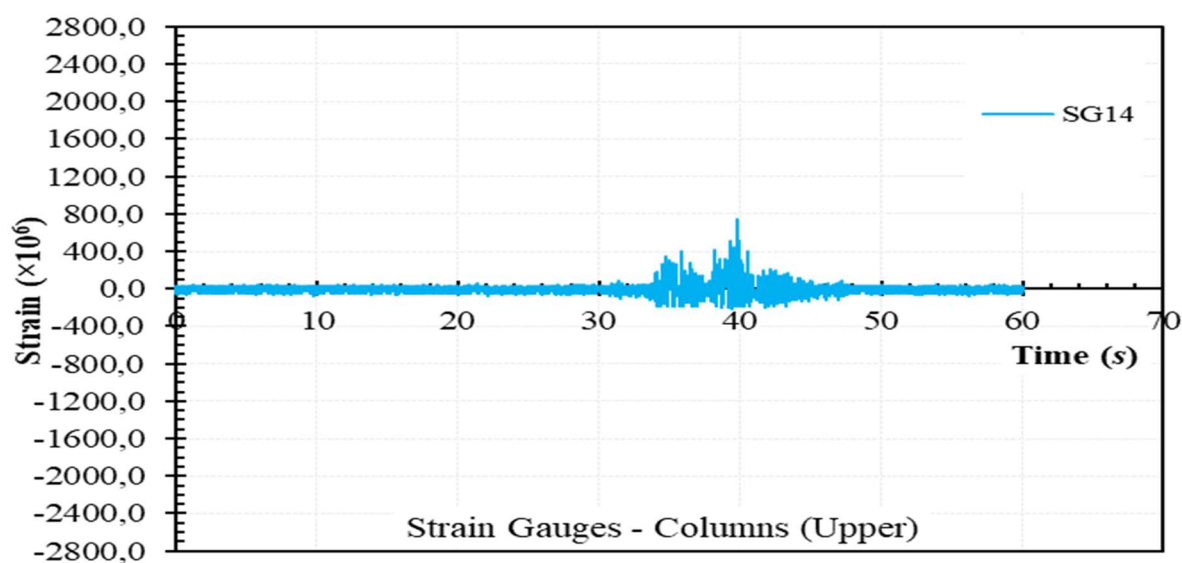
The strain gauges shown in the figures 3.8.15, 3.8.16, 3.8.17 and 3.8.20 are located in the longitudinal reinforcement, on the upper side. More specifically, strain gauge SG9 has 15,46 μ strain maximum strain, -1322,93 μ strain minimum strain and 12,21 μ strain residual. Strain gauge SG10 has

250,05 μ strain maximum strain, -1521,18 μ strain minimum strain and 3,27 μ strain residual. Strain gauge SG11 has maximum strain 824 μ strain and minimum -183,11 μ strain deformation. The residual strain is 15,26 μ strain for strain gauge SG11. Strain gauge SG12 has maximum strain 549,33 μ strain and minimum strain -61,04 μ strain. The residual value is 0,15 μ strain. Strain gauge SG13 has maximum strain 701,93 μ strain and minimum strain -45,78 μ strain. The residual is 15,26 μ strain. Strain gauge SG14 has maximum strain 747,70 μ strain and minimum strain -213,63 μ strain. The residual is 15,26 μ strain. Finally strain gauges SG15 has maximum strain 900,30 μ strain and minimum strain -228,89 μ strain. The residual is -15,26 μ strain. Strain gauge SG16 has maximum strain 610,37 μ strain, minimum strain -152,59 μ strain and residual strain -30,52 μ strain.

Sg 11Max: 824,00 μ strainMin: -183,11 μ strainResidual: 15,26 μ strain**Sg 12**Max: 549,33 μ strainMin: -61,04 μ strainResidual: 0,15 μ strain



(a)



(b)

Figure 3.8.16 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 13 and (b) strain gauge 14

Sg 13

Max: 701,93 μ strain

Min: -45,78 μ strain

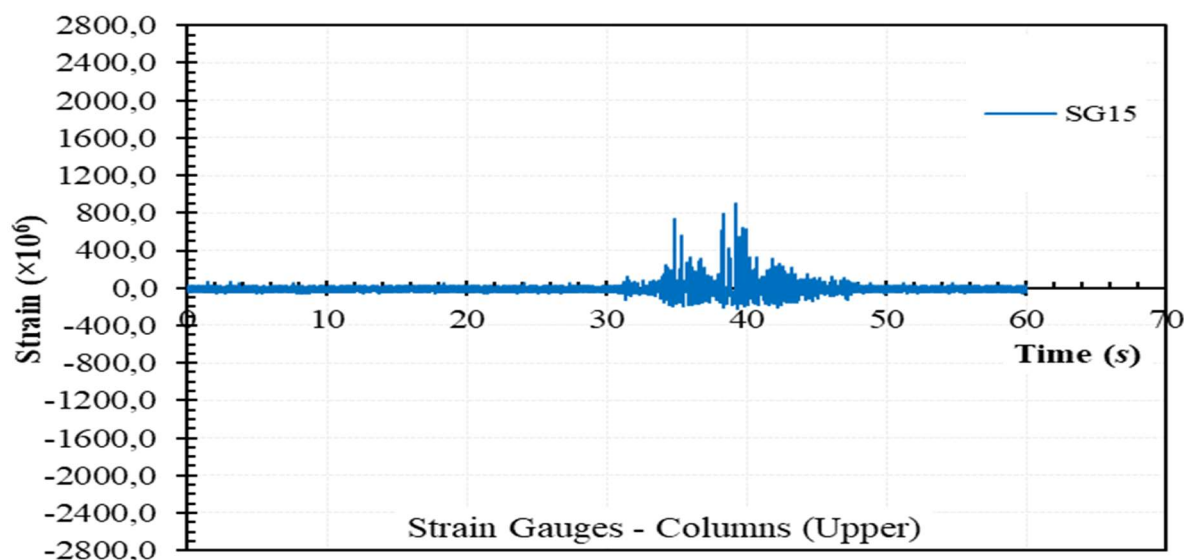
Residual: 15,26 μ strain

Sg 14

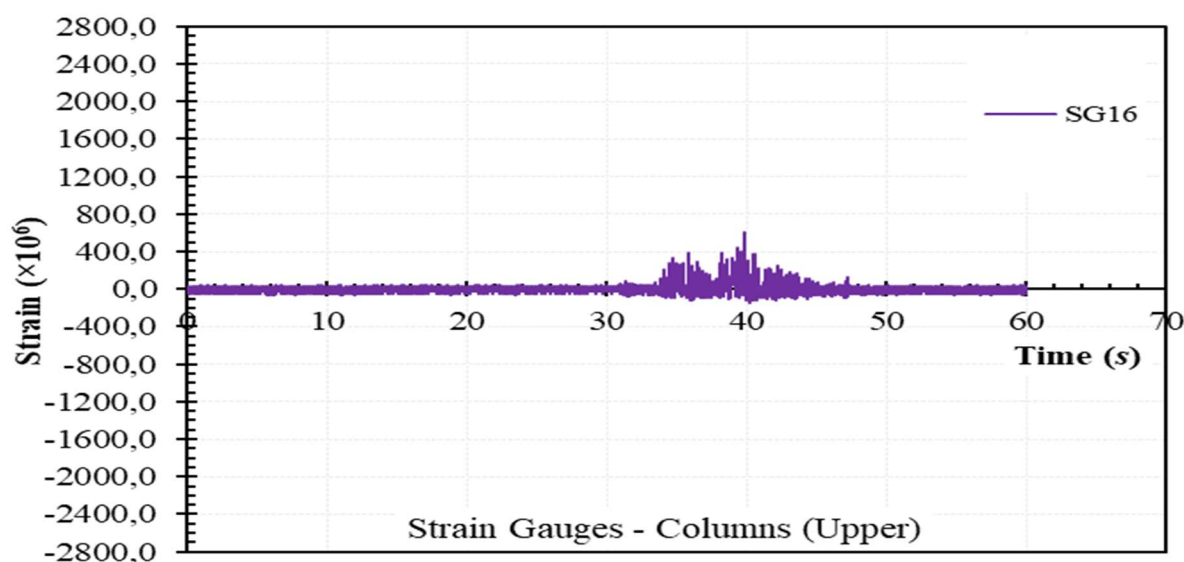
Max: 747,70 μ strain

Min: -213,63 μ strain

Residual: 15,26 μ strain



(a)



(b)

Figure 3.8.17 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 15 and (b) strain gauge 16

Sg 15

Max: 900,30 μ strain

Min: -228,89 μ strain

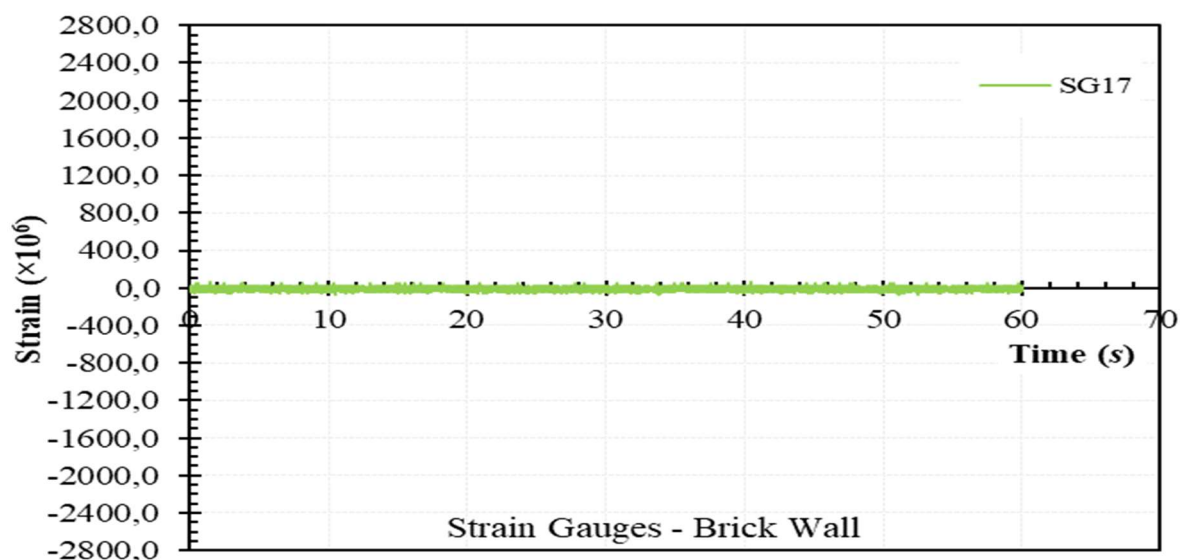
Residual: -15,26 μ strain

Sg 16

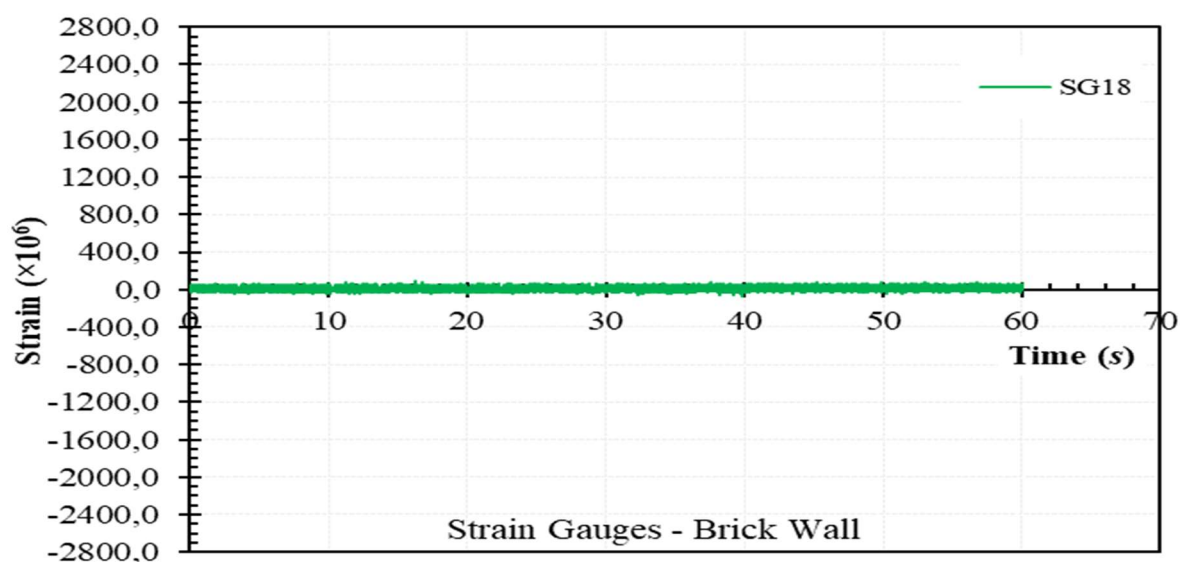
Max: 610,37 μ strain

Min: -152,59 μ strain

Residual: -30,52 μ strain



(a)



(b)

Figure 3.8.18 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 17 and (b) strain gauge 18

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauges SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge SG17 has 61,04 μ strain maximum strain. Strain gauge SG17 has minimum deformation -76,30 μ strain and strain gauge 18 -76,30 μ strain. Strain gauge SG18 has maximum strain 91,56 μ strain. Finally strain gauge SG17 presents 15,26 μ strain residual. Strain gauge SG18 presents 45,78 μ strain residual.

Sg 17

Max: 61,04 μ strain

Min: -76,30 μ strain

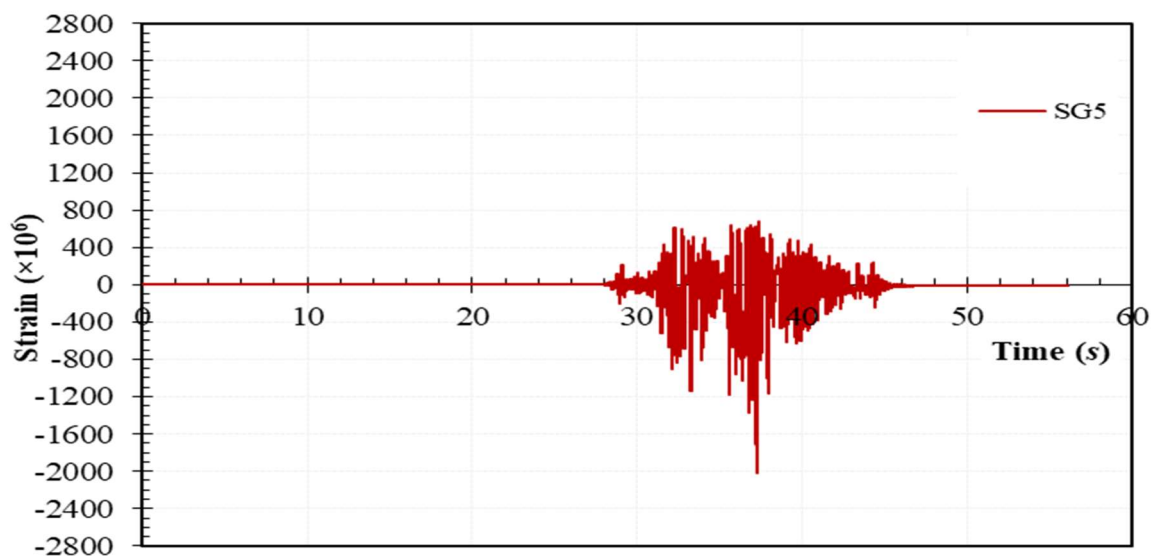
Residual: 15,26 μ strain

Sg 18

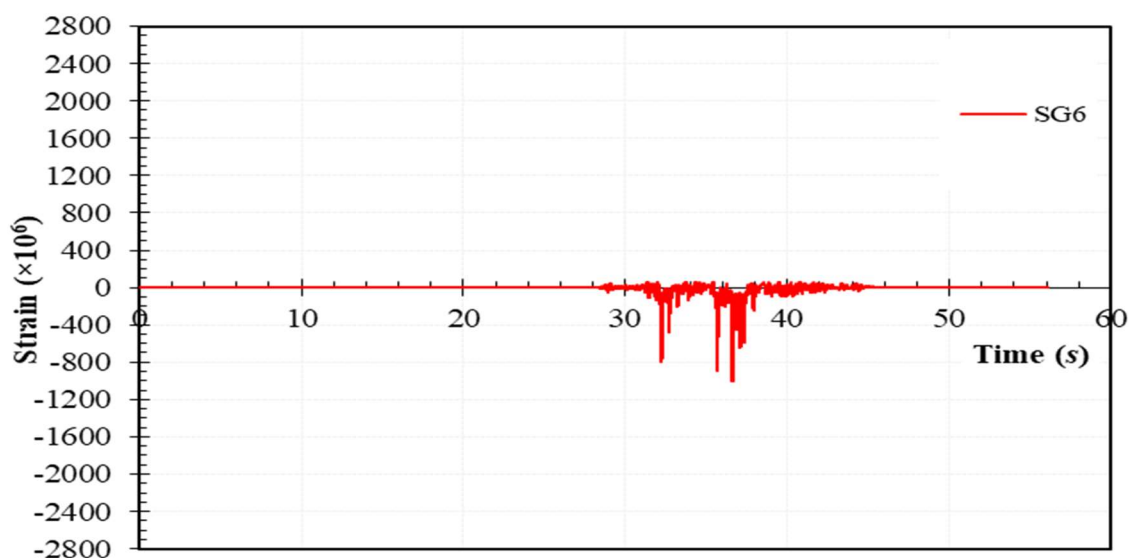
Max: 91,56 μ strain

Min: -76,30 μ strain

Residual: 45,78 μ strain



(a)



(b)

Figure 3.8.19 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 5 and (b) strain gauge 6

Sg 5

Max: 680,56 μ strain

Min: -2015,62 μ strain

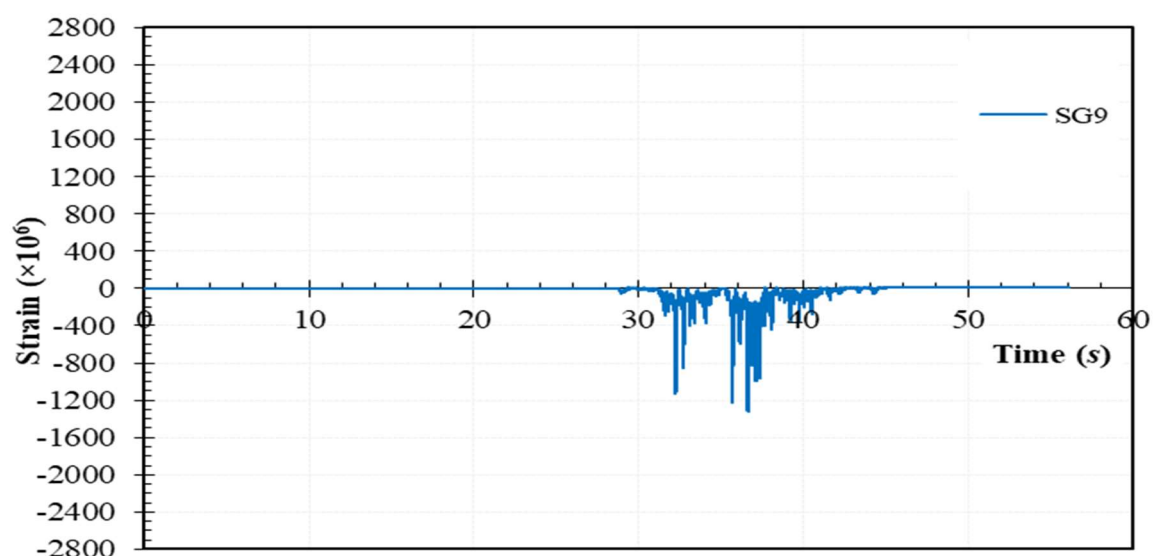
Residual: -11,39 μ strain

Sg 6

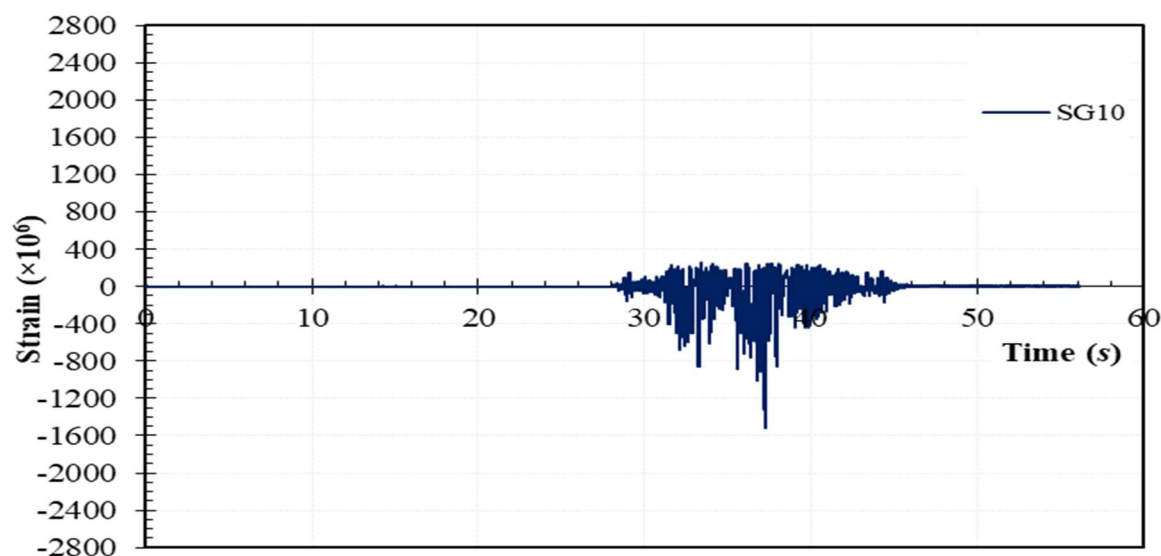
Max: 61,11 μ strain

Min: -1003,52 μ strain

Residual: 4,89 μ strain



(a)



(b)

Figure 3.8.20 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 9 and (b) strain gauge 10

Sg 9

Max: 15,46 μ strain

Min: -1322,93 μ strain

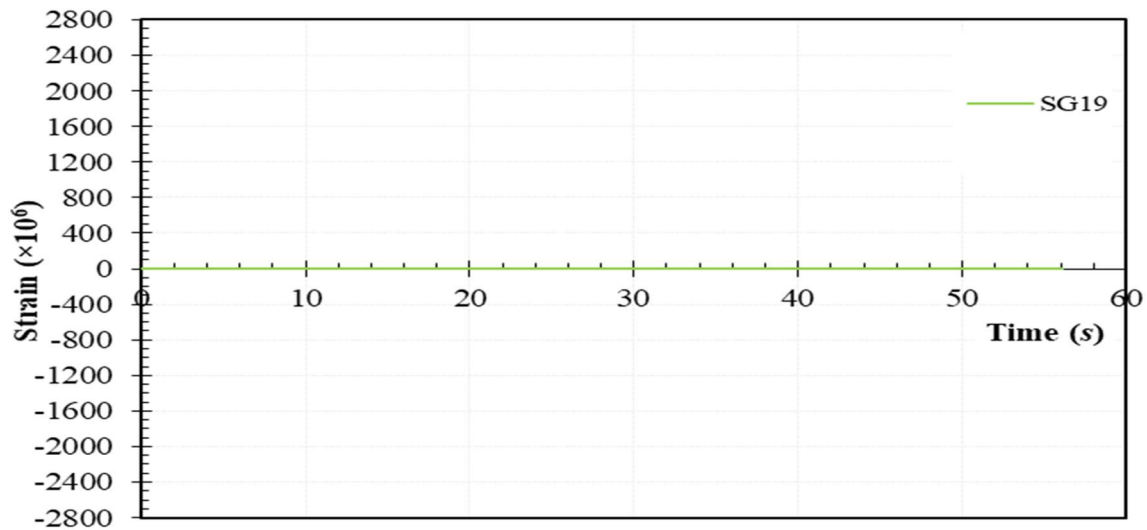
Residual: 12,21 μ strain

Sg 10

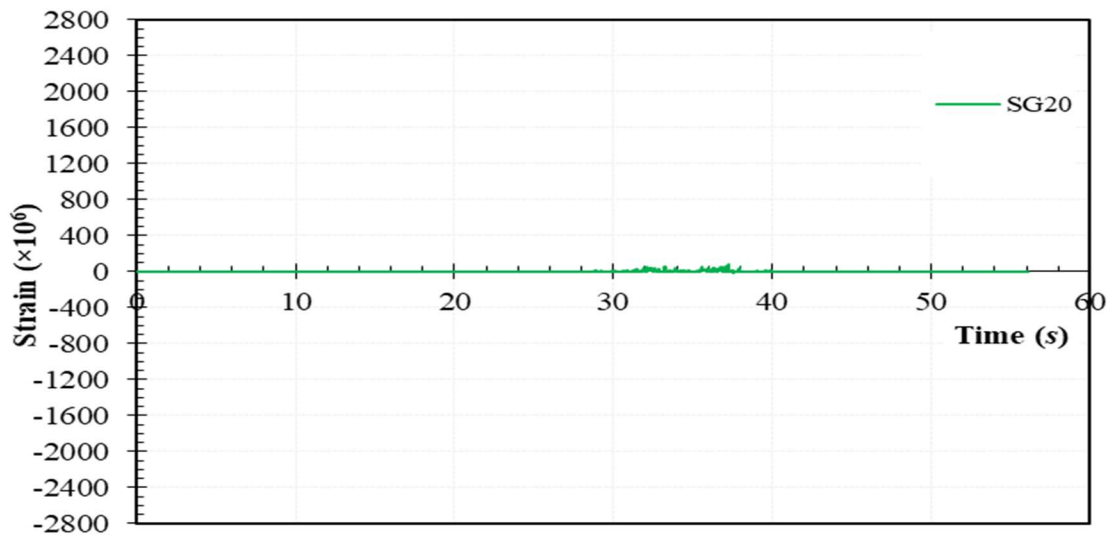
Max: 250,05 μ strain

Min: -1521,18 μ strain

Residual: 3,27 μ strain



(a)



(b)

Figure 3.8.21 Characteristic results for phase A (0,8g earthquake) (a) strain gauge 19 and (b) strain gauge 20

Strain gauge 19 is located on the centre of partial masonry 2 along direction x. Strain gauge 20 is located on the centre of partial masonry 2 along direction x. More specifically strain gauge SG19 has maximum 2,43 μ strain and minimum -2,43 μ strain. Strain gauge SG20 has maximum strain 78,89 μ strain and minimum -9,76 μ strain. The residual strain for strain gauge SG19 is -5,69 μ strain and residual for strain gauge SG20 is 0 μ strain.

Sg 19

Max: 2,43 μ strain

Min: -2,43 μ strain

Residual: -5,69 μ strain

Sg 20

Max: 78,89 μ strain

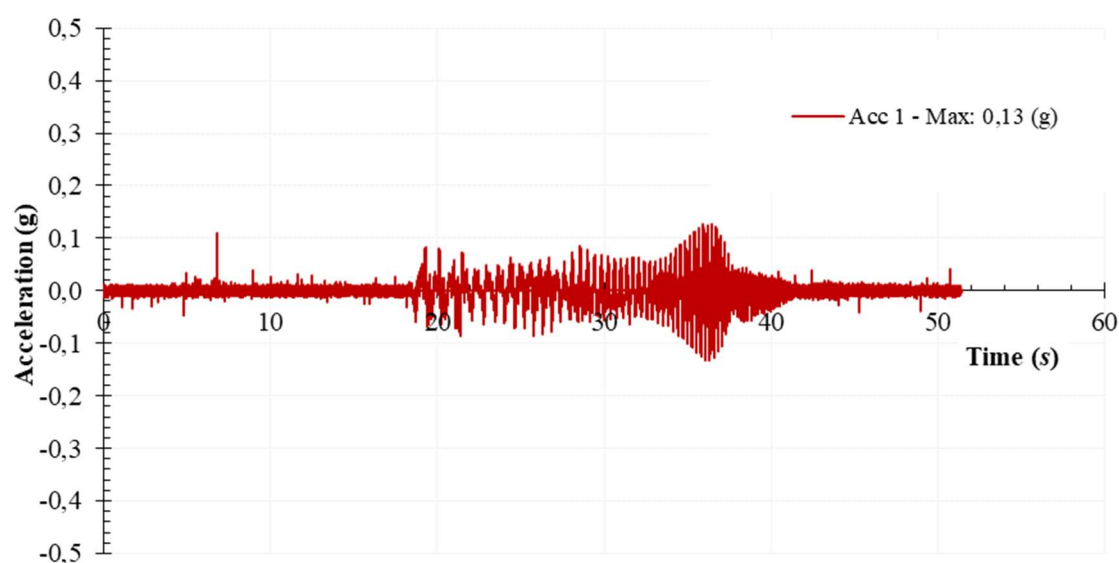
Min: -9,76 μ strain

Residual: 0 μ strain

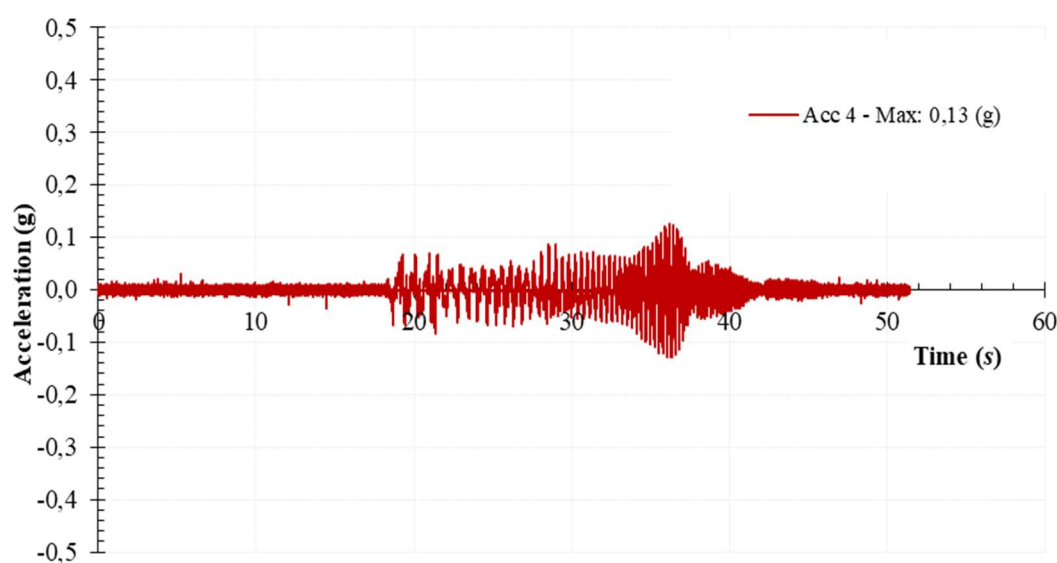
3.9) White noise test before earthquake EQ1,1g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for white noise before EQ1,1g. The max acceleration at the slab level on the accelerometer acc1 and acc4 is 0,13g for both. The max acceleration at the foundation level on the accelerometer acc10 is 0,07g.

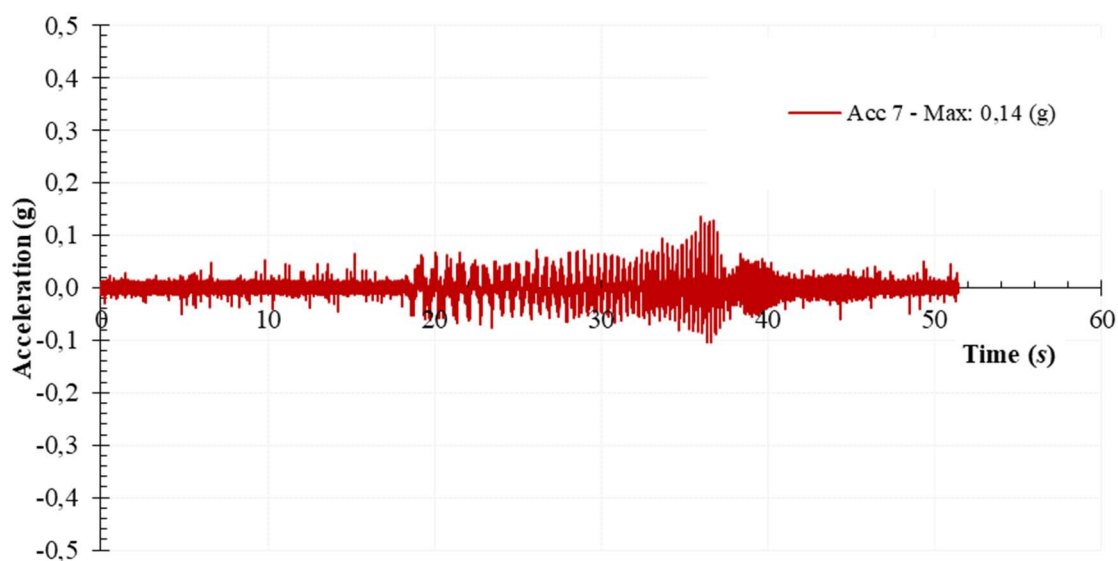


(a)

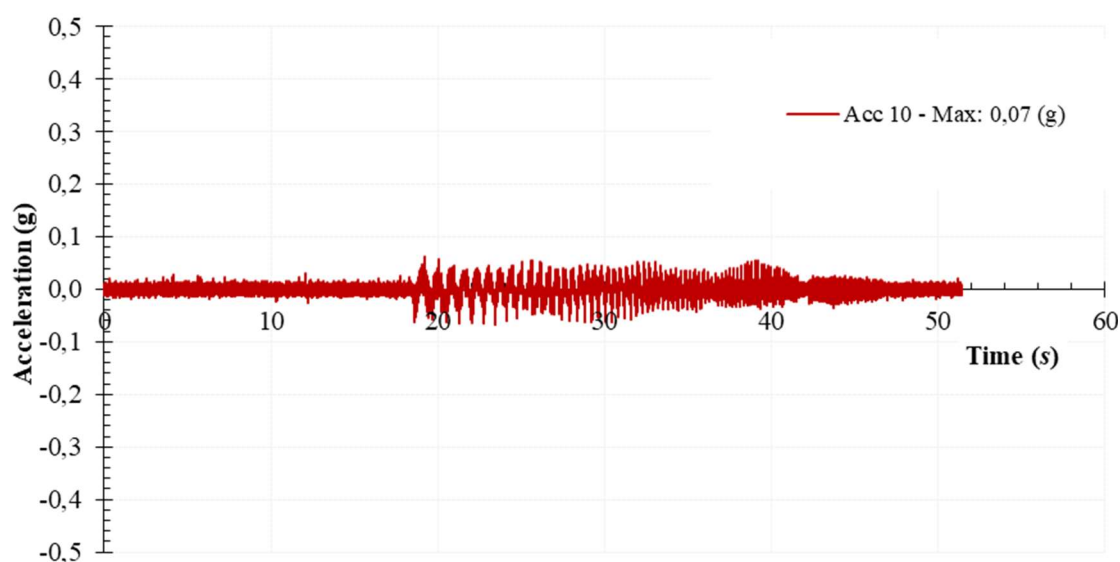


(b)

Figure 3.9.1 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 1 (b) Accelerometer 4

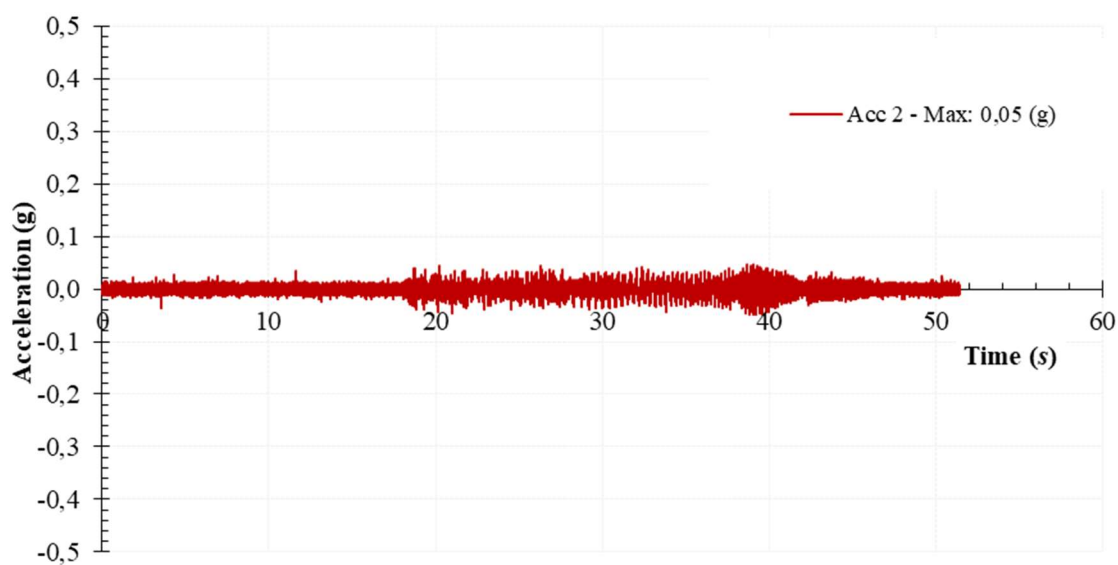


(a)

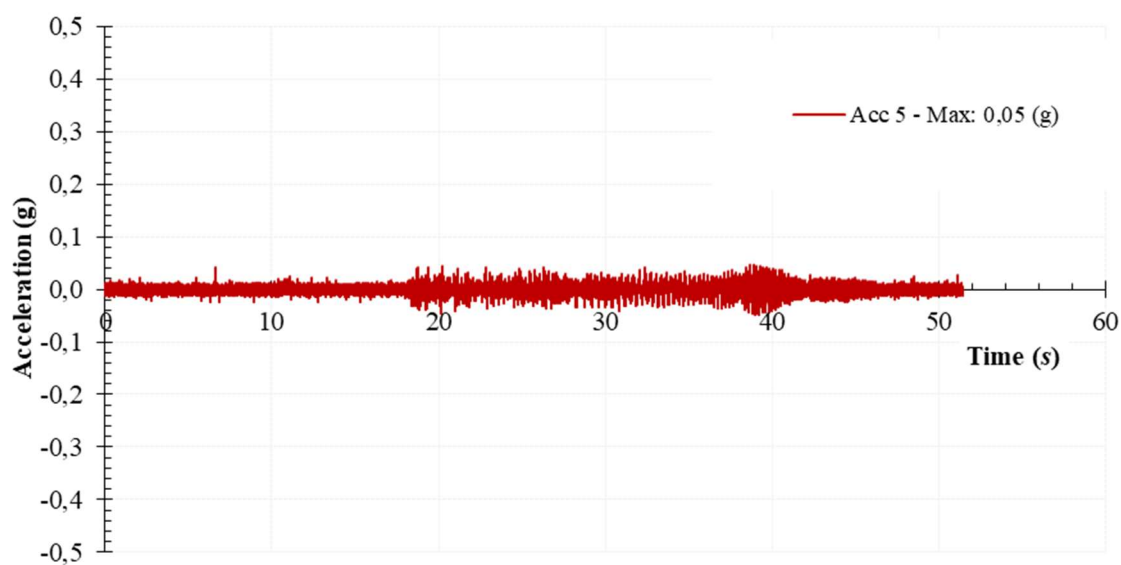


(b)

Figure 3.9.2 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

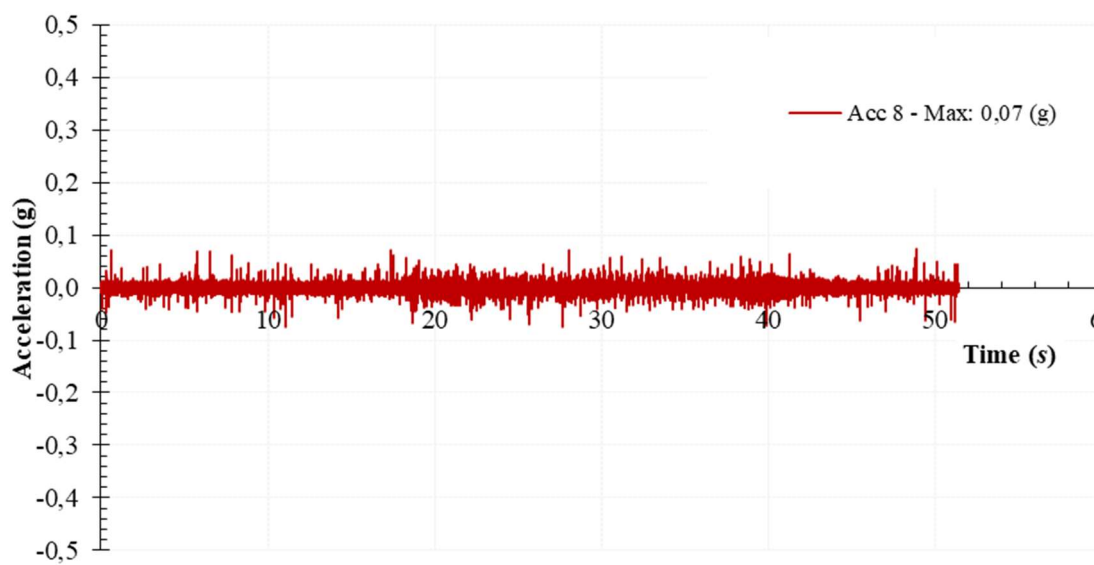


(a)

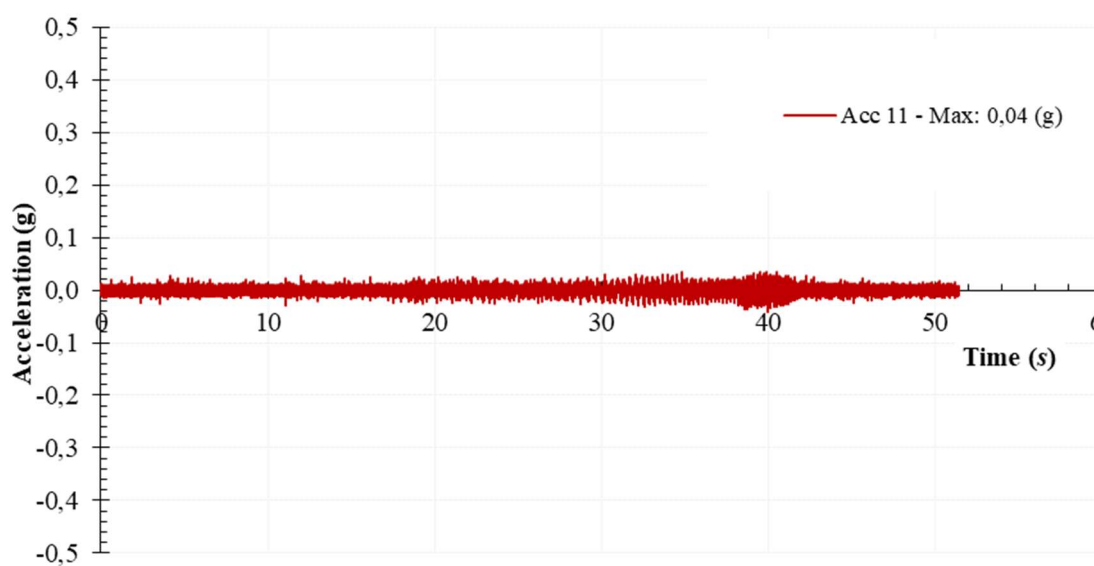


(b)

Figure 3.9.3 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

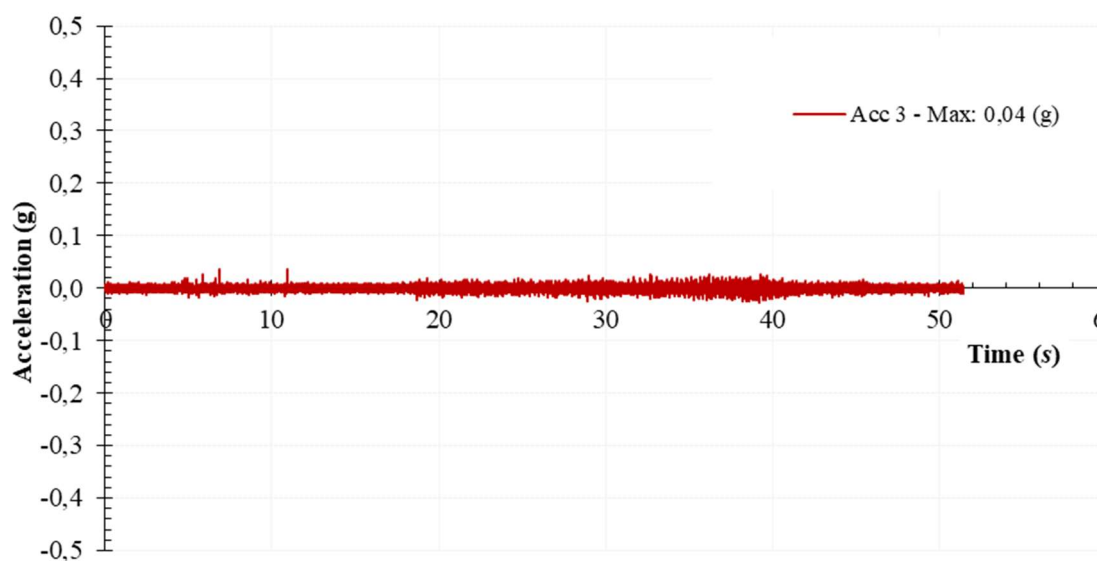


(a)

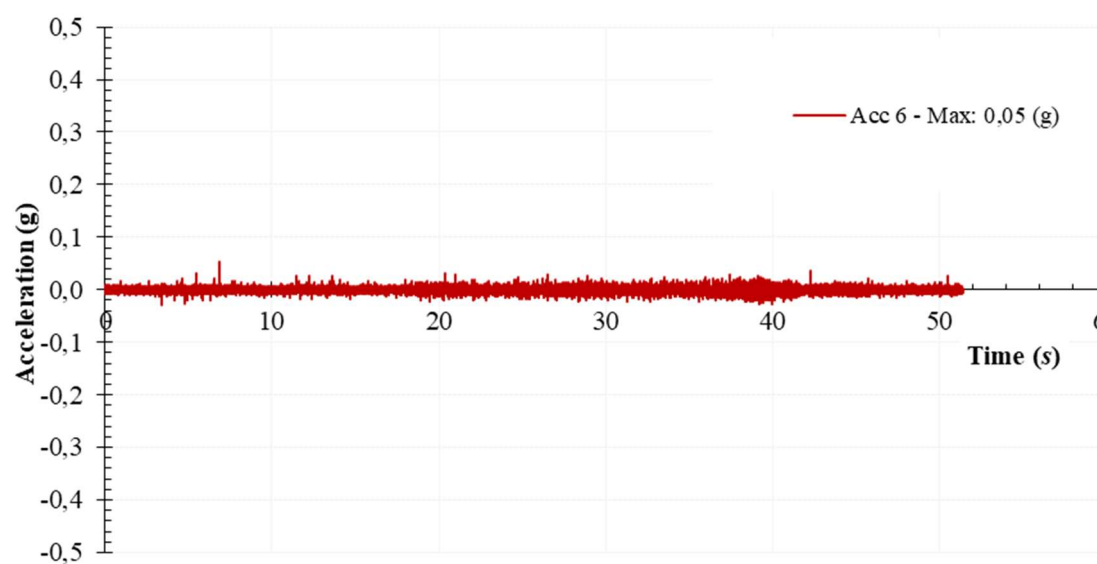


(b)

Figure 3.9.4 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 8 (b) Accelerometer 11



(a)



(b)

Figure 3.9.5 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer 3 (b) Accelerometer 6

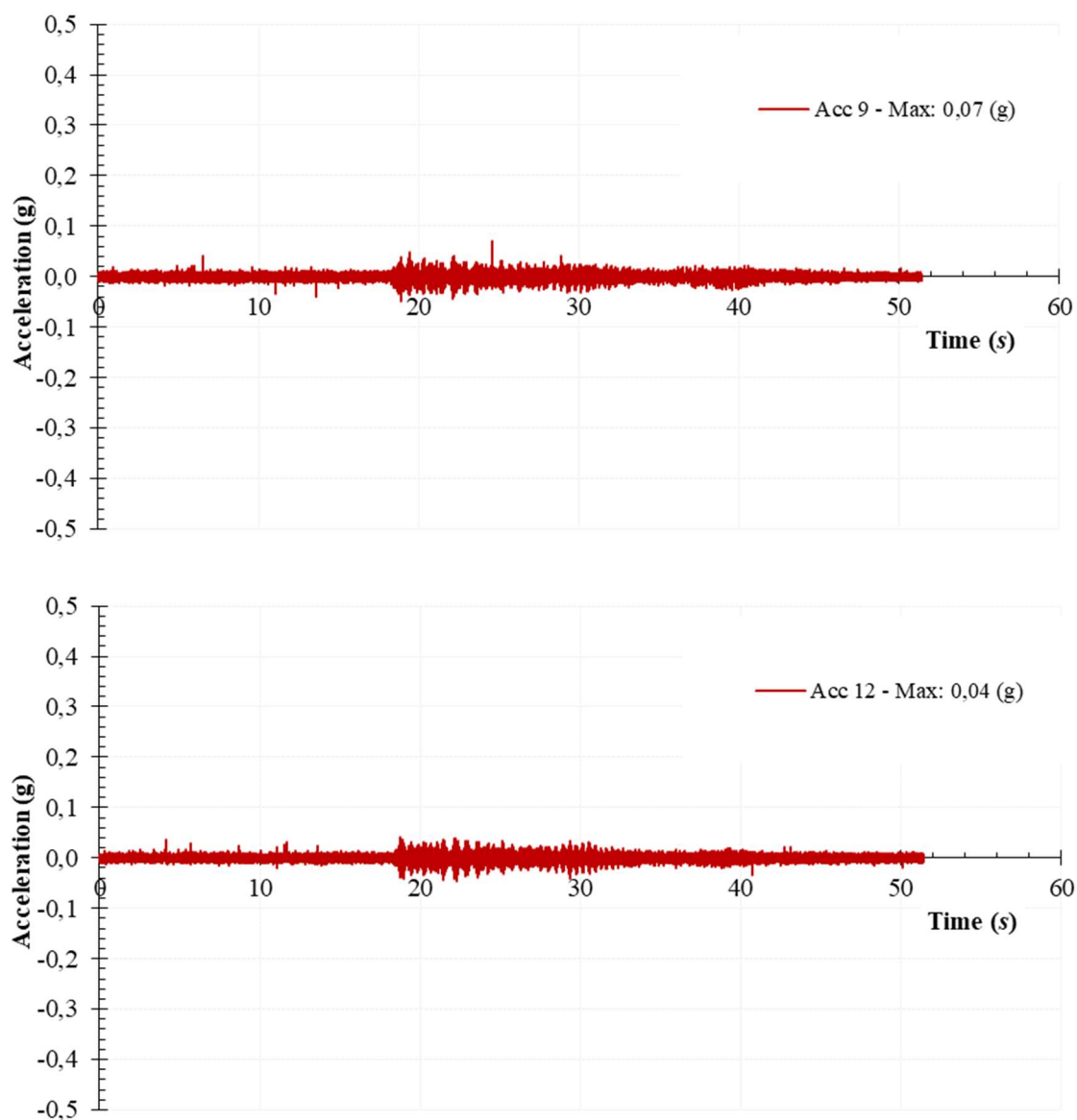
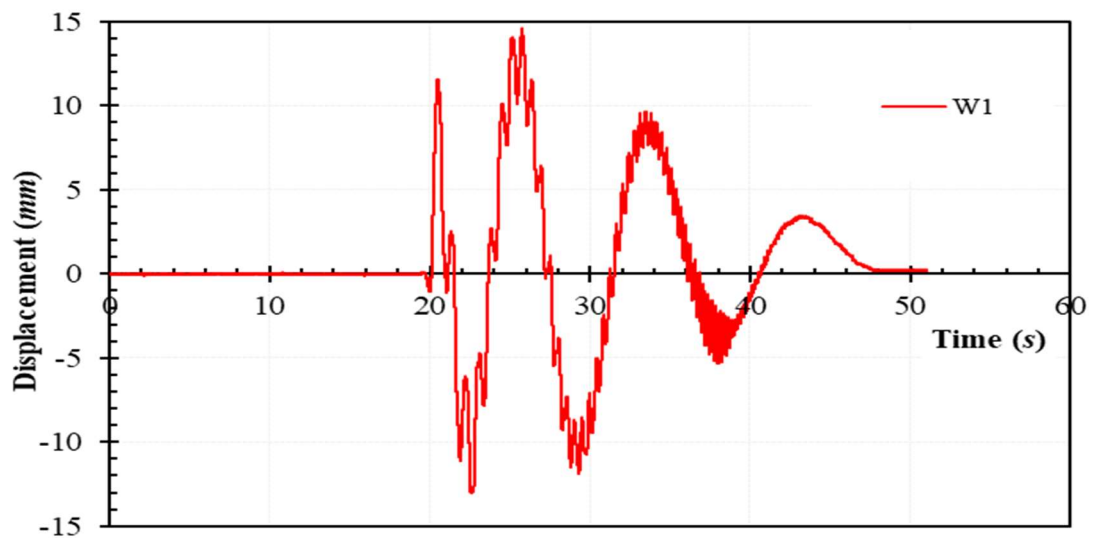
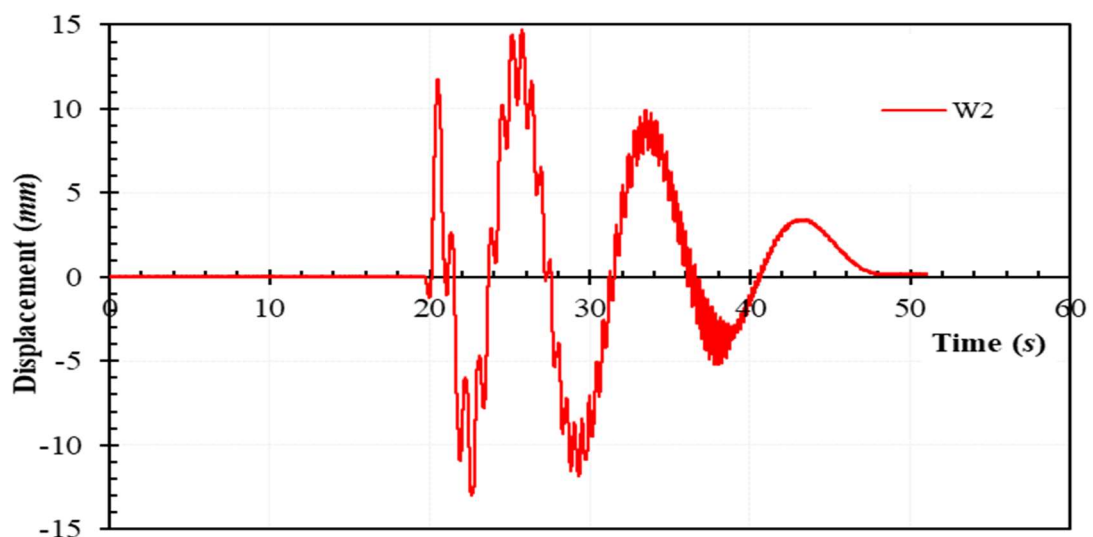


Figure 3.9.6 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Accelerometer91 (b) Accelerometer 12



(a)



(b)

Figure 3.9.7 Characteristic results for phase A (white noise before 1,1g earthquake): (a) draw wire sensor 1 and (b) draw wire sensor 2

Figure 3.9.7 shows draw wire sensors W1 and W2. More specifically, draw wire sensor W1 is located on the slab, on the left side and draw wire sensor W2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor W1 is 14,63 mm while the minimum is -13,02 mm. The maximum movement detected by draw wire sensor 2 is 14,76 mm while the minimum is -12,97 mm.

W1

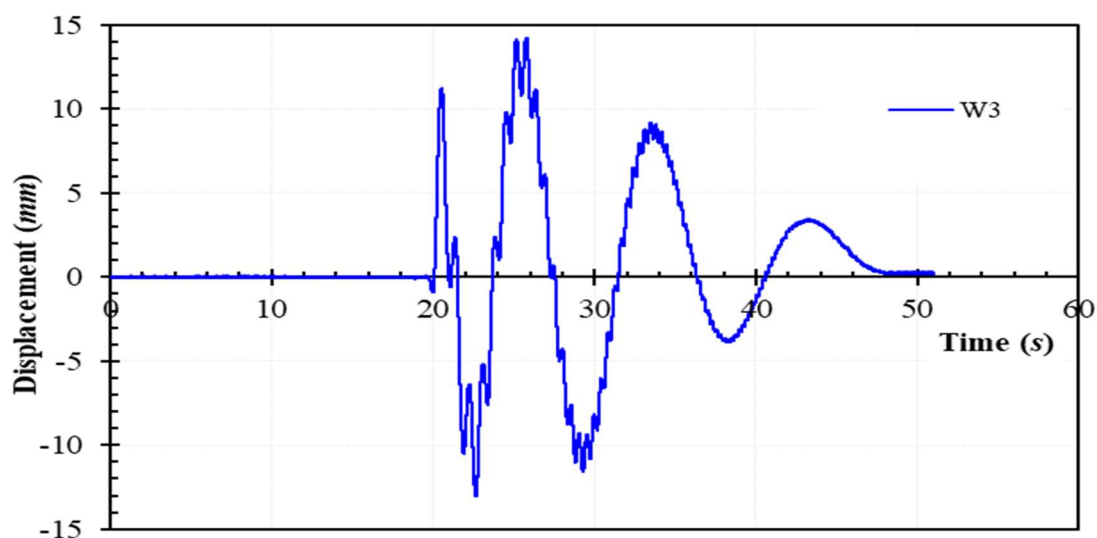
Max: 14,63 mm

Min: -13,02 mm

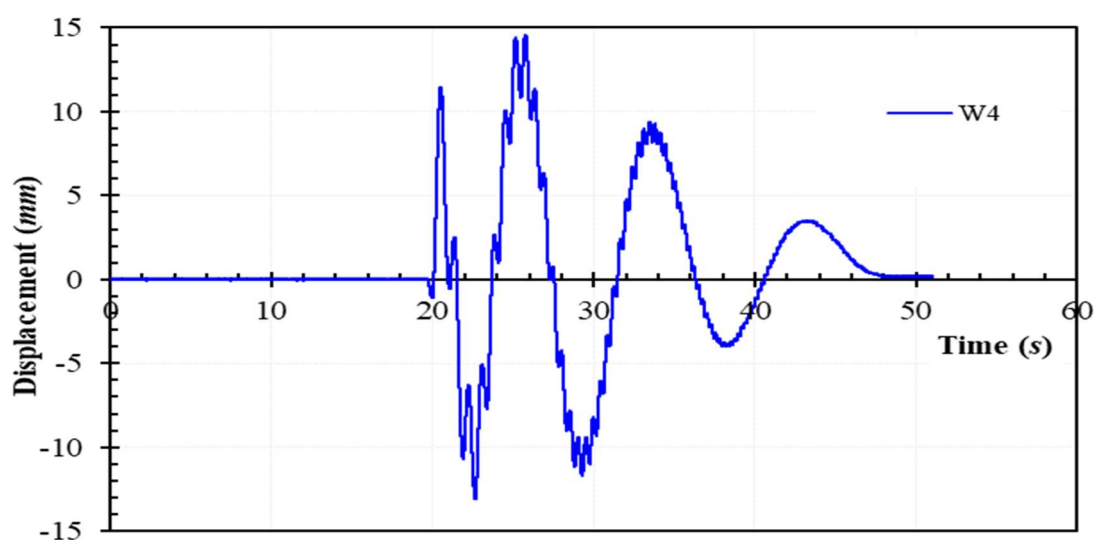
W2

Max: 14,76 mm

Min: -12,97 mm



(a)



(b)

Figure 3.9.8 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Draw wire sensor 3 and (b) Draw wire sensor 4

Figure 3.9.8 shows draw wire sensors W3 and W4. More specifically, draw wire sensor W3 is located on the foundation, on the left side and draw wire sensor W4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor W3 is 14,23 mm while the minimum is -13,06 mm. The maximum movement detected by draw wire sensor W4 is 14,60 mm while the minimum is -13,06 mm.

W3

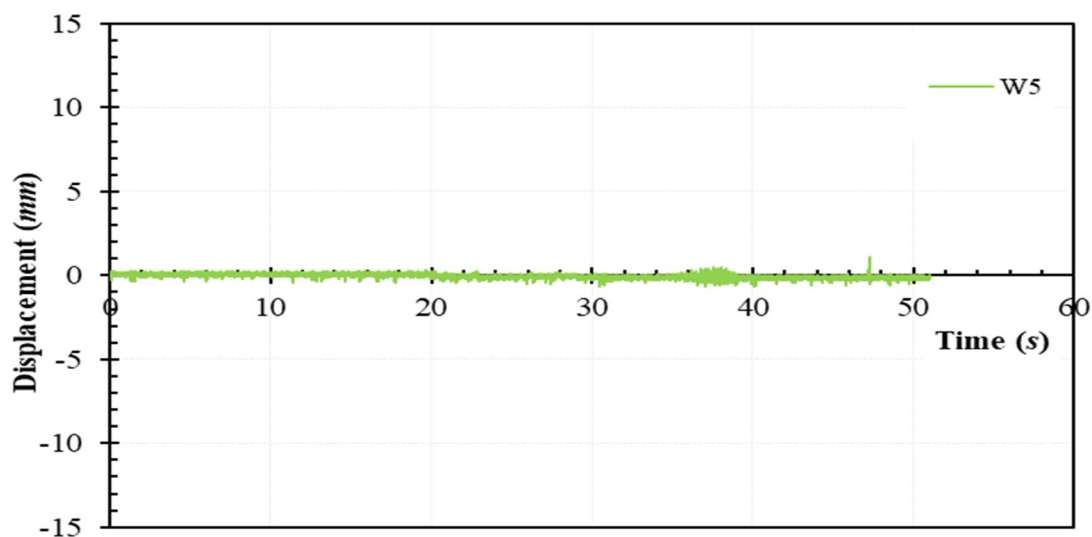
Max: 14,23 mm

Min: -13,06 mm

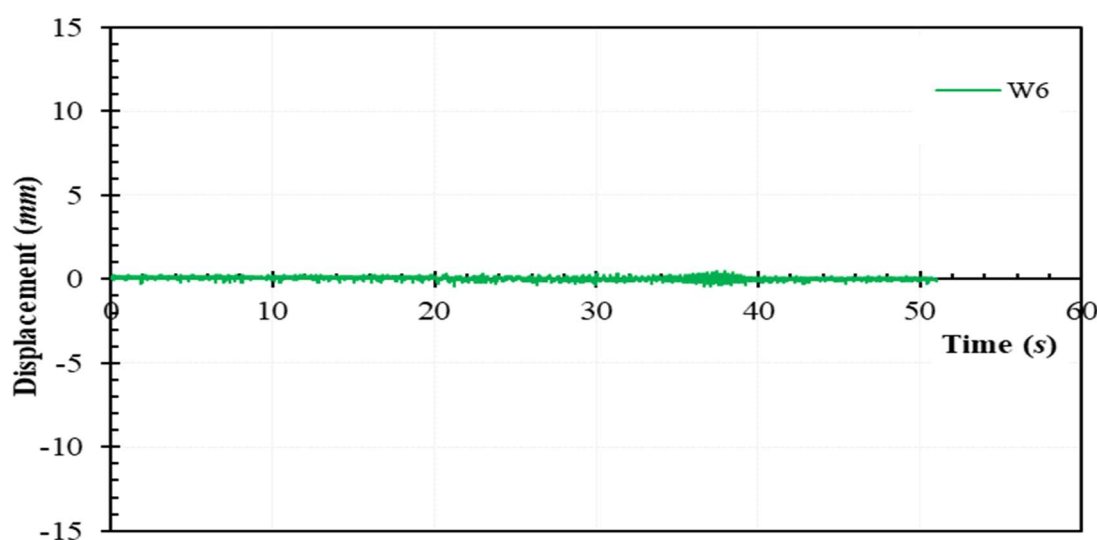
W4

Max: 14,60 mm

Min: -13,06 mm



(a)



(b)

Figure 3.9.9 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Draw wire sensor 5 and (b) Draw wire sensor 6

Figure 3.9.9 shows draw wire sensors 5 and 6. More specifically, draw wire sensor 5 is located along the partial masonry infill diagonal and draw wire sensor 6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor 5 is 1,11 mm while the minimum is -0,70 mm. The maximum movement detected by draw wire sensor 6 is 0,51 mm while the minimum is -0,43 mm.

W5

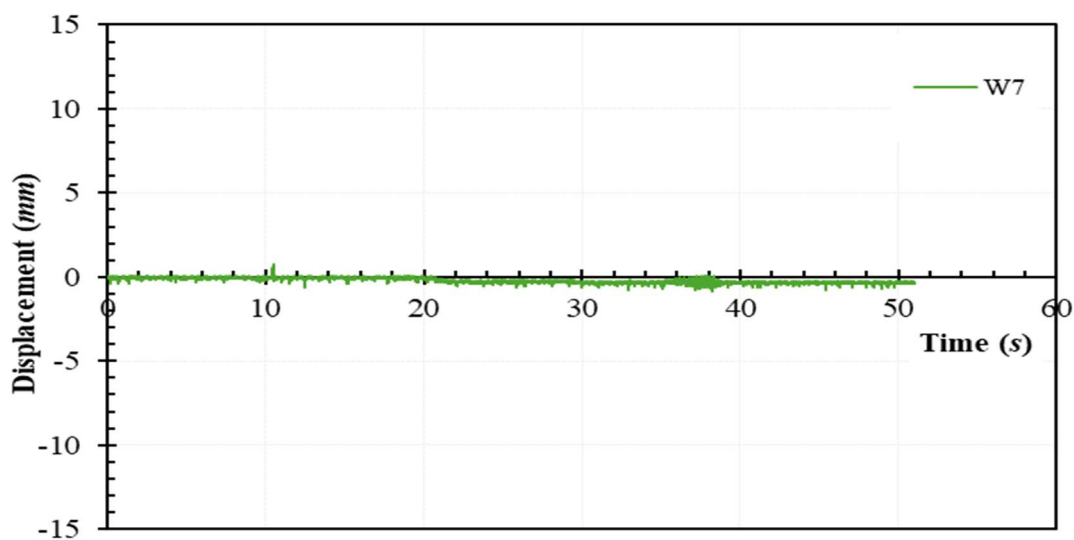
Max: 1,11 mm

Min: -0,70 mm

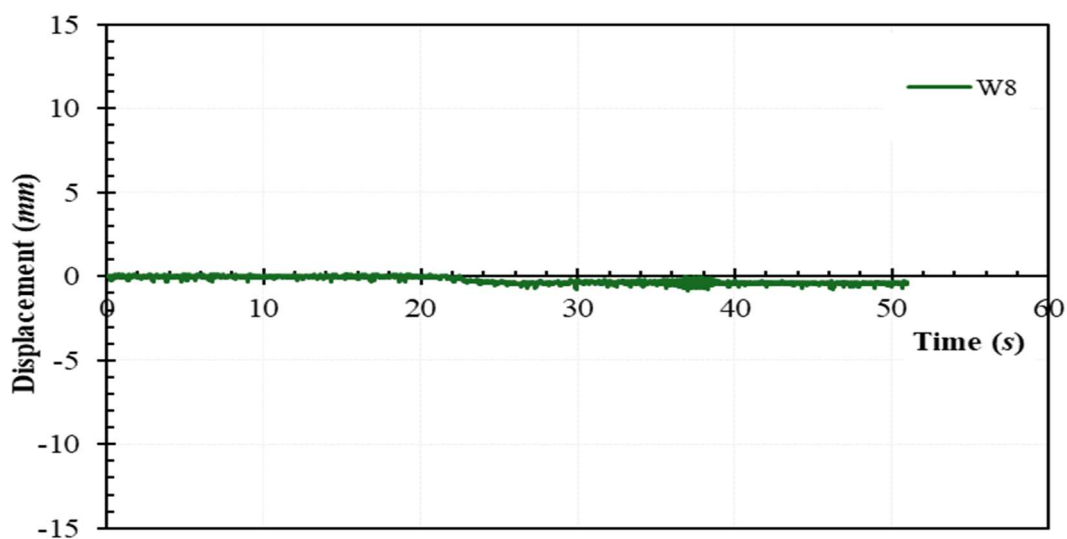
W6

Max: 0,51 mm

Min: -0,43 mm



(a)



(b)

Figure 3.9.10 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Draw wire sensor 7 and (b) Draw wire sensor 8

Figure 3.9.10 shows draw wire sensors 7 and 8. More specifically, draw wire sensor 7 is located along the partial masonry infill diagonal and draw wire sensor 8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor 7 is 0,72 mm while the minimum is -0,85 mm. The maximum movement detected by draw wire sensor 8 is 0,15 mm while the minimum is -0,82 mm.

W7

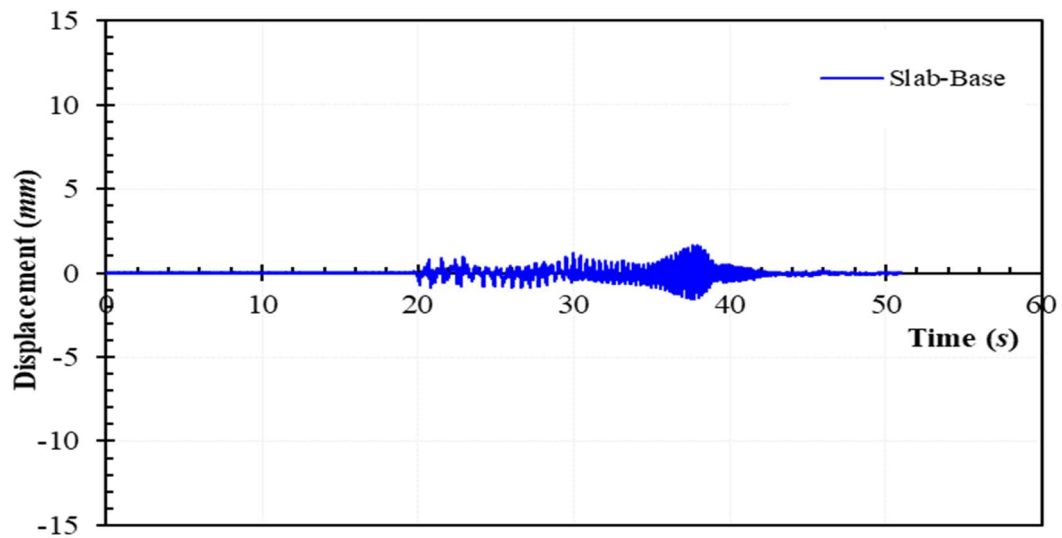
Max: 0,72 mm

Min: -0,85 mm

W8

Max: 0,15 mm

Min: -0,82 mm



(a)

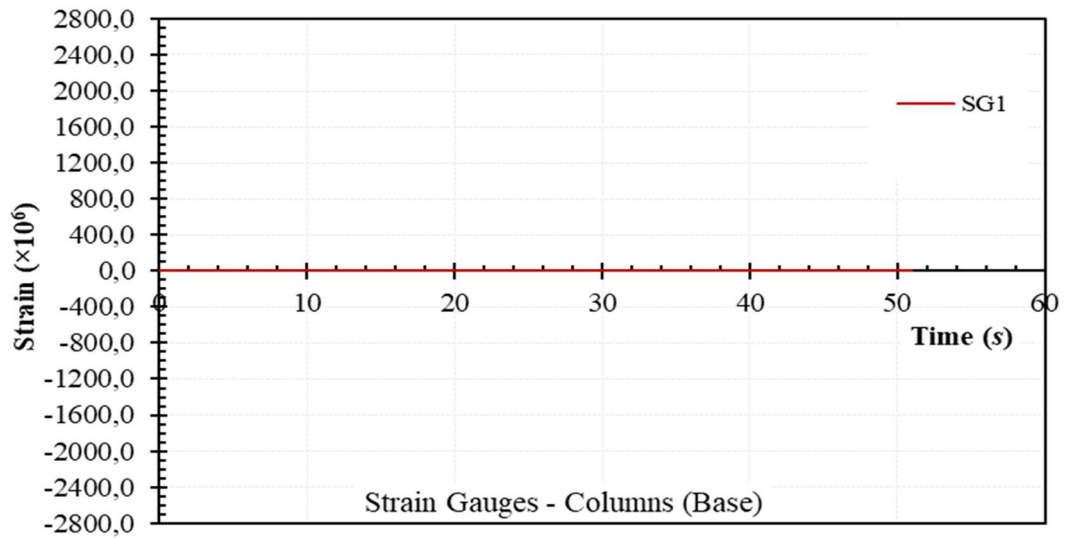
Figure 3.9.11 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Diagram of displacement Slab – Base

Figure 3.9.11 shows slab – base displacement. More specifically, the maximum drift detected is 1,32 ‰ while the minimum is -1,29 ‰. The residual drift is -0,03 mm.

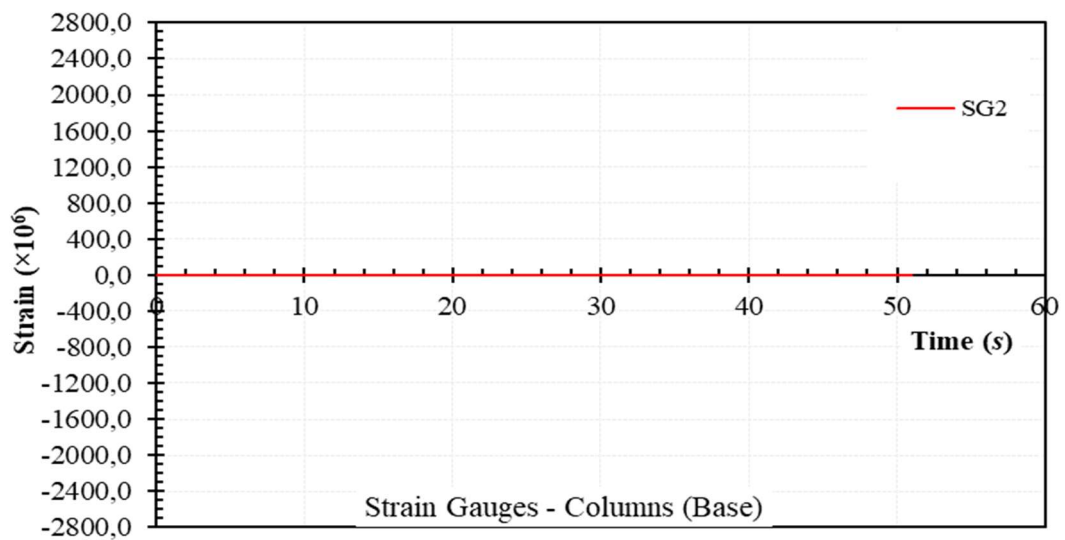
Maximum drift (‰): 1,32 (1,617 m/1,225 m=1,32 ‰)

Minimum drift (‰): -1,29

Residual: -0,03 mm



(a)



(b)

Figure 3.9.12 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Strain gauge 1 and (b) Strain gauge 2

Strain gauges detect strain. The strain gauges shown in the figures 3.9.12, 3.9.13, 3.9.14 and 3.9.19 are located in the longitudinal reinforcement, on the underside. More specifically, strain gauge SG1 has maximum strain $1,37\mu\text{strain}$ and minimum strain $-1,35\mu\text{strain}$. The residual strain is $0\mu\text{strain}$. Strain gauge SG2 has maximum deformation $0,76\mu\text{strain}$ and minimum $-0,61\mu\text{strain}$. The residual strain is $0\mu\text{strain}$. Strain gauge SG3 has $0,76\mu\text{strain}$ and $-0,61\mu\text{strain}$ maximum and minimum strain respectively. The residual strain is $0\mu\text{strain}$. Strain gauge SG4 as we can see in figure 3.2.13 has maximum $1,53\mu\text{strain}$ and minimum $-0,92\mu\text{strain}$ deformation. The residual strain is $15,26\mu\text{strain}$. Figure 3.9.19 shows strain gauges SG5 and SG6. Strain gauge 5 has $235,79\mu\text{strain}$ and $-241,36\mu\text{strain}$ maximum and minimum strain respectively. Strain gauge SG5 presents $11,38\mu\text{strain}$ residual strain. Strain gauge SG6 has $39,78\mu\text{strain}$ maximum strain, $-55,19\mu\text{strain}$ minimum strain and $-8,12\mu\text{strain}$ residual. Finally in figure 3.9.14 see strain gauge SG7 and SG8. Strain gauge SG7 has maximum strain $0,31\mu\text{strain}$ and SG8 has maximum strain $1,37\mu\text{strain}$. Strain gauge SG7 has $-0,92\mu\text{strain}$ minimum

deformation and SG8 has $-1,53\mu\text{strain}$. The residual strain for strain gauge SG7 and SG8 is $-30,52, 0$ respectively.

Sg 1

Max: $1,37\mu\text{strain}$

Min: $-1,35\mu\text{strain}$

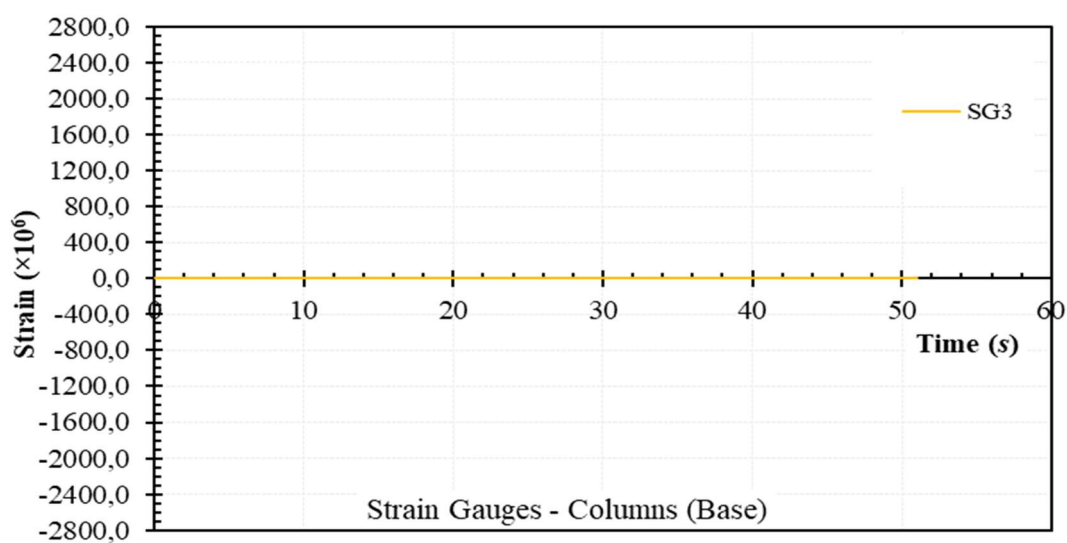
Residual: $0\mu\text{strain}$

Sg2

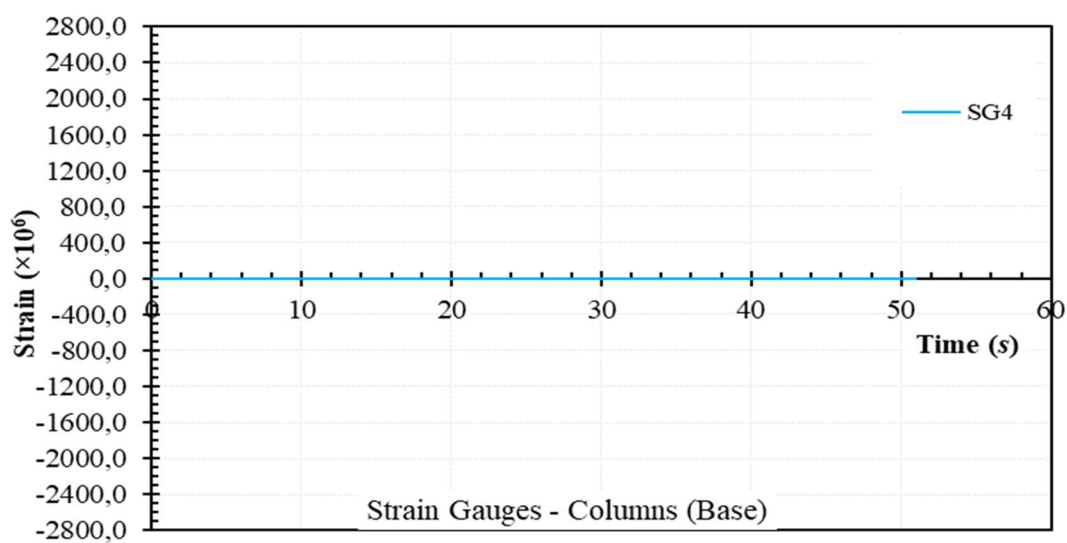
Max: $0,76\mu\text{strain}$

Min: $-0,61\mu\text{strain}$

Residual: $0\mu\text{strain}$



(a)



(b)

Figure 3.9.13 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Strain gauge 3 and (b) Strain gauge 4

Sg3

Max: 0,76 μ strain

Min: -0,61 μ strain

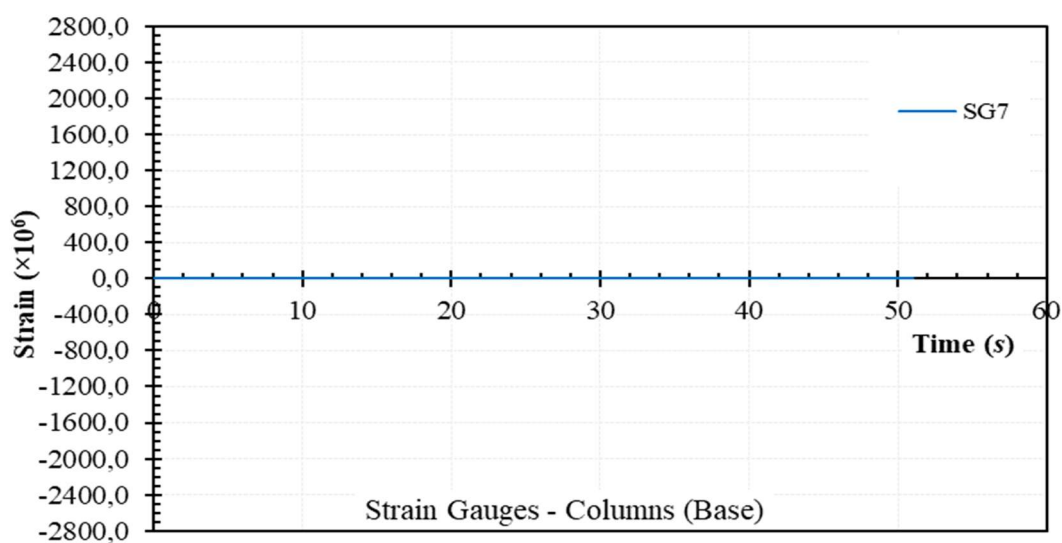
Residual: 0 μ strain

Sg4

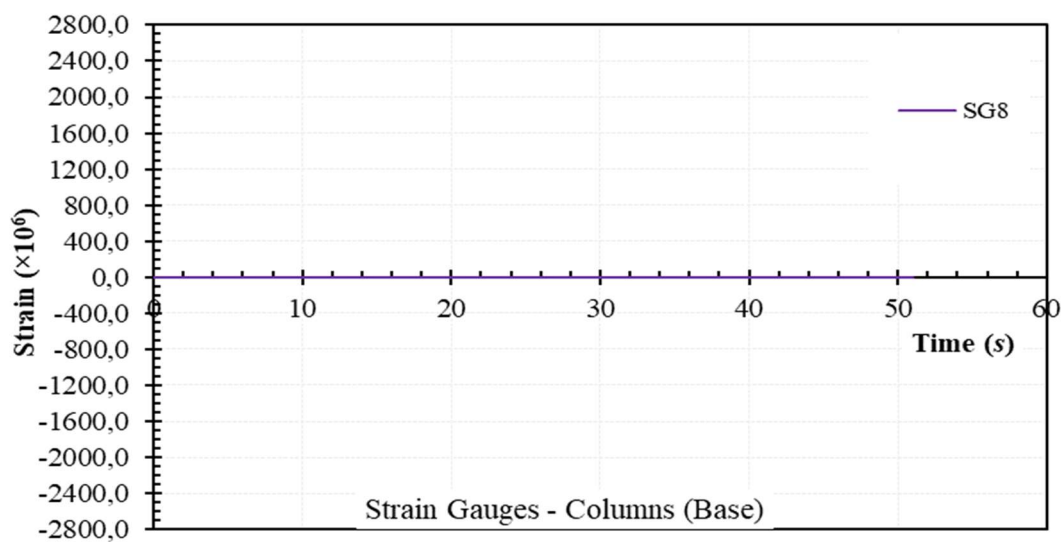
Max: 1,53 μ strain

Min: -0,92 μ strain

Residual: 15,26 μ strain



(a)



(b)

Figure 3.9.14 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 7 and (b) Strain gauge 8

Sg7

Max: 0,31 μ strain

Min: -0,92 μ strain

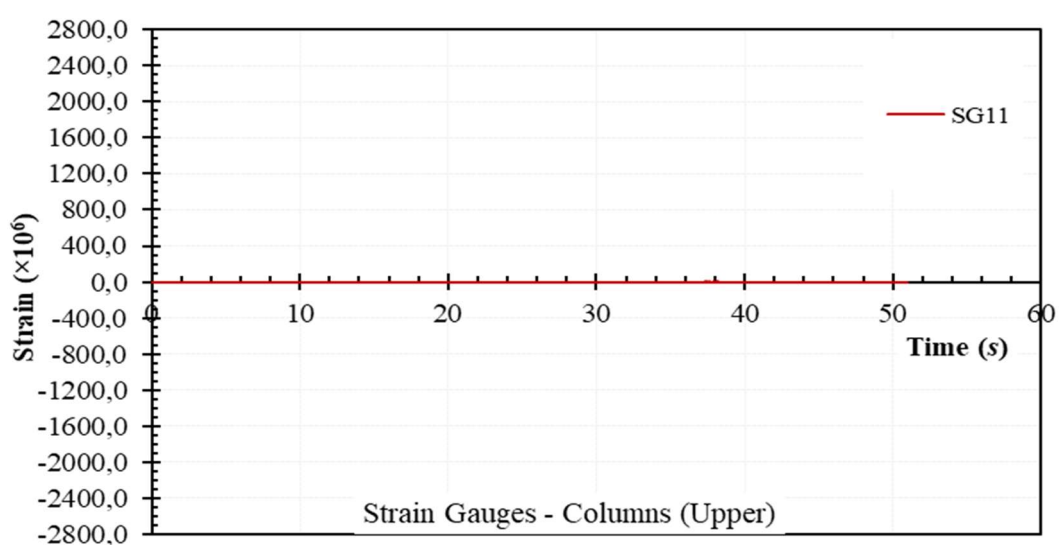
Residual: -30,52 μ strain

Sg8

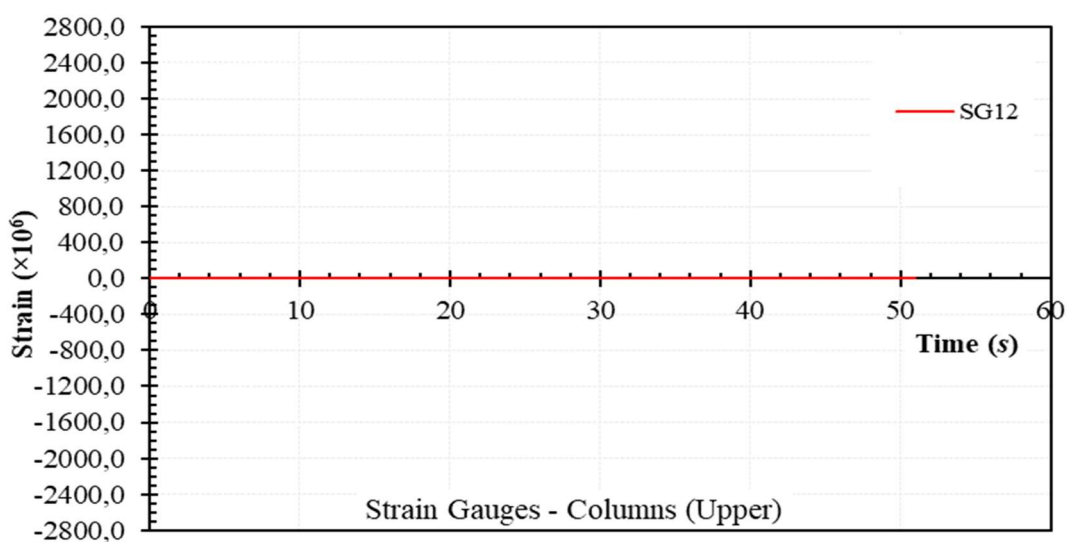
Max: 1,37 μ strain

Min: -1,53 μ strain

Residual: 0 μ strain



(a)

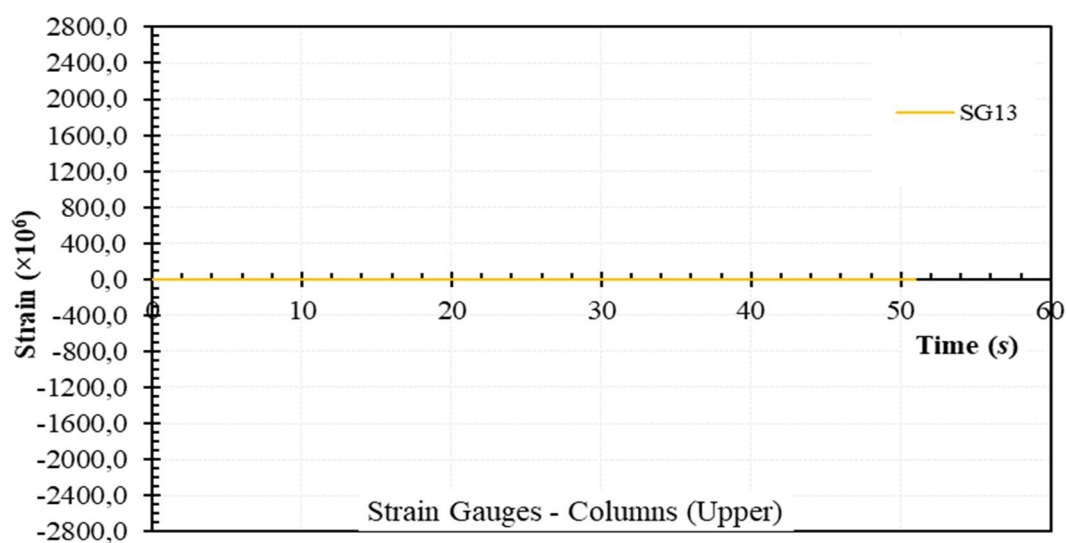


(b)

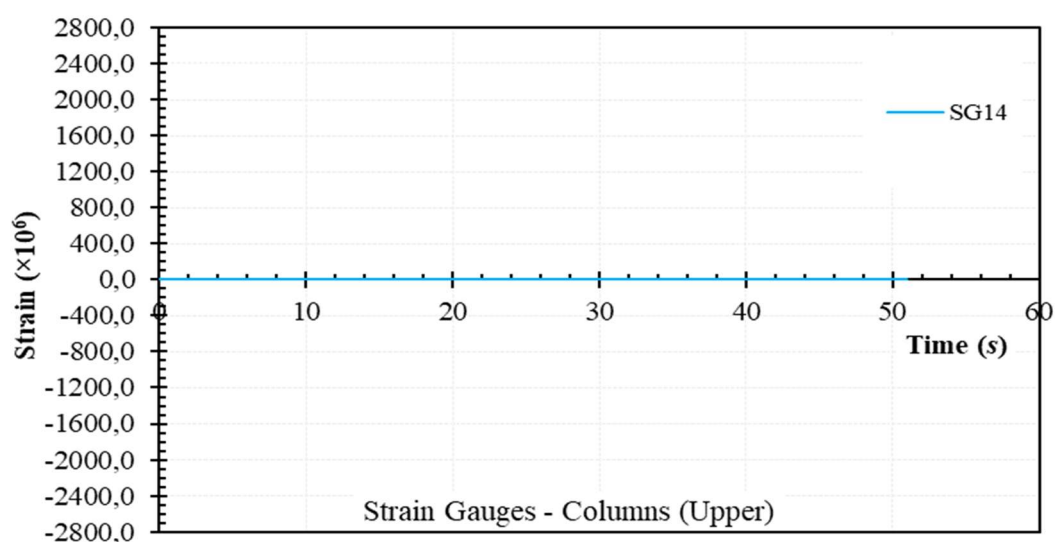
Figure 3.9.15 Characteristic results for phase A (white noise before 1,1g earthquake): (a) Strain gauge 11 and (b) Strain gauge 12

The strain gauges shown in the figures 3.9.15, 3.9.16, 3.9.17 and 3.9.20 are located in the longitudinal reinforcement, on the upper side. More specifically, strain gauge SG9 has 11,39 μ strain maximum strain, -62,61 μ strain minimum strain and 0 μ strain residual. Strain gauge SG10 has 158,38 μ strain maximum strain, -165,67 μ strain minimum strain and 13,88 μ strain residual. Strain gauge SG11 has maximum strain 1,22 μ strain and minimum -1,22 μ strain deformation. The residual strain is -30,52 μ strain for strain gauge SG11. Strain gauge SG12 has maximum strain 0,76 μ strain and minimum strain -0,76 μ strain. The residual value is -15,26 μ strain. Strain gauge SG13 has maximum strain 0,61 μ strain and minimum strain -0,61 μ strain. The residual is -30,52 μ strain. Strain gauge SG14 has maximum strain 1,22 μ strain and minimum strain -1,22 μ strain. The residual is 0 μ strain. Finally strain gauges SG15 has maximum strain 1,37 μ strain and minimum strain -1,07 μ strain. The residual is 15,26 μ strain. Strain gauge SG16 has maximum strain 1,22 μ strain, minimum strain -0,76 μ strain and residual strain 0 μ strain.

Sg11Max: 1,22 μ strainMin: -1,22 μ strainResidual: -30,52 μ strain**Sg12**Max: 0,76 μ strainMin: -0,76 μ strainResidual: -15,26 μ strain



(a)



(b)

Figure 3.9.16 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 13 and (b) Strain gauge 14

Sg13

Max: 0,61 μ strain

Min: -0,61 μ strain

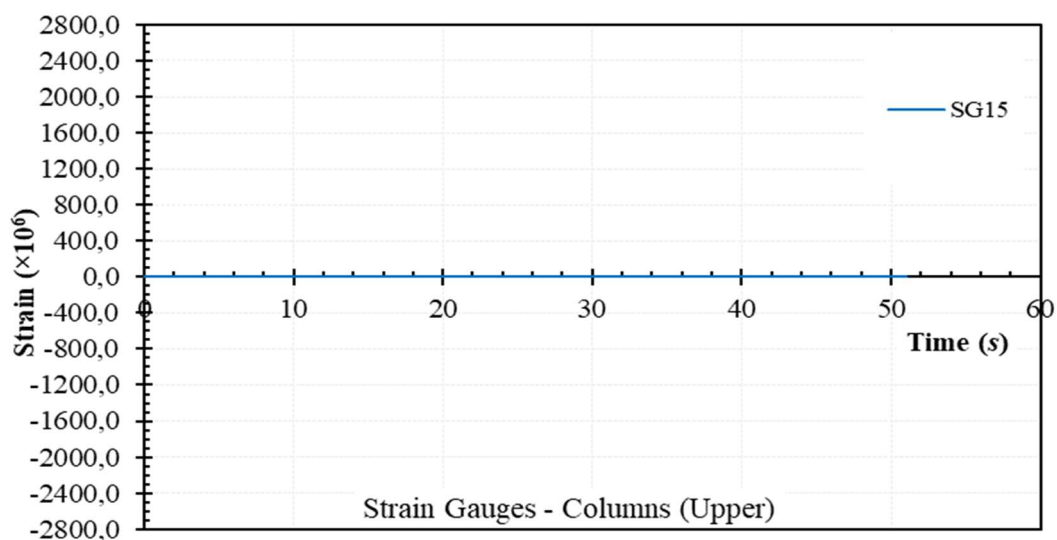
Residual: -30,52 μ strain

Sg14

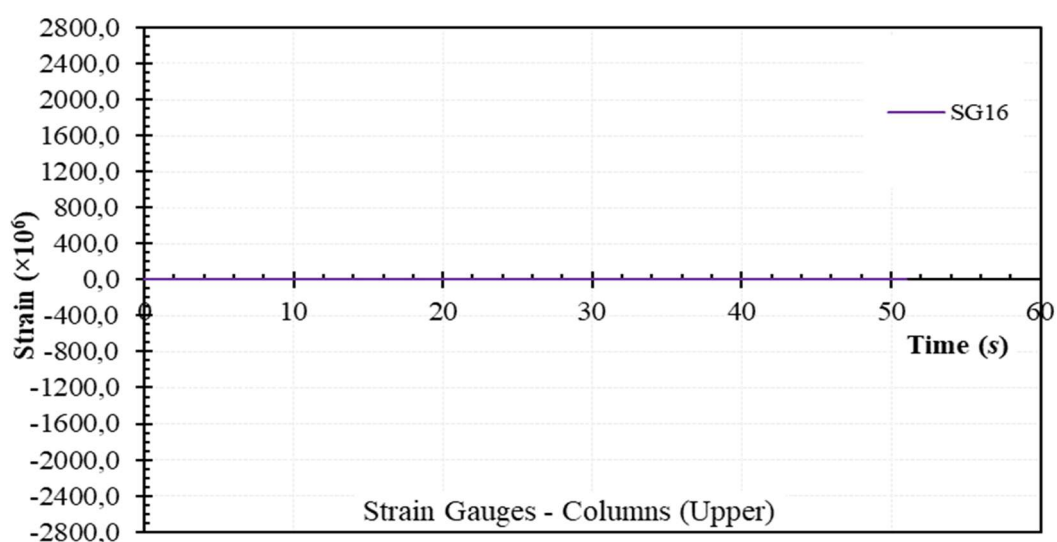
Max: 1,22 μ strain

Min: -1,22 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.9.17 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 13 and (b) Strain gauge 14

Sg15

Max: 1,37 μ strain

Min: -1,07 μ strain

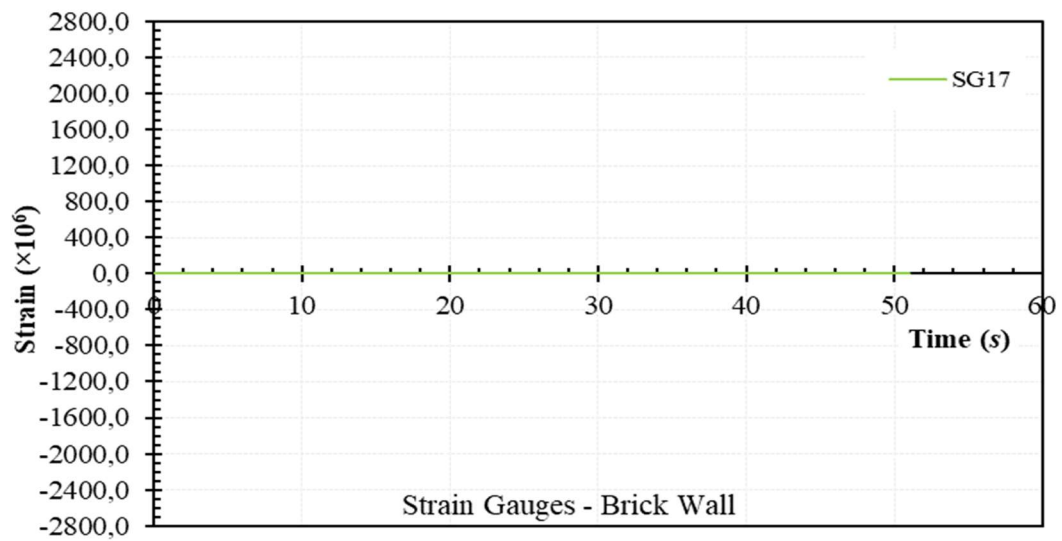
Residual: 15,26 μ strain

Sg16

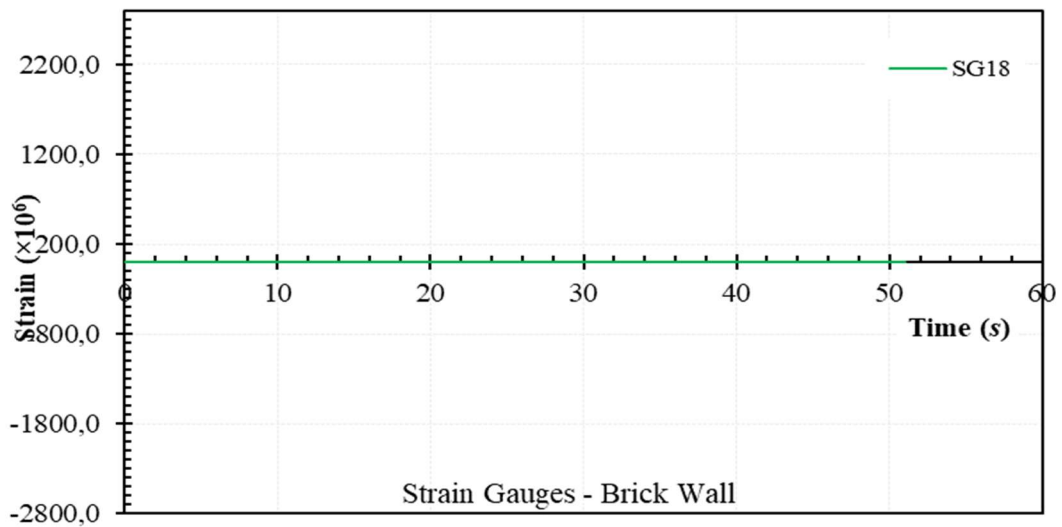
Max: 1,22 μ strain

Min: -0,76 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.9.18 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 13 and (b) Strain gauge 14

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauges SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge SG17 has $0,61\mu\text{strain}$ maximum strain. Strain gauge SG17 has minimum deformation $-0,76\mu\text{strain}$ and strain gauge SG18 $-0,76\mu\text{strain}$. Strain gauge SG18 has maximum strain $0,61\mu\text{strain}$. Finally strain gauge SG17 presents $-15,26\mu\text{strain}$ residual. Strain gauge SG18 presents $-15,26\mu\text{strain}$ residual.

Sg17

Max: $0,61\mu\text{strain}$

Min: $-0,76\mu\text{strain}$

Residual: $-15,26\mu\text{strain}$

Sg18

Max: $0,61\mu\text{strain}$

Min: -0,76 μ strain

Residual: -15,26 μ strain

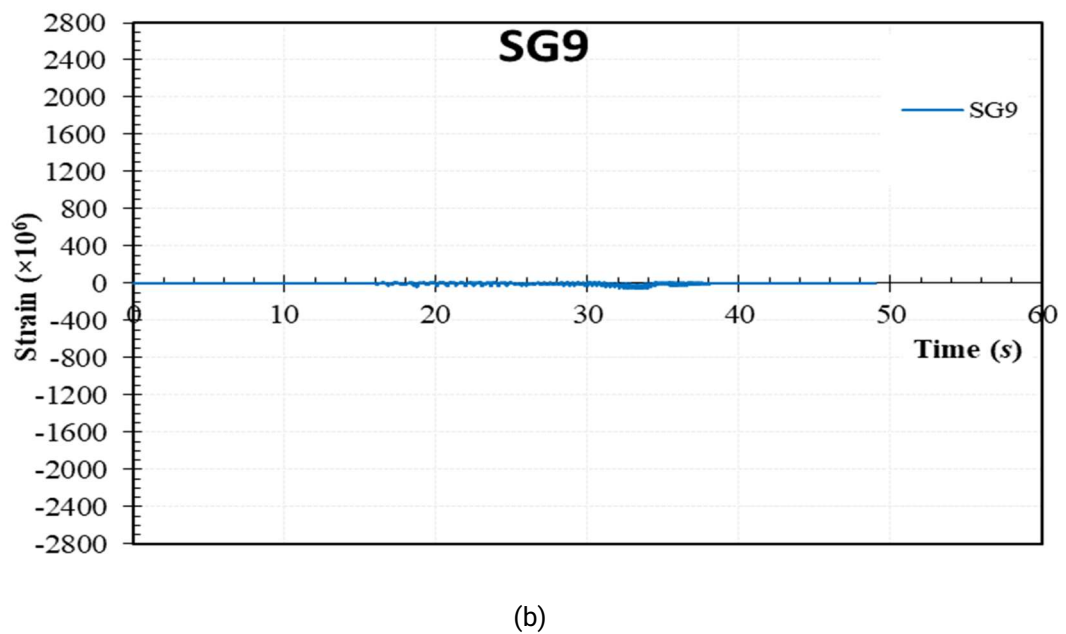
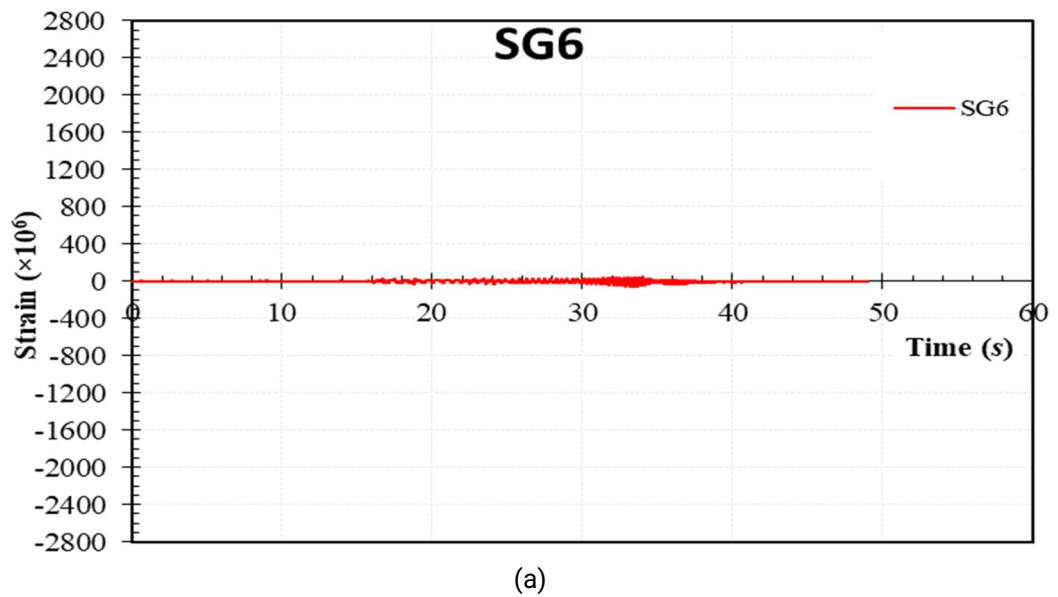


Figure 3.9.19 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 6 and (b) Strain gauge 9

Sg6

Max: 39,78 μ strain

Min: -55,19 μ strain

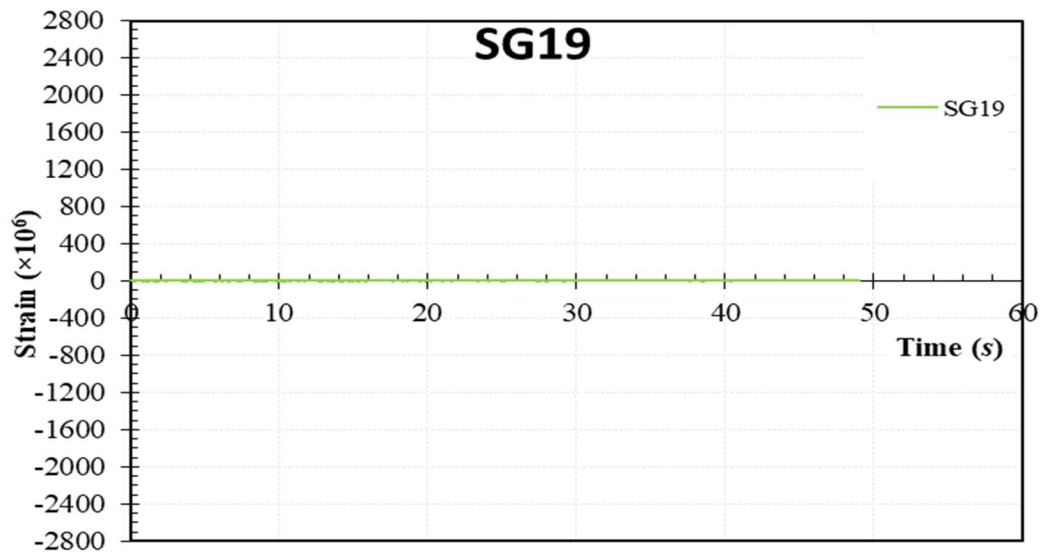
Residual: -8,12 μ strain

Sg9

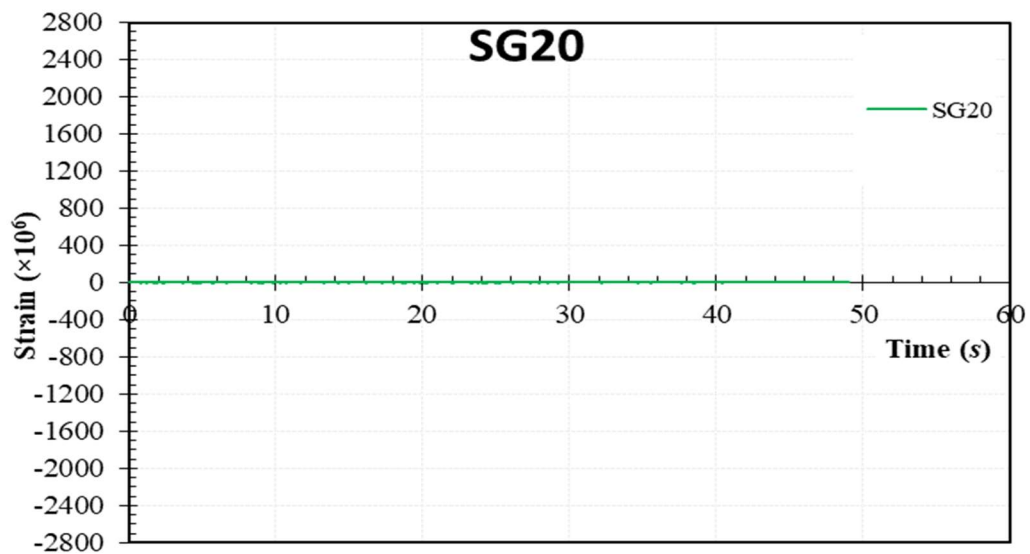
Max: 11,39 μ strain

Min: -62,61 μ strain

Residual: 0 μ strain



(a)



(b)

Figure 3.9.20 Characteristic results for phase A (white noise before 1,1g earthquake) : (a) Strain gauge 19 and (b) Strain gauge 20

Strain gauge 19 is located on the centre of partial masonry 2 along direction x. Strain gauges 20 is located on the centre of partial masonry 2 along direction x. More specifically strain gauge SG19 has maximum 3,24 μ strain and minimum -2,43 μ strain. Strain gauge SG20 has maximum strain 4,88 μ strain and minimum -2,44 μ strain. The residual strain for strain gauge SG19 is 0,81 μ strain and residual for strain gauge SG20 is 0,81 μ strain.

Sg19

Max: 3,24 μ strain

Min: -2,43 μ strain

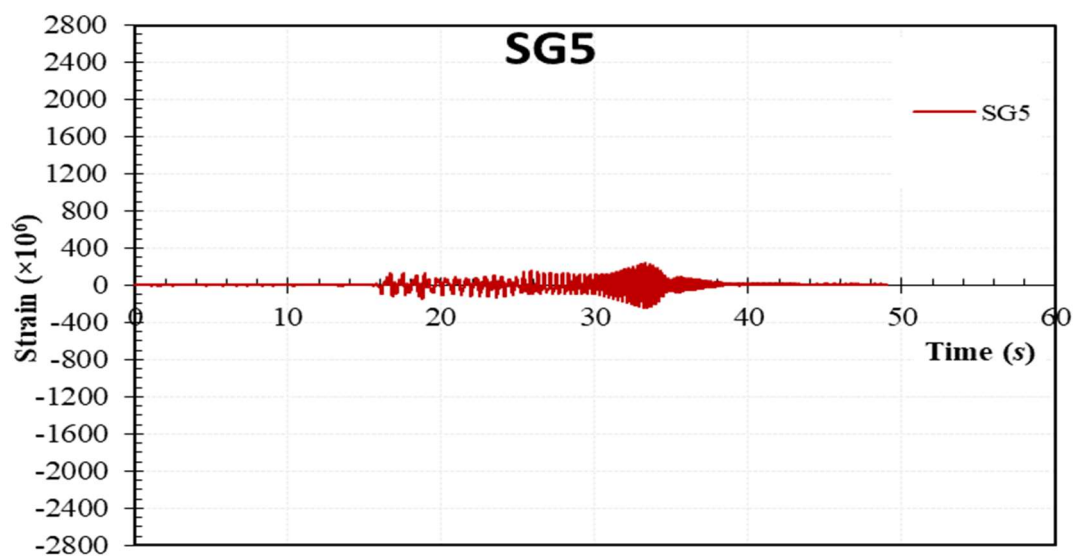
Residual: 0,81 μ strain

Sg20

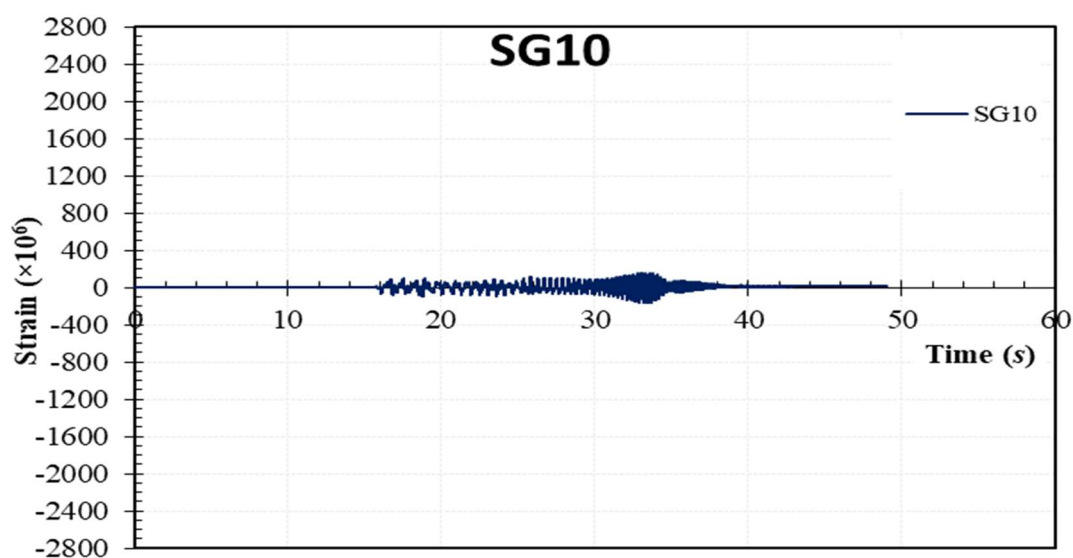
Max: 4,88 μ strain

Min: -2,44 μ strain

Residual: 0,81 μ strain



(a)



(b)

Figure 3.9.21 Characteristic results for phase A (white noise before 1,1g earthquake) (a) strain gauge 5 and (b) strain gauge 10

Sg5

Max: 235,79 μ strain

Min: -241,36 μ strain

Residual: 11,38 μ strain

Sg10

Max: 158,38 μ strain

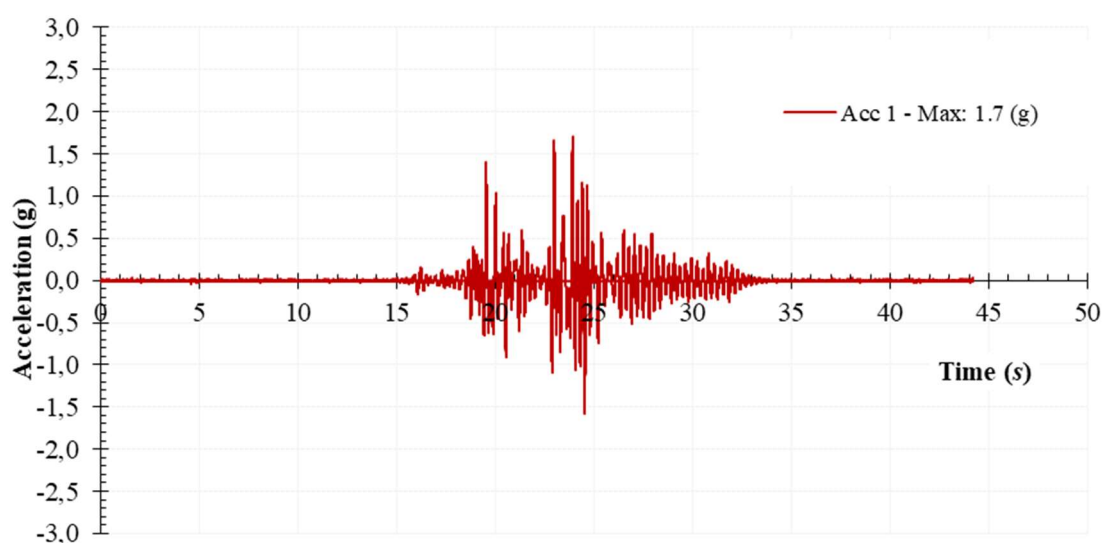
Min: -165,67 μ strain

Residual: 13,88 μ strain

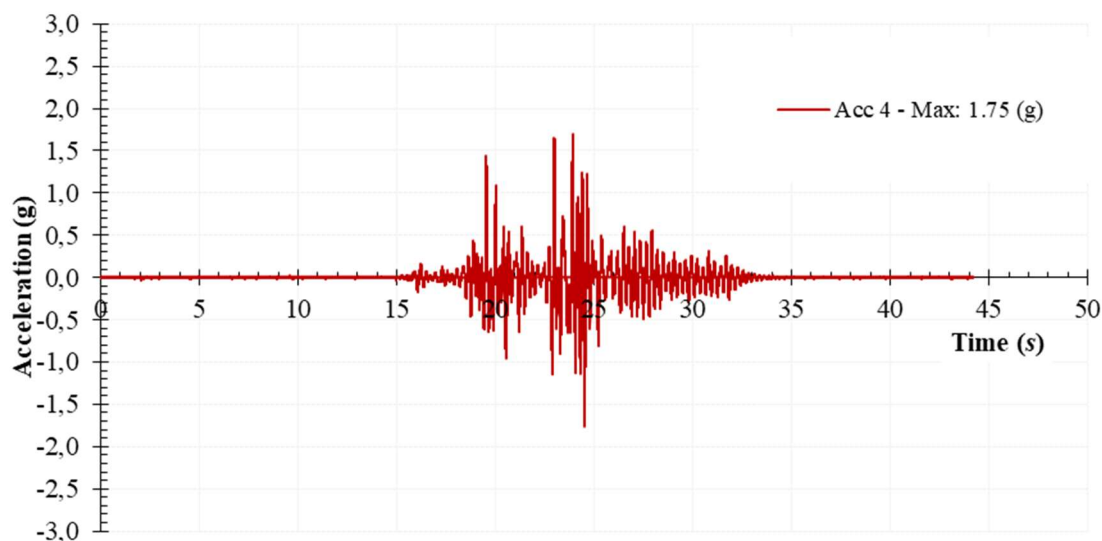
3.10) Earthquake EQ1,1g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for EQ1,1g. The max acceleration at the slab level on the accelerometer acc1 and acc4 is 1,7g and 1,75g respectively. The max acceleration at the foundation level on the accelerometer acc10 is 1,08g.

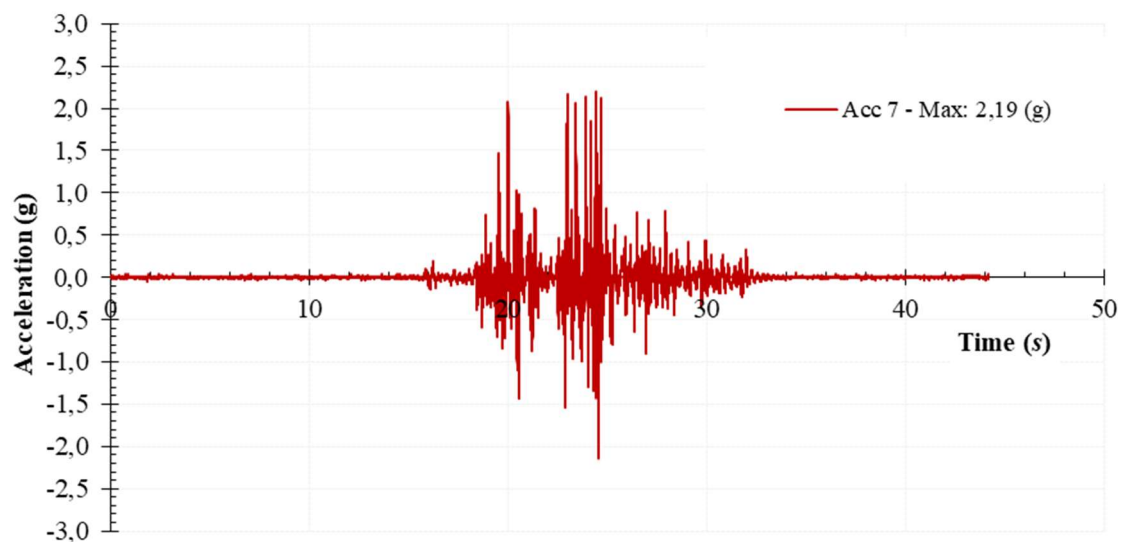


(a)

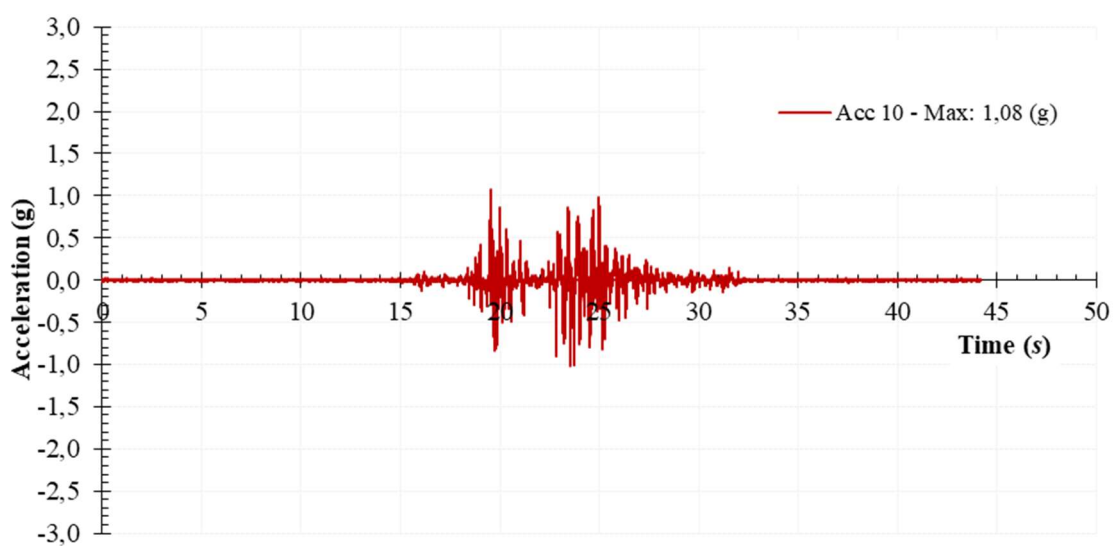


(b)

Figure 3.10.1 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 1 (b) Accelerometer 4

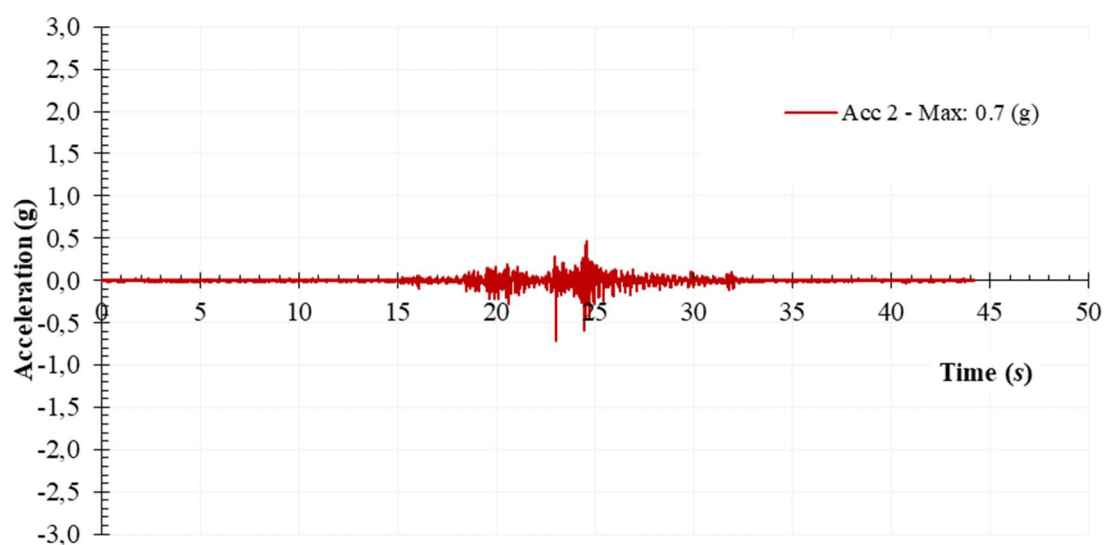


(a)

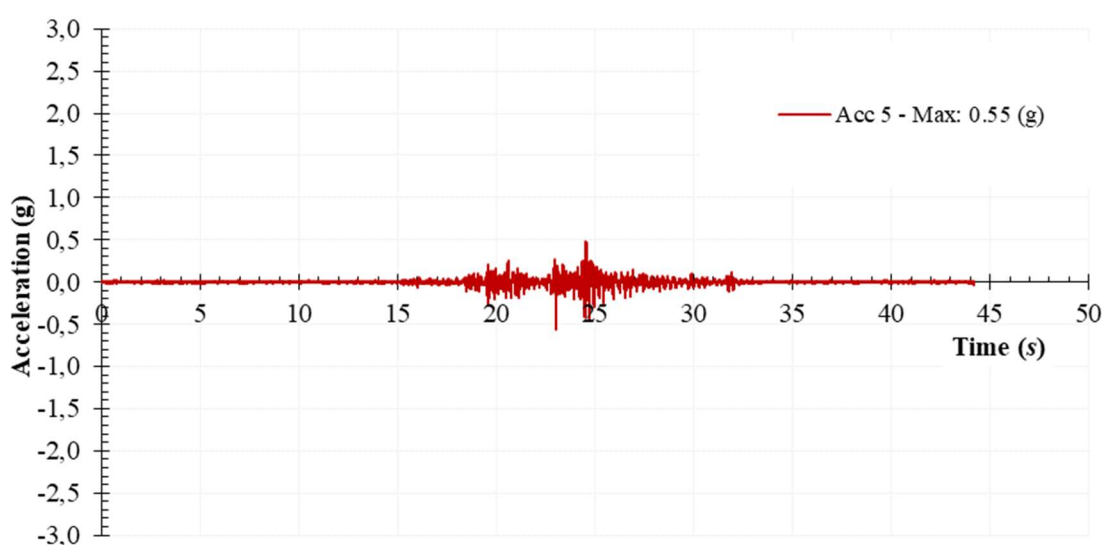


(b)

Figure 3.10.2 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

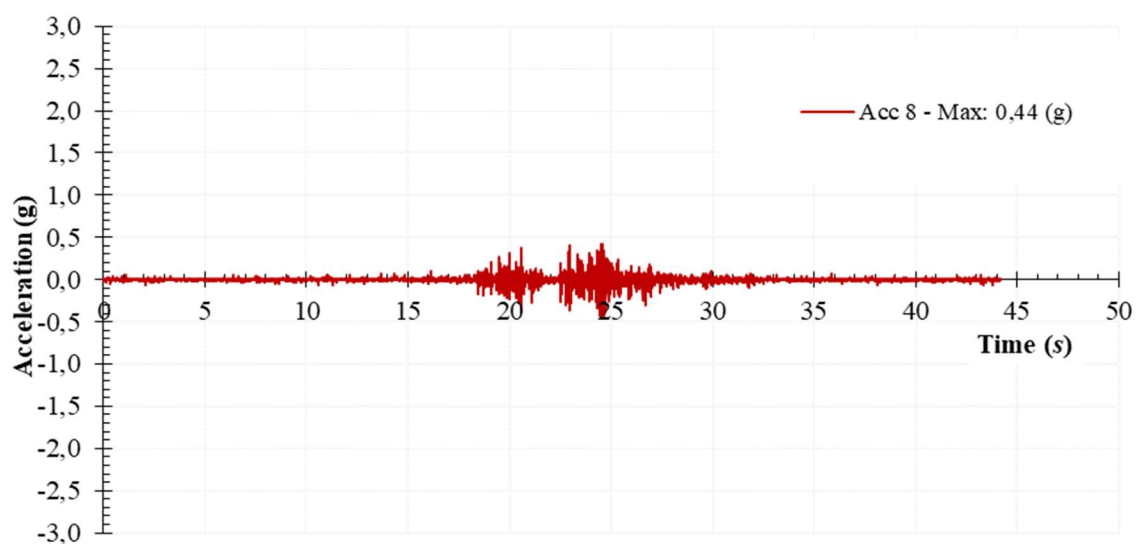


(a)

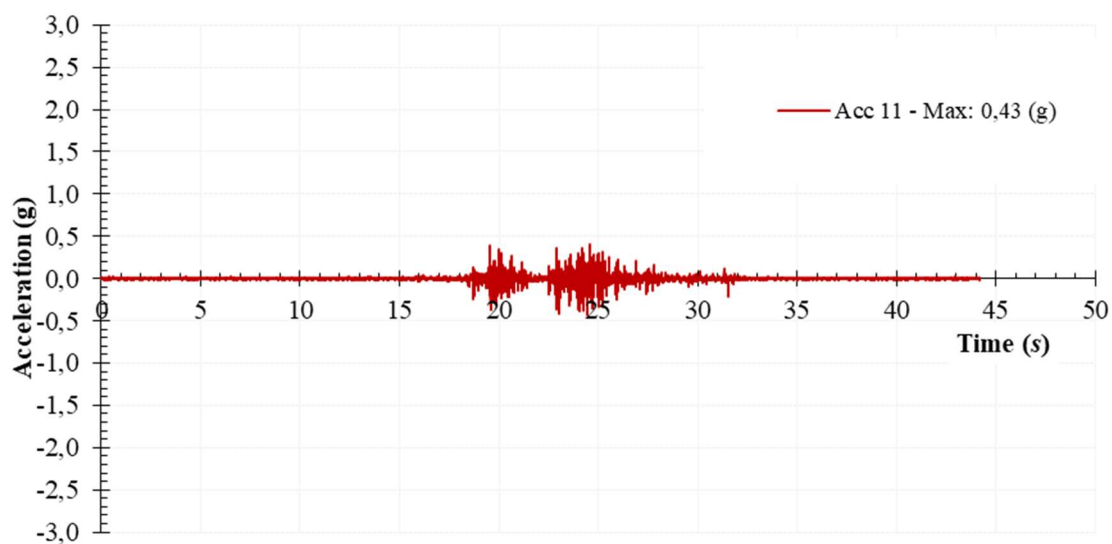


(b)

Figure 3.10.3 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

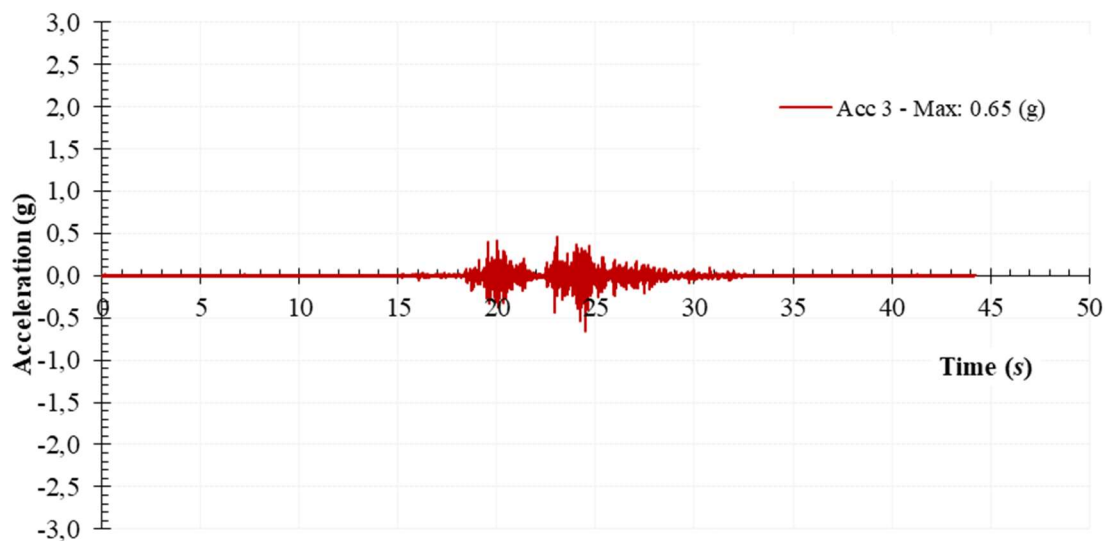


(a)

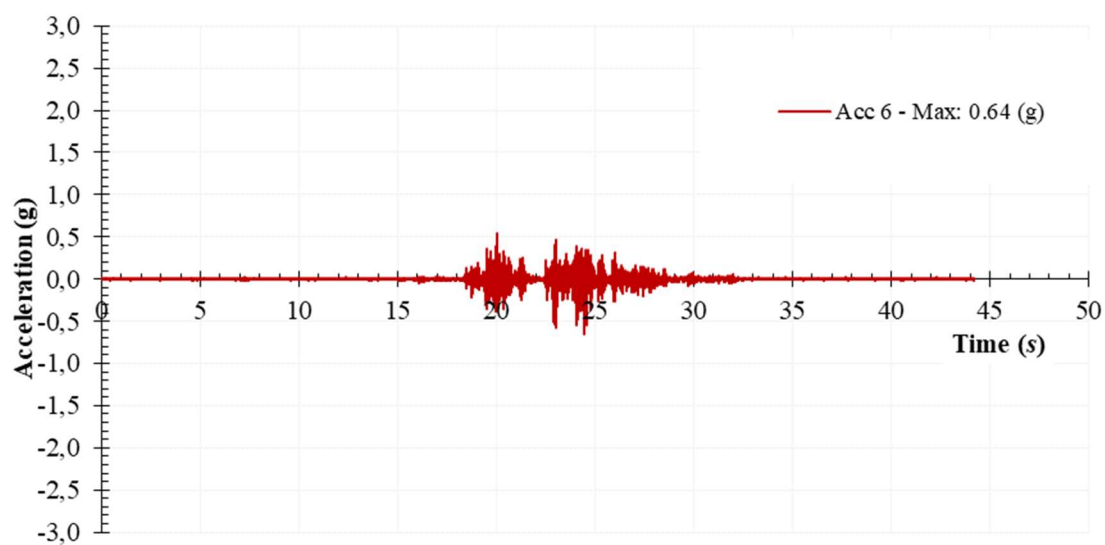


(b)

Figure 3.10.4 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 8 (b) Accelerometer 11

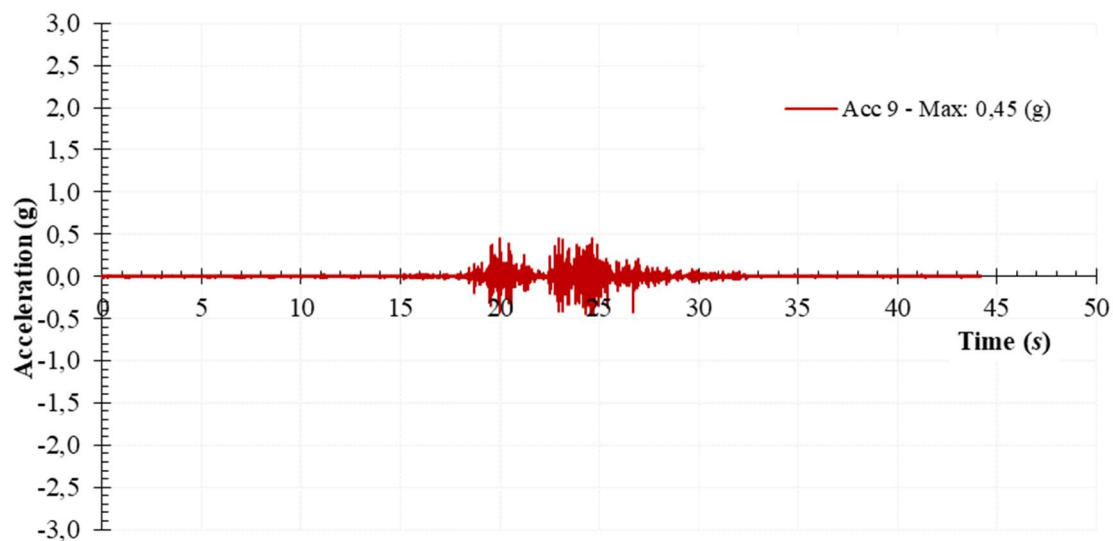


(a)

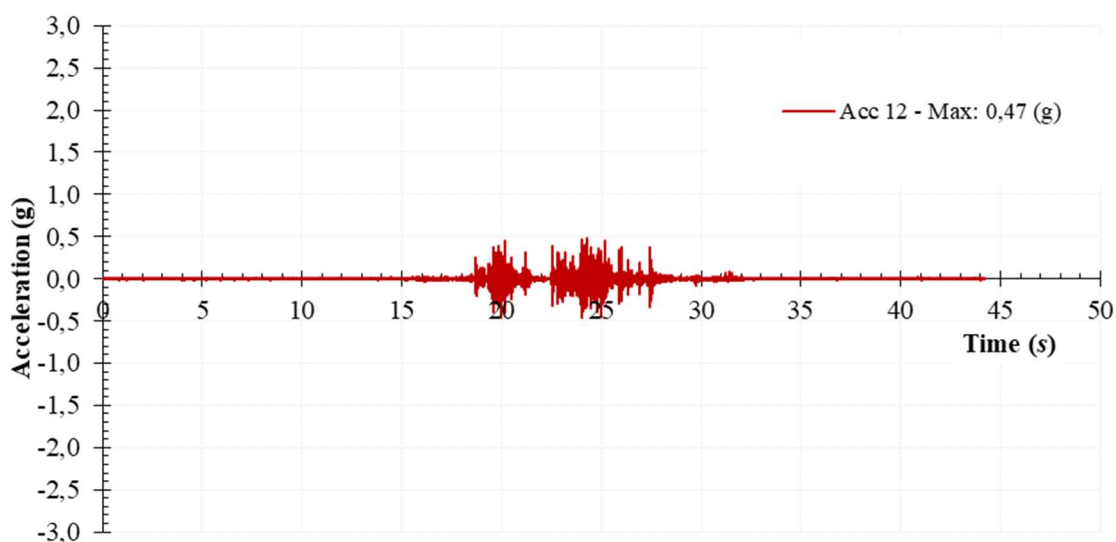


(b)

Figure 3.10.5 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 3 (b) Accelerometer 6

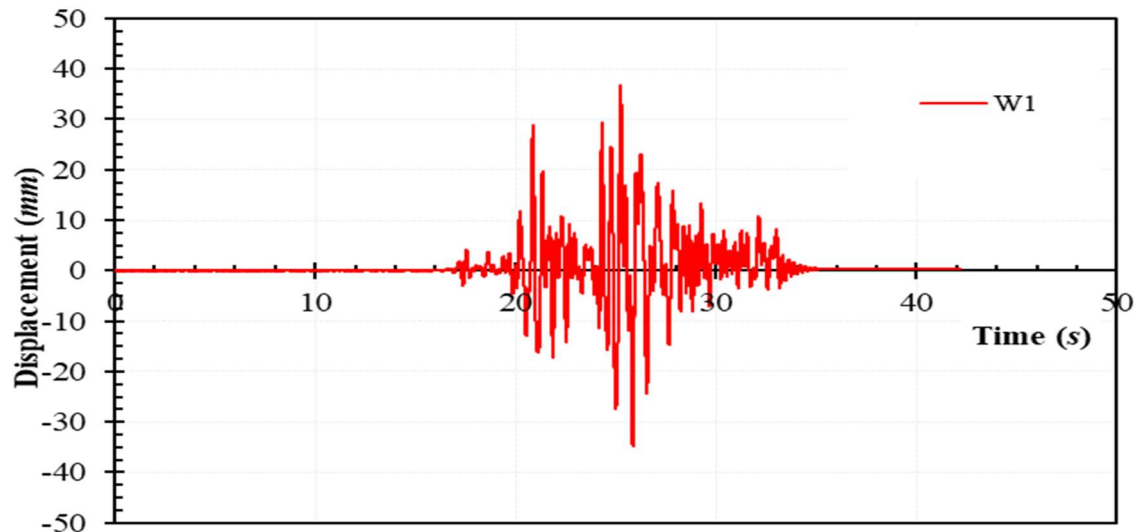


(a)

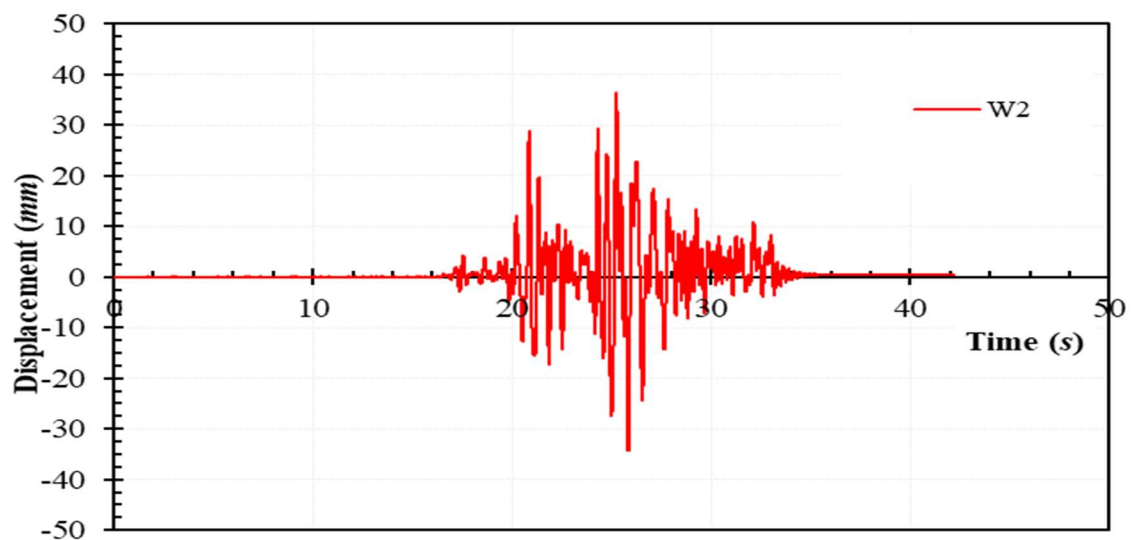


(b)

Figure 3.10.6 Characteristic results for phase A (1,1g earthquake): (a) Accelerometer 9 (b) Accelerometer 12



(a)



(b)

Figure 3.10.7 Characteristic results for phase A (1,1g earthquake): (a) Draw wire sensor W1 (b) Draw wire sensor W2

Figure 3.10.7 shows draw wire sensors W1 and W2. More specifically, draw wire sensor W1 is located on the slab, on the left side and draw wire sensor W2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor W1 is 36,69 mm while the minimum is -34,67 mm. The maximum movement detected by draw wire sensor W2 is 36,31 mm while the minimum is -34,33 mm.

W1

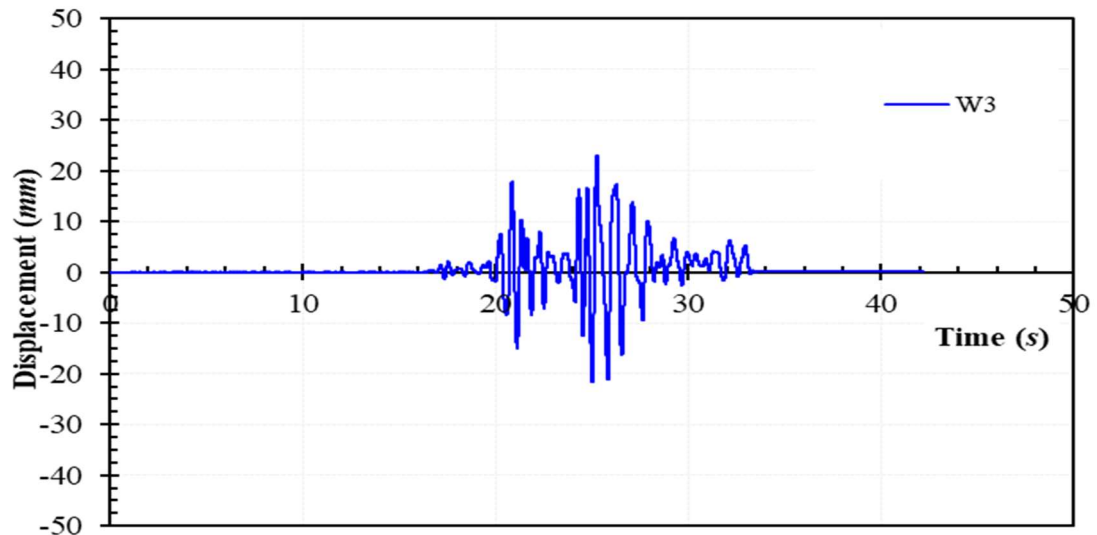
Max: 36,69 mm

Min: -34,67 mm

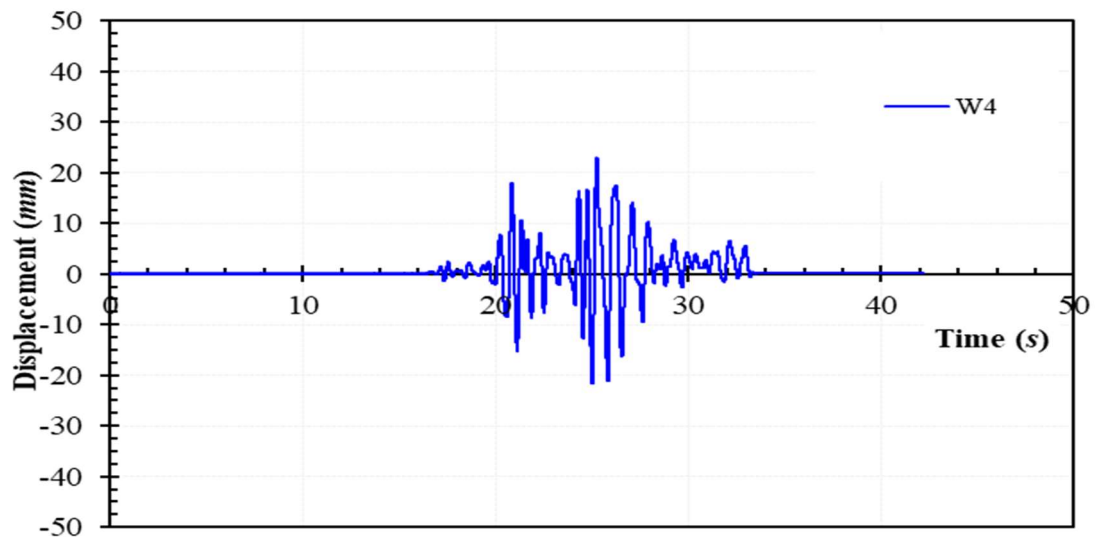
W2

Max: 36,31 mm

Min: -34,33 mm



(a)



(b)

Figure 3.10.8 Characteristic results for phase A (1,1g earthquake): (a) Draw wire sensor W3 (b) Draw wire sensor W4

Figure 3.10.8 shows draw wire sensors W3 and W4. More specifically, draw wire sensor W3 is located on the foundation, on the left side and draw wire sensor W4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor W3 is 22,90 mm while the minimum is -21,67 mm. The maximum movement detected by draw wire sensor W4 is 22,97 mm while the minimum is -21,71 mm.

W3

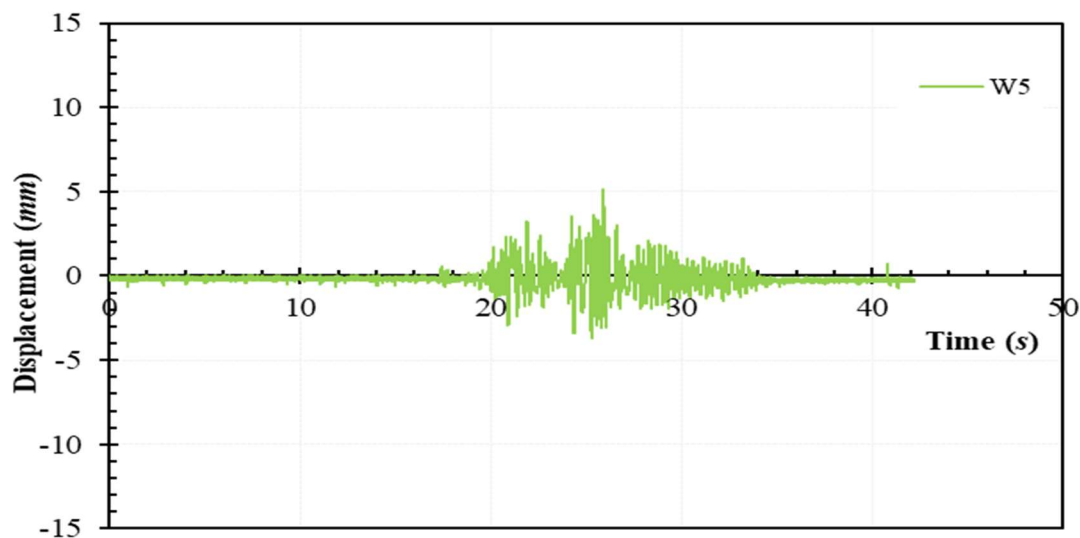
Max: 22,90 mm

Min: -21,67 mm

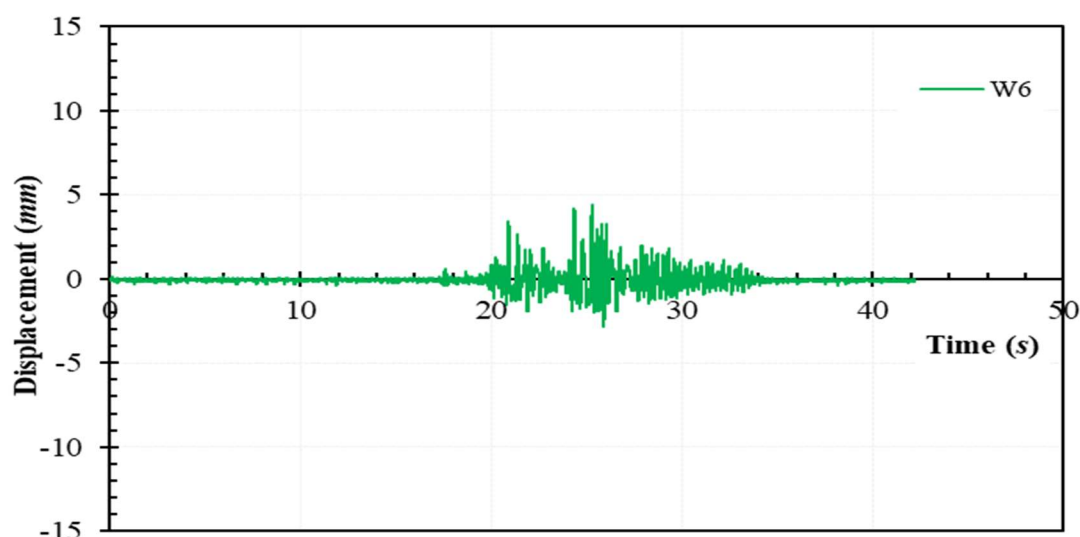
W4

Max: 22,97 mm

Min: -21,71 mm



(a)



(b)

Figure 3.10.9 Characteristic results for phase A (1,1g earthquake): (a) Draw wire sensor W5 (b) Draw wire sensor W6

Figure 3.10.9 shows draw wire sensors 5 and 6. More specifically, draw wire sensor 5 is located along the partial masonry infill diagonal and draw wire sensor 6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor 5 is 5,17 mm while the minimum is -3,69 mm. The maximum movement detected by draw wire sensor 6 is 4,44 mm while the minimum is -2,83 mm.

W5

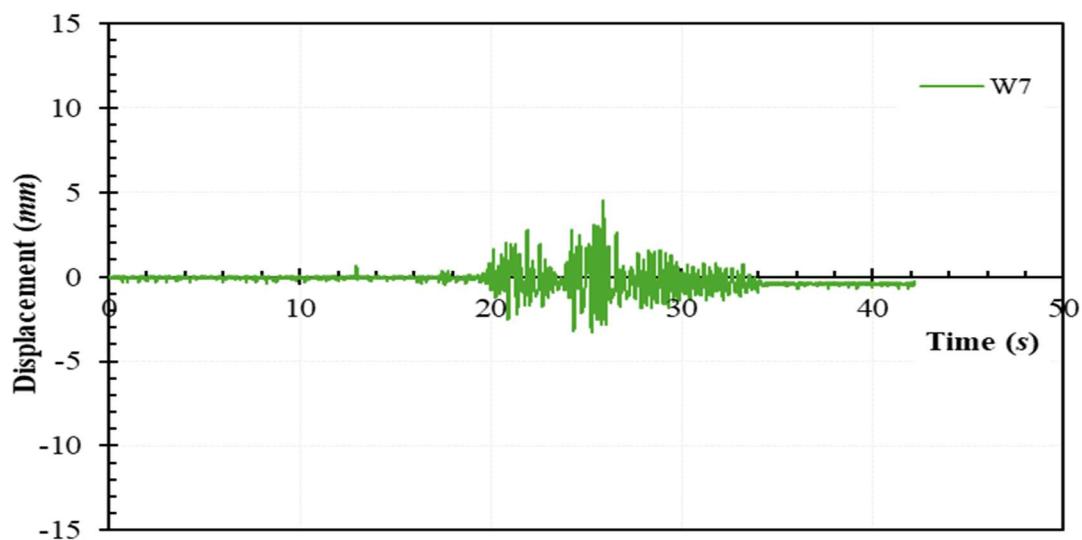
Max: 5,17 mm

Min: -3,69 mm

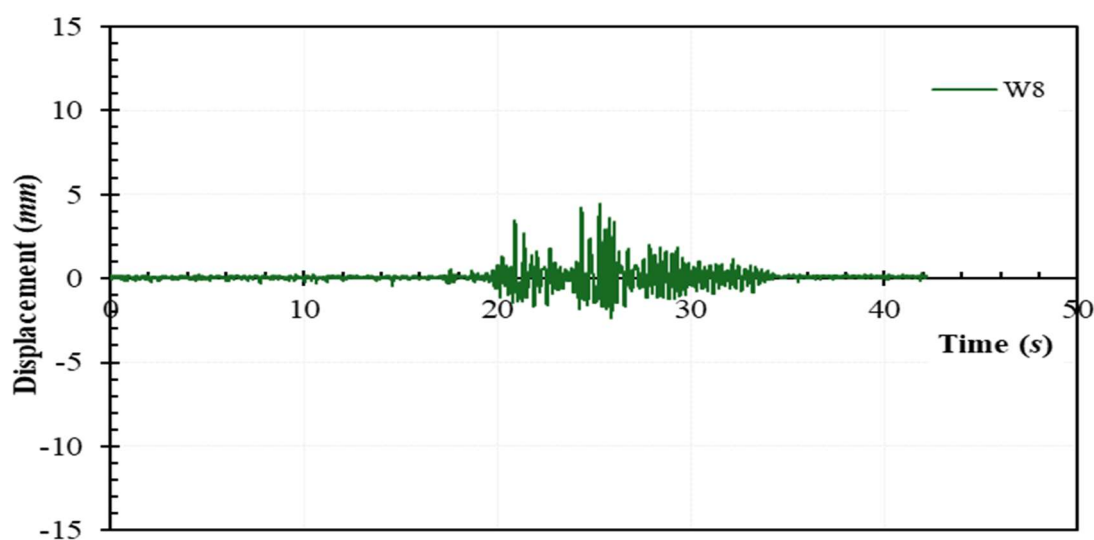
W6

Max: 4,44 mm

Min: -2,83 mm



(a)



(b)

Figure 3.10.10 Characteristic results for phase A (1,1g earthquake): (a) Draw wire sensor W7 (b) Draw wire sensor W8

Figure 3.10.10 shows draw wire sensors 7 and 8. More specifically, draw wire sensor 7 is located along the partial masonry infill diagonal and draw wire sensor 8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor 7 is 4,55 mm while the minimum is -3,32 mm. The maximum movement detected by draw wire sensor 8 is 4,43 mm while the minimum is -2,39 mm.

W7

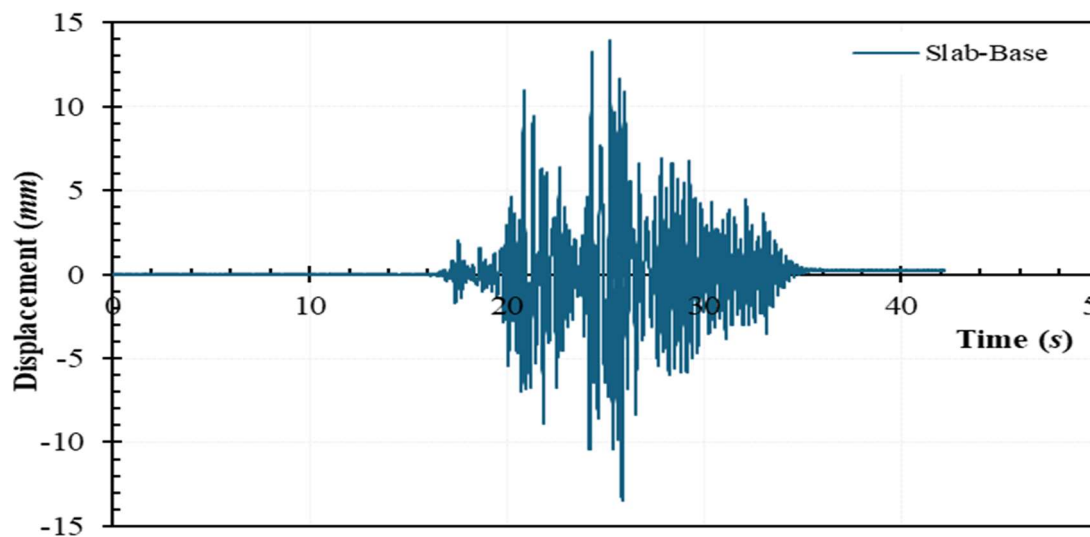
Max: 4,55 mm

Min: -3,32 mm

W8

Max: 4,43 mm

Min: -2,39 mm



(a)

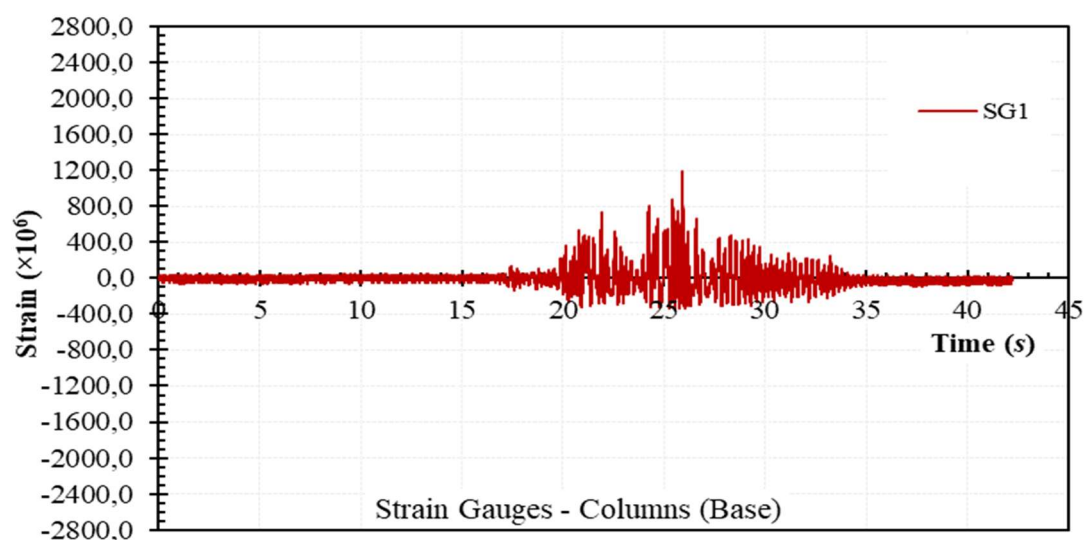
Figure 3.10.11 Characteristic results for phase A (1,1g earthquake): (a) Diagram of displacement Slab – Base

Figure 3.1.11 shows slab – base displacement. More specifically, the maximum drift detected is 11,37 ‰ while the minimum is -10,97 ‰. The residual drift is 0,25 mm.

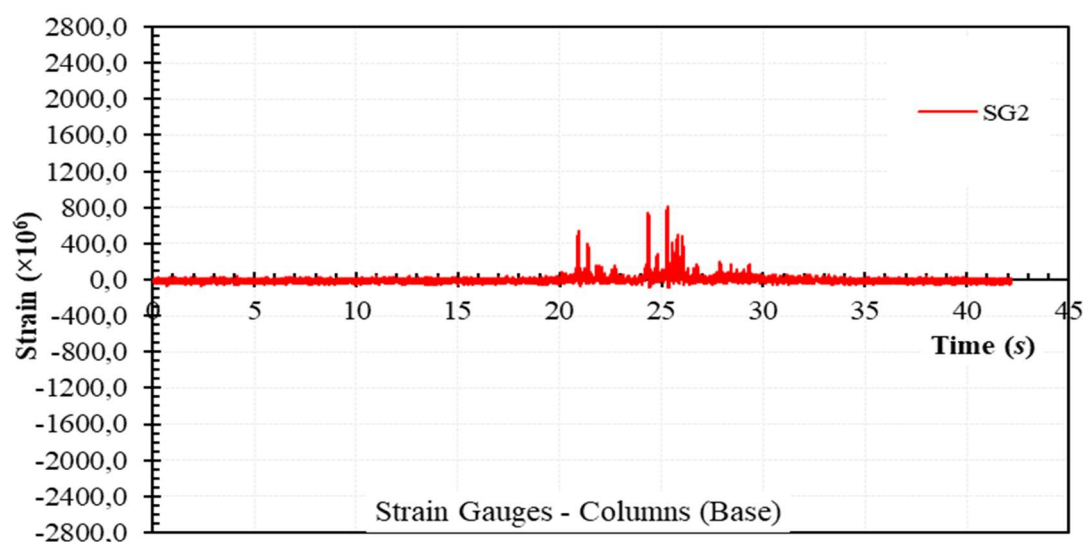
Maximum drift (‰): 11,37 (13,92825 m /1,225 m = 11,37 ‰)

Minimum drift (‰): -10,97

Residual: 0,25 mm



(a)



(b)

Figure 3.10.12 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 1 and (b) strain gauge 2

Strain gauges detect strain. The strain gauges shown in the figures 3.10.12, 3.10.13, 3.10.14 and 3.10.19 are located in the longitudinal reinforcement, on the underside. More specifically, strain gauge SG1 has maximum strain 1190,22 μ strain and minimum strain -335,70 μ strain. The residual strain is -15,26 μ strain. Strain gauge SG2 has maximum deformation 808,74 μ strain and minimum -91,56 μ strain. The residual strain is -15,26 μ strain. Strain gauge SG3 has 701,93 μ strain and -91,56 μ strain maximum and minimum strain respectively. The residual strain is 30,52 μ strain. Strain gauge SG4 as we can see in figure 3.10.13 has maximum 1205,48 μ strain and minimum -427,26 μ strain deformation. The residual strain is -76,30 μ strain. Figure 3.10.19 shows strain gauges SG5 and SG6. Strain gauge SG5 has 1136,19 μ strain and -2234,67 μ strain maximum and minimum strain respectively. Strain gauge SG5 presents 411,52 μ strain residual strain. Strain gauge SG6 has 73,87 μ strain maximum strain, -1763,86 μ strain minimum strain and 49,52 μ strain residual. Finally in figure 3.2.14 see strain gauge SG7 and SG8. Strain gauge SG7 has maximum strain 701,93 μ strain and SG8 has maximum strain

1129,18 μ strain. Strain gauge SG7 has -45,78 μ strain minimum deformation and SG8 has -442,52 μ strain. The residual strain for strain gauge SG7 and SG8 is -83,15, -91,56 respectively.

Sg1

Max: 1190,22 μ strain

Min: -335,70 μ strain

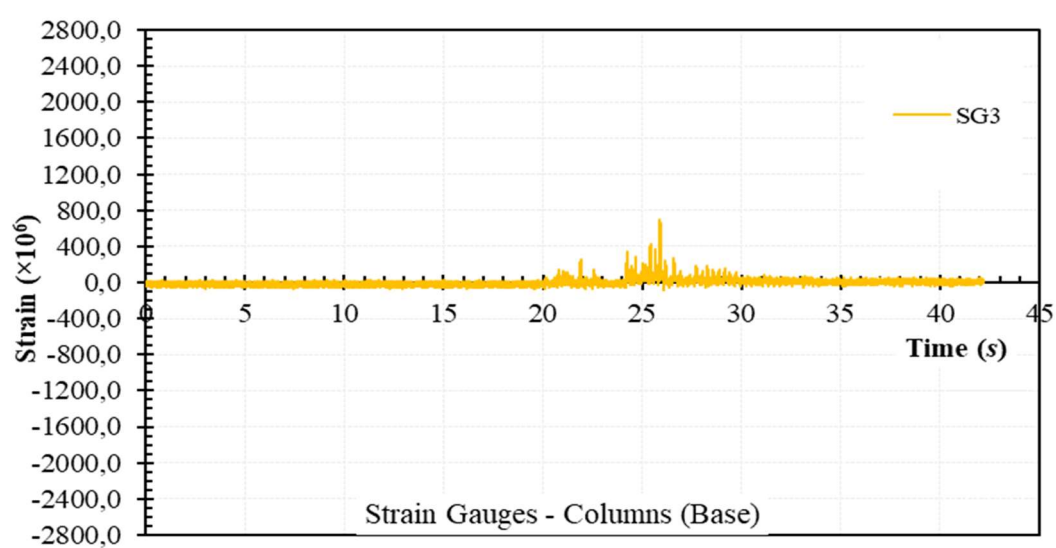
Residual: -15,26 μ strain

Sg2

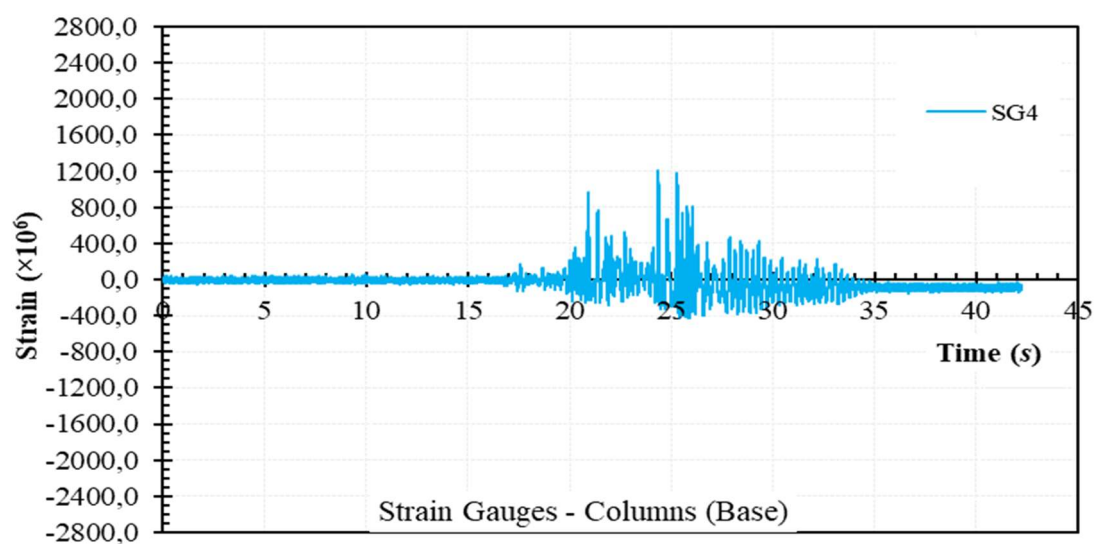
Max: 808,74 μ strain

Min: -91,56 μ strain

Residual: -15,26 μ strain



(a)



(b)

Figure 3.10.13 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 3 and (b) strain gauge 4

Sg3

Max: 701,93 μ strain

Min: -91,56 μ strain

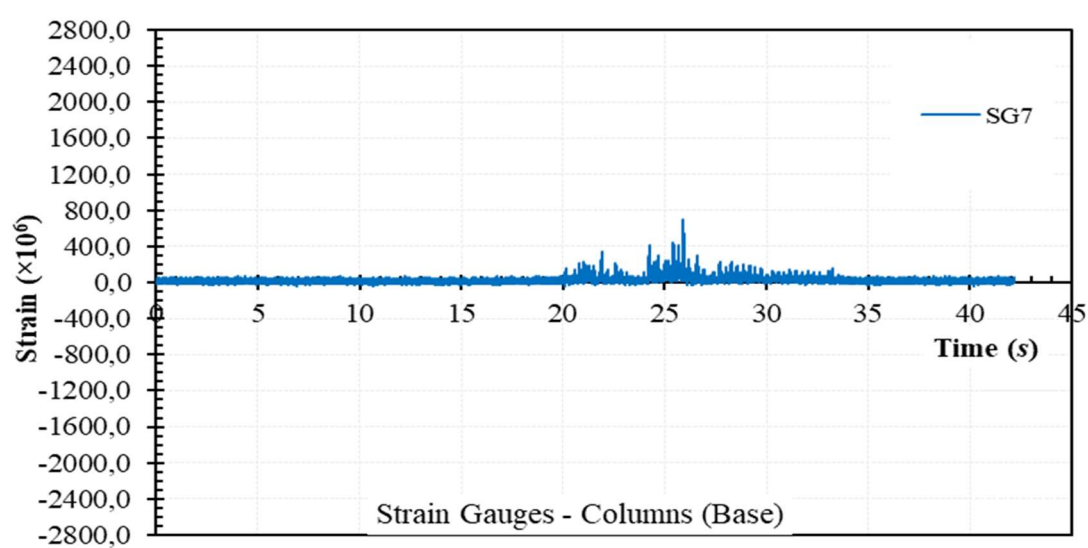
Residual: 30,52 μ strain

Sg4

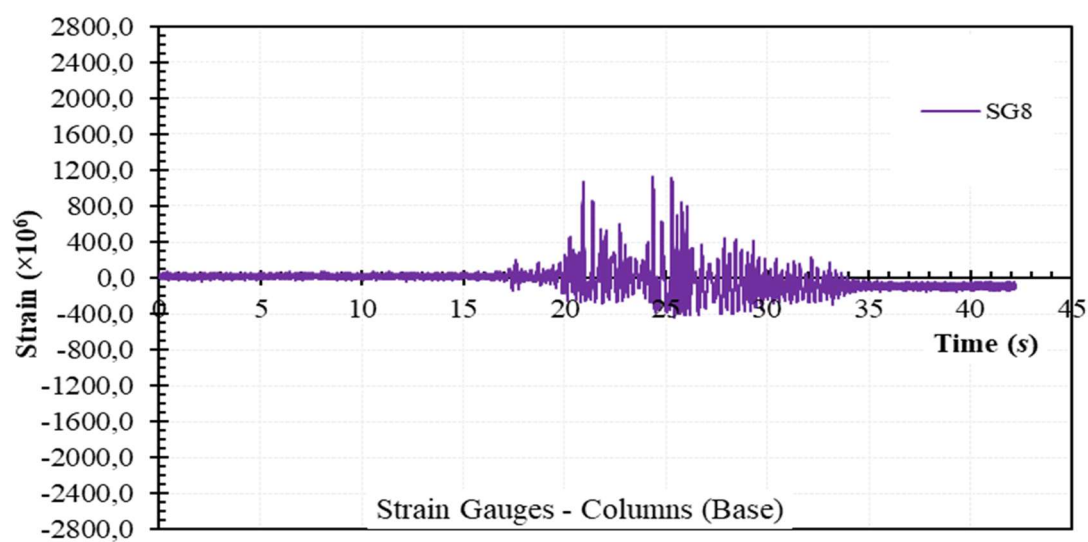
Max: 1205,48 μ strain

Min: -427,26 μ strain

Residual: -76,30 μ strain



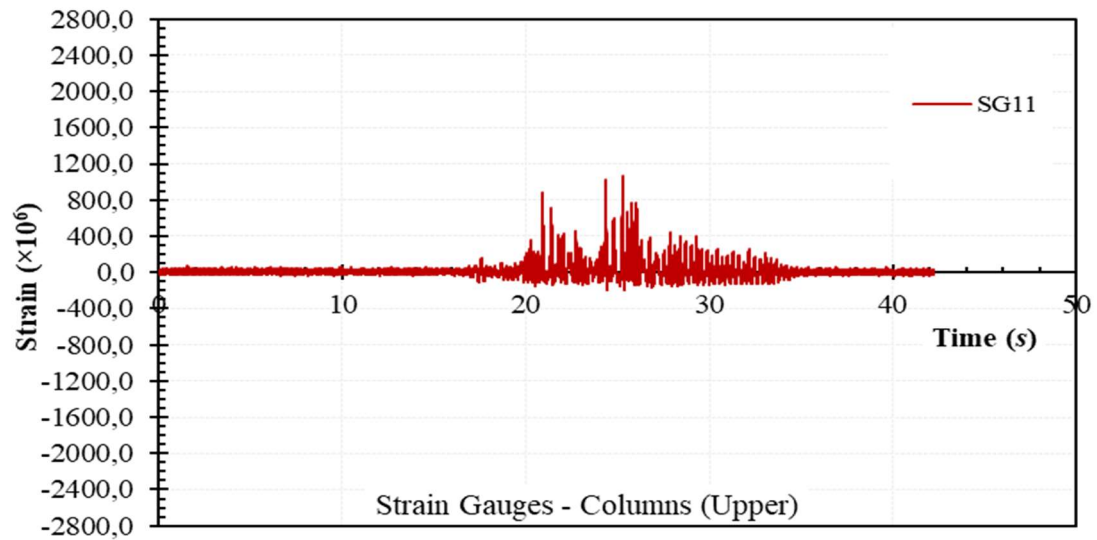
(a)



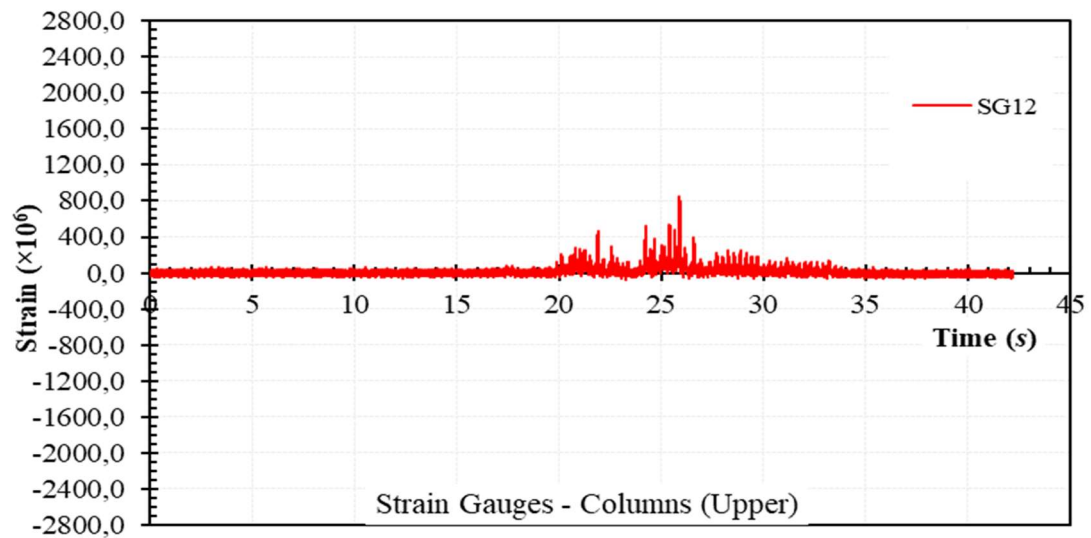
(b)

Figure 3.10.14 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 7 and (b) strain gauge 8

Sg7Max: 701,93 μ strainMin: -45,78 μ strainResidual: -83,15 μ strain**Sg8**Max: 1129,18 μ strainMin: -442,52 μ strainResidual: -91,56 μ strain



(a)



(b)

Figure 3.10.15 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12

The strain gauges shown in the figures 3.10.15, 3.10.16, 3.10.17 and 3.10.20 are located in the longitudinal reinforcement, on the upper side. More specifically, strain gauge SG9 has 56,12 μ strain maximum strain, -1979,40 μ strain minimum strain and 46,36 μ strain residual. Strain gauge SG10 has 269,46 μ strain maximum strain, -1961,66 μ strain minimum strain and 53,88 μ strain residual. Strain gauge SG11 has maximum strain 1068,15 μ strain and minimum -198,37 μ strain deformation. The residual strain is -30,52 μ strain for strain gauge SG11. Strain gauge SG12 has maximum strain 854,52 μ strain and minimum strain -76,30 μ strain. The residual value is -0,46 μ strain. Strain gauge SG13 has maximum strain 1007,11 μ strain and minimum strain -91,56 μ strain. The residual is 0 μ strain. Strain gauge SG14 has maximum strain 1083 μ strain and minimum strain -198,37 μ strain. The residual is -0,15 μ strain. Finally strain gauges SG15 has maximum strain 1174,96 μ strain and minimum strain -

259,41 μ strain. The residual is 0 μ strain. Strain gauge SG16 has maximum strain 839,26 μ strain, minimum strain -137,33 μ strain and residual strain 0,15 μ strain.

Sg11

Max: 1068,15 μ strain

Min: -198,37 μ strain

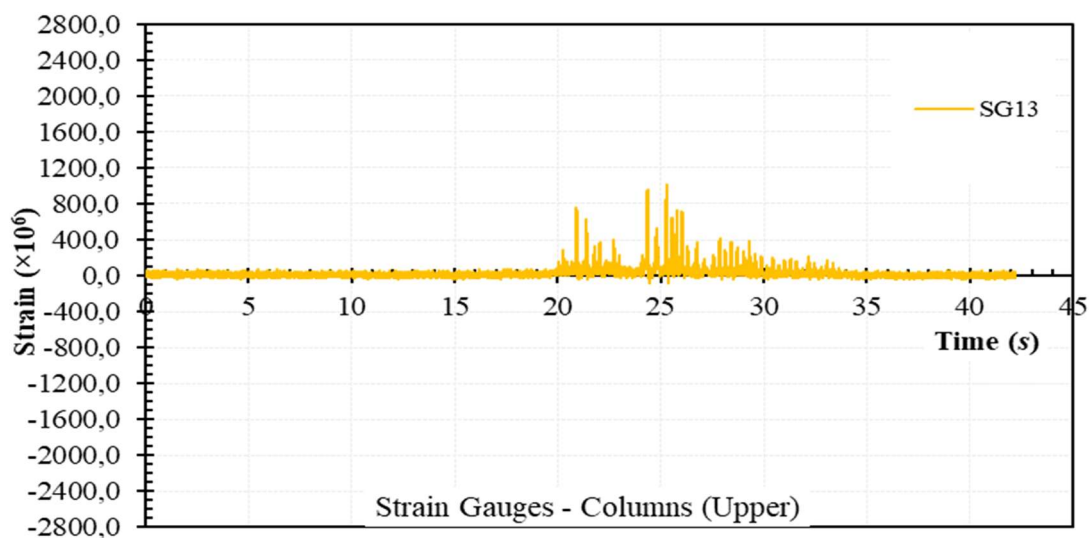
Residual: -30,52 μ strain

Sg12

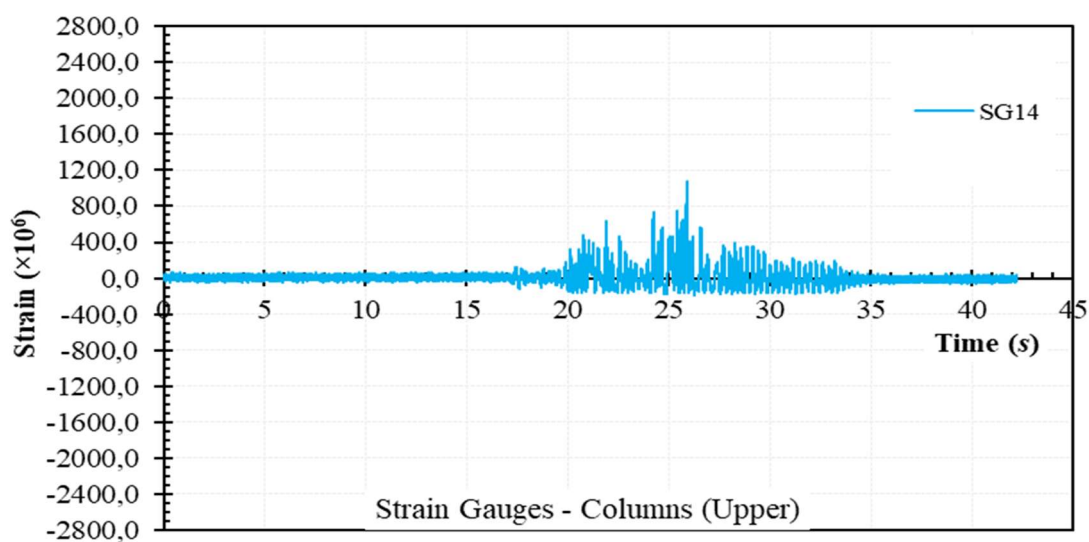
Max: 854,52 μ strain

Min: -76,30 μ strain

Residual: -0,46 μ strain



(a)



(b)

Figure 3.10.16 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 13 and (b) strain gauge 14

Sg13

Max: 1007,11 μ strain

Min: -91,56 μ strain

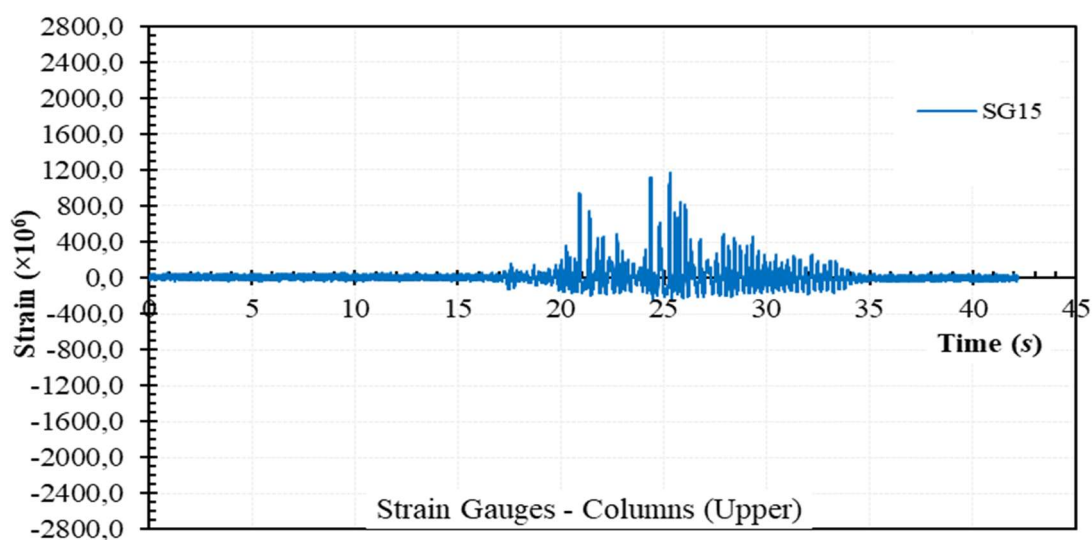
Residual: 0 μ strain

Sg14

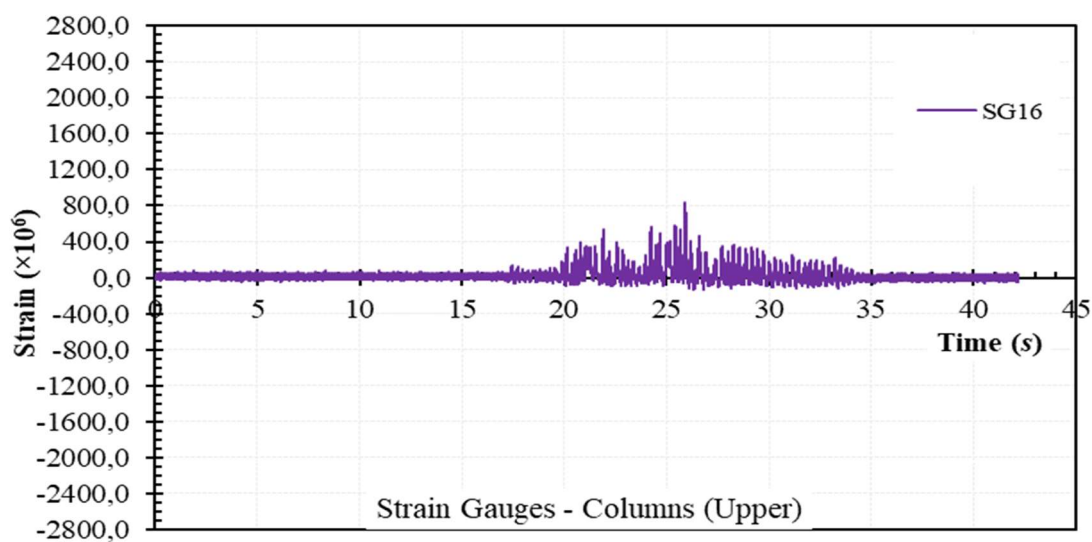
Max: 1083,41 μ strain

Min: -198,37 μ strain

Residual: -0,15 μ strain



(a)



(b)

Figure 3.10.17 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12

Sg15

Max: 1174,96 μ strain

Min: -259,41 μ strain

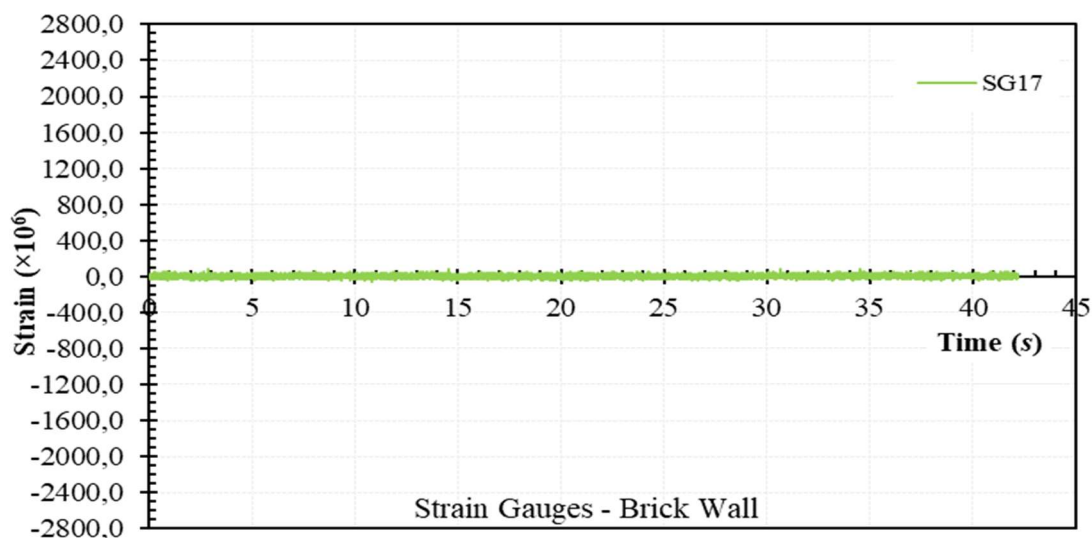
Residual: 0 μ strain

Sg16

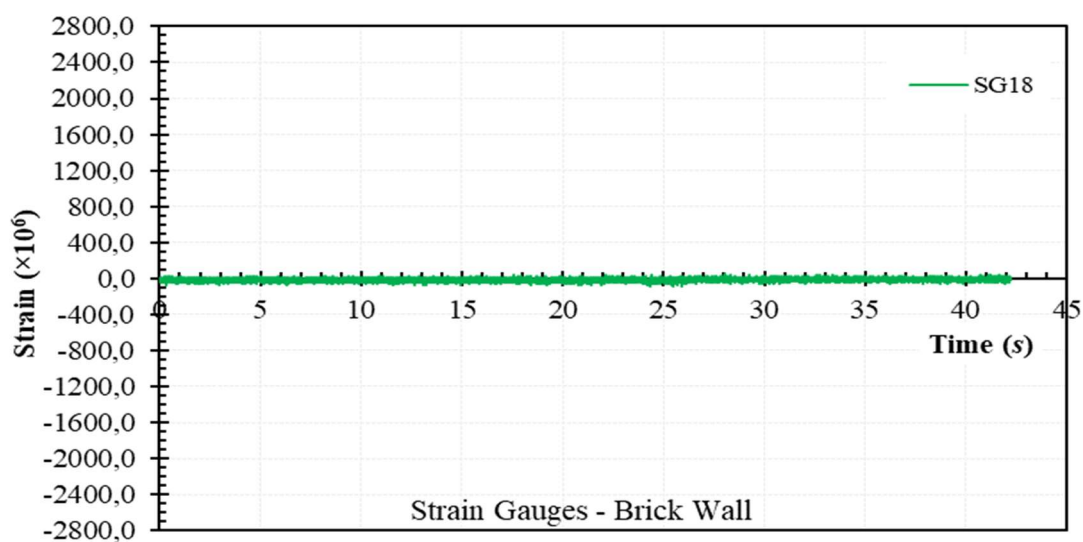
Max: 839,26 μ strain

Min: -137,33 μ strain

Residual: 0,15 μ strai



(a)



(b)

Figure 3.10.18 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauges SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge SG17 has 76,30 μ strain maximum strain. Strain gauge SG17 has minimum deformation -61,04 μ strain and strain gauge SG18 -91,56 μ strain. Strain gauge SG18 has maximum strain 61,04 μ strain. Finally strain gauge SG17 presents 0 μ strain residual. Strain gauge SG18 presents 23,27 μ strain residual.

Sg17

Max: 76,30 μ strain

Min: -61,04 μ strain

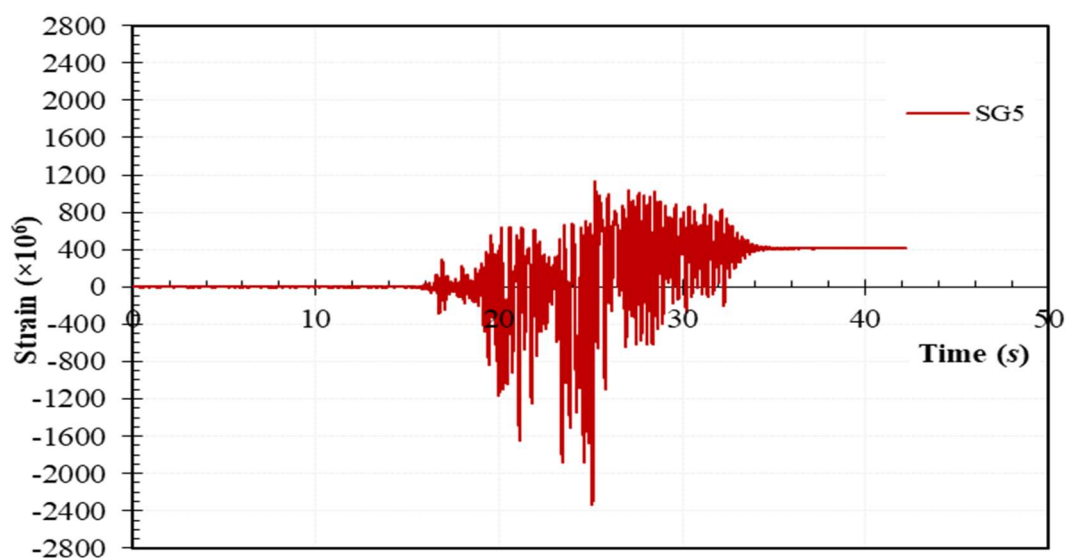
Residual: 0 μ strain

Sg18

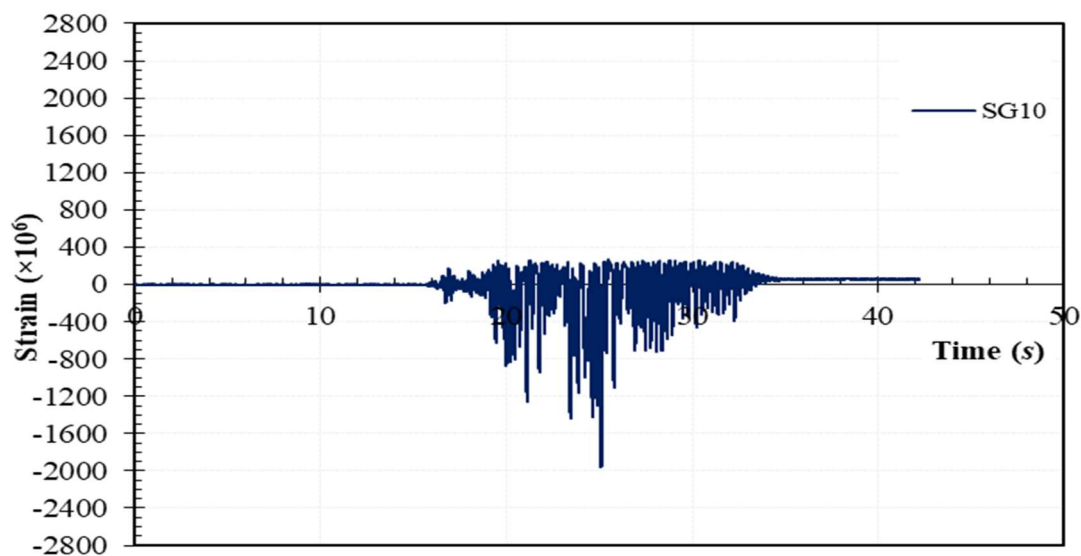
Max: 61,04 μ strain

Min: -91,56 μ strain

Residual: 23,27 μstrain



(a)



(b)

Figure 3.10.19 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 5 and (b) strain gauge 10

Sg5

Max: 1136,19 μstrain

Min: -2334,67 μstrain

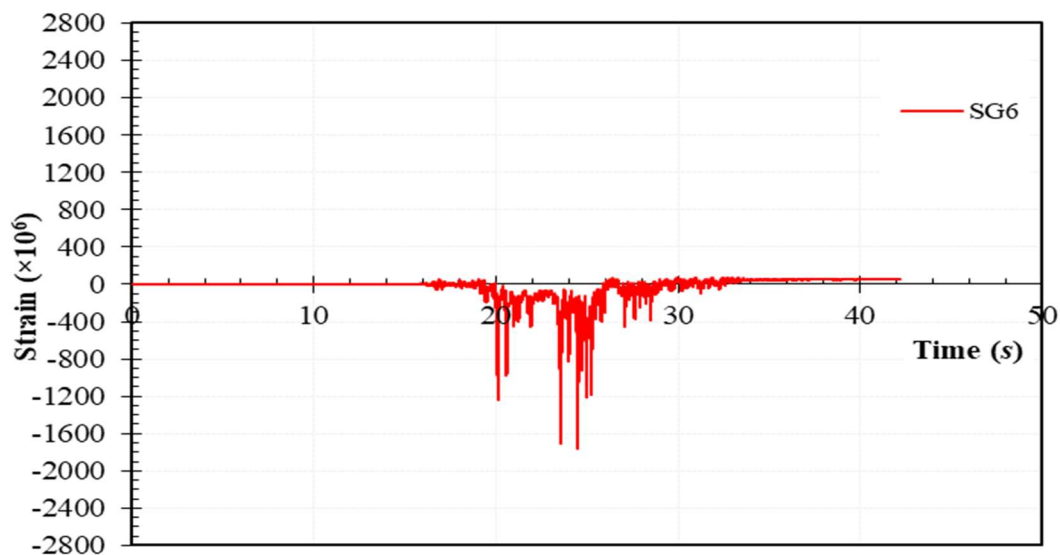
Residual: 411,52 μstrain

Sg10

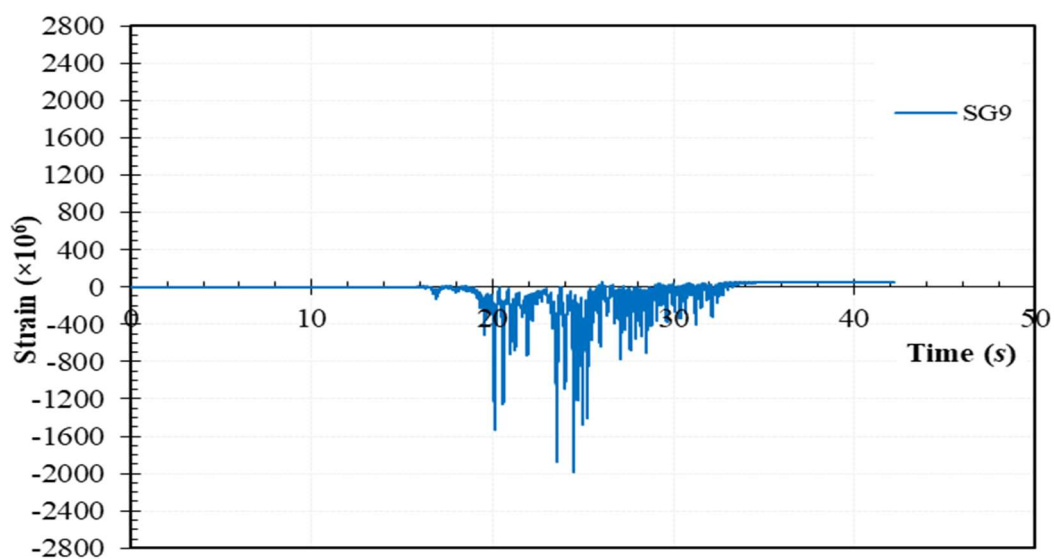
Max: 269,46 μstrain

Min: -1961,66 μstrain

Residual: 53,88 μ strain



(a)



(b)

Figure 3.10.20 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 6 and (b) strain gauge 9

Sg6

Max: 73,87 μ strain

Min: -1763,86 μ strain

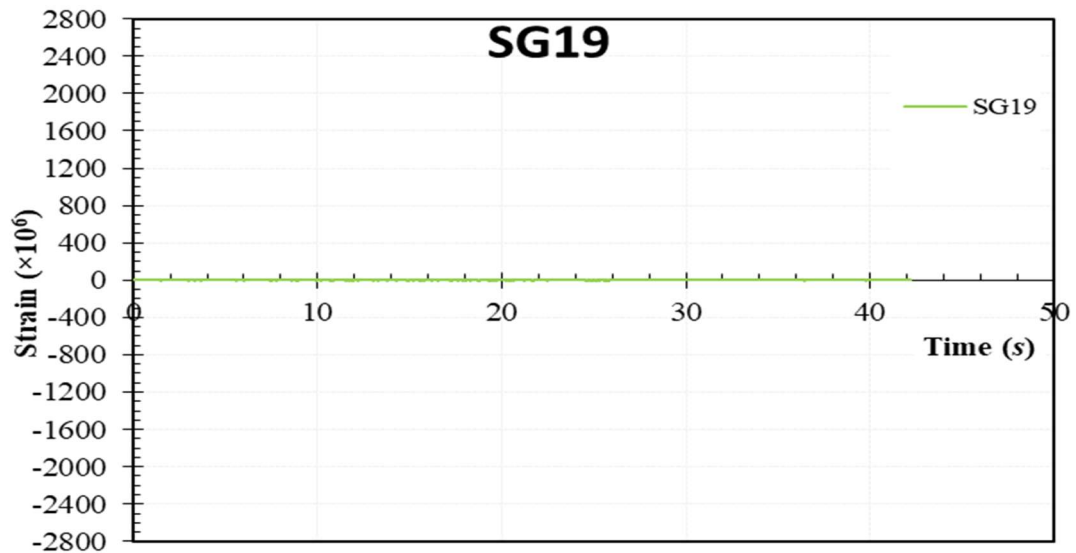
Residual: 49,52 μ strain

Sg9

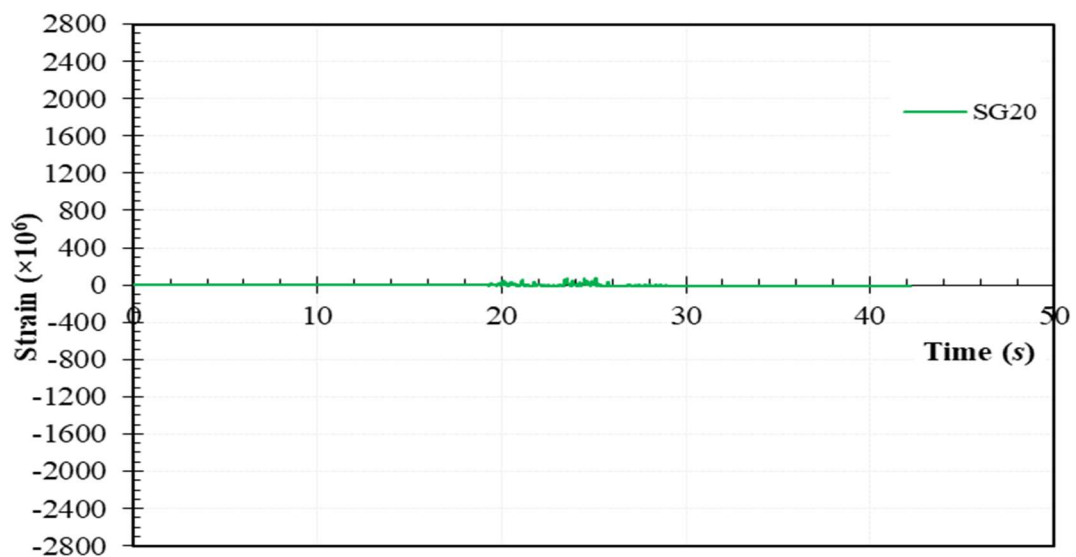
Max: 56,12 μ strain

Min: -1979,40 μ strain

Residual: 46,36 μ strain



(a)



(b)

Figure 3.10.21 Characteristic results for phase A (1,1g earthquake) (a) strain gauge 6 and (b) strain gauge 9\

Strain gauge 19 is located on the centre of partial masonry 2 along direction x. Strain gauges 20 is located on the centre of partial masonry 2 along direction x. More specifically strain gauge SG19 has maximum 3,24 μ strain and minimum -4,87 μ strain. Strain gauge SG20 has maximum strain 71,52 μ strain and minimum -16,25 μ strain. The residual strain for strain gauge SG19 is -1,62 μ strain and residual for strain gauge SG20 is -12,19 μ strain.

Sg19

Max: 3,24 μ strain

Min: -4,87 μ strain

Residual: -1,62 μ strain

Sg20

Max: 71,52 μ strain

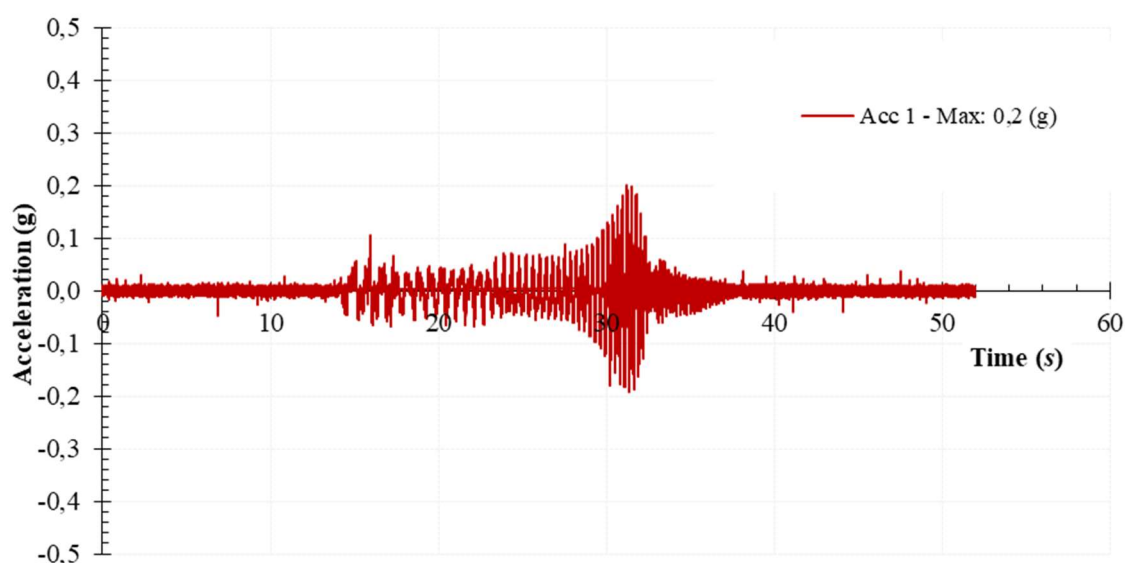
Min: -16,25 μ strain

Residual: -12,19 μ strain

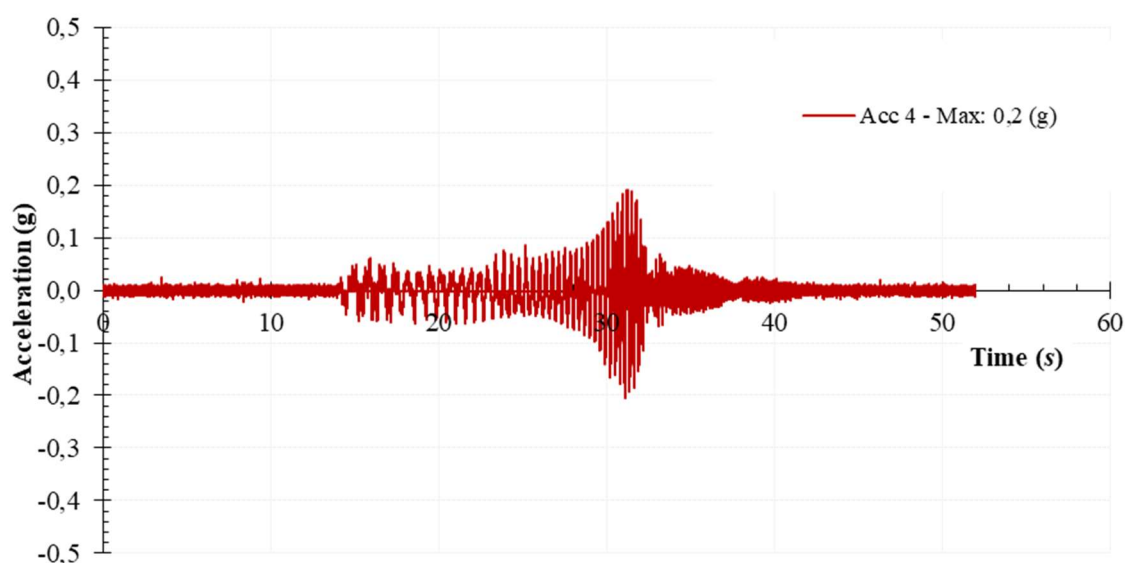
3.11) White noise test after EQ1,1g

Accelerometers

Characteristic extracts from the time histories of accelerations of different accelerometers are given below for white noise after EQ1,1g. The max acceleration at the slab level on the accelerometer acc1 and acc4 is 0,2g for both. The max acceleration at the foundation level on the accelerometer acc10 is 0,09g.

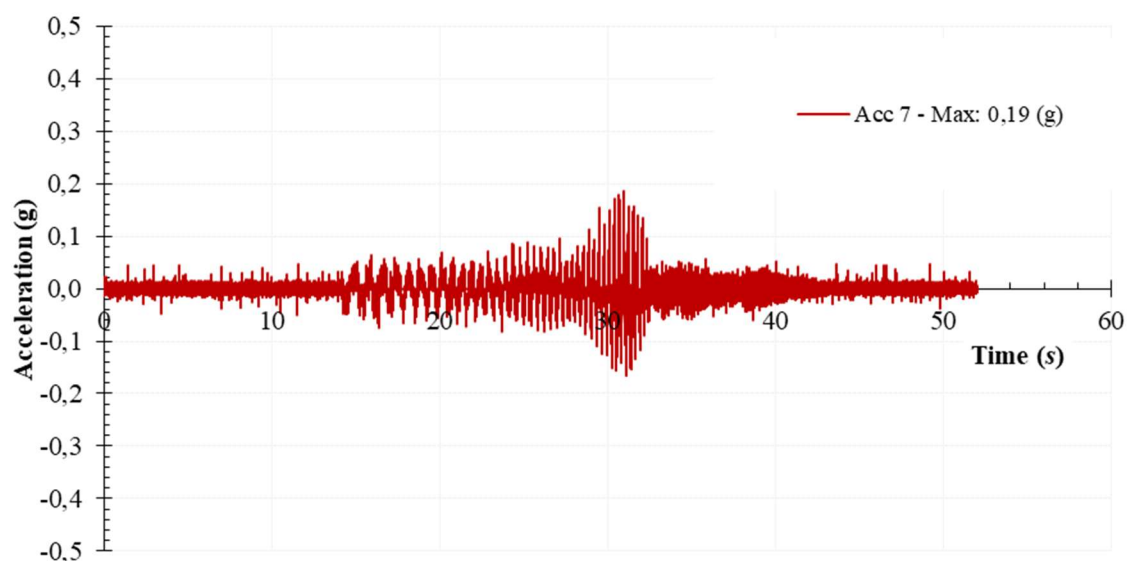


(a)

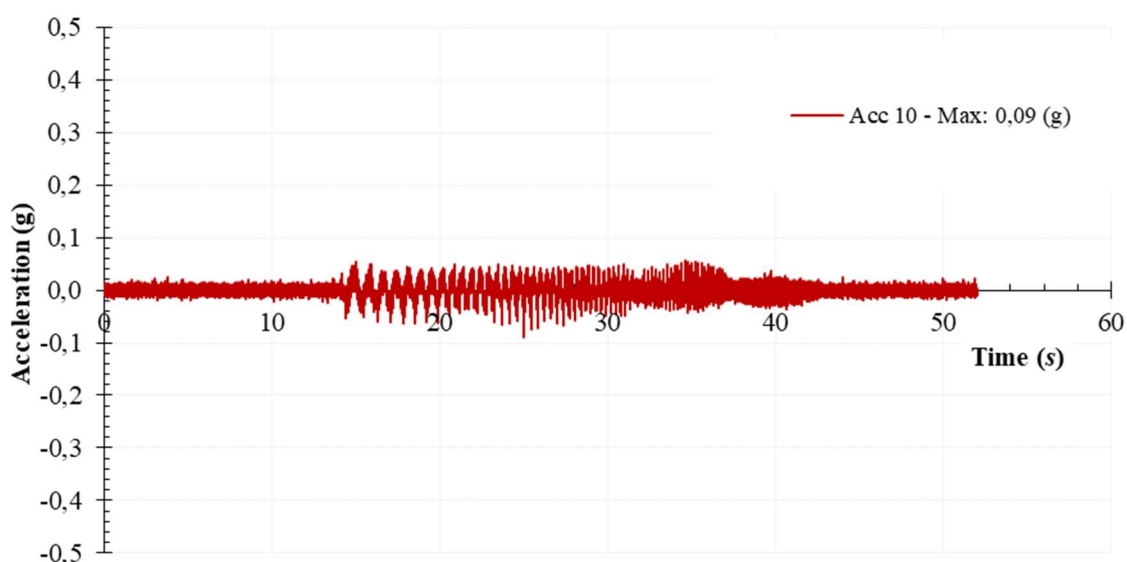


(b)

Figure 3.11.1 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 1 (b) Accelerometer 4

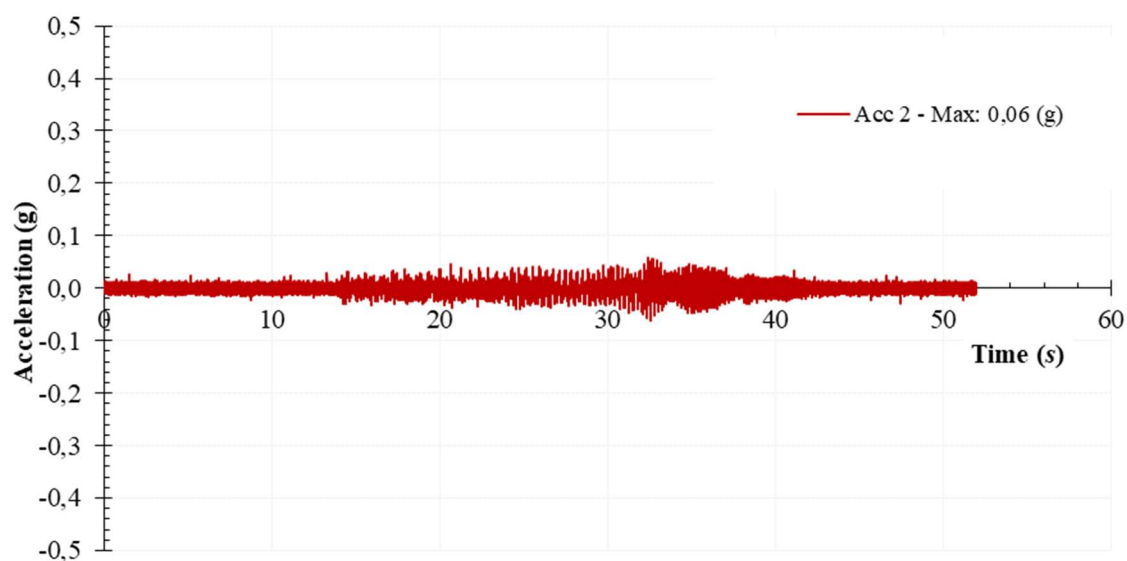


(a)

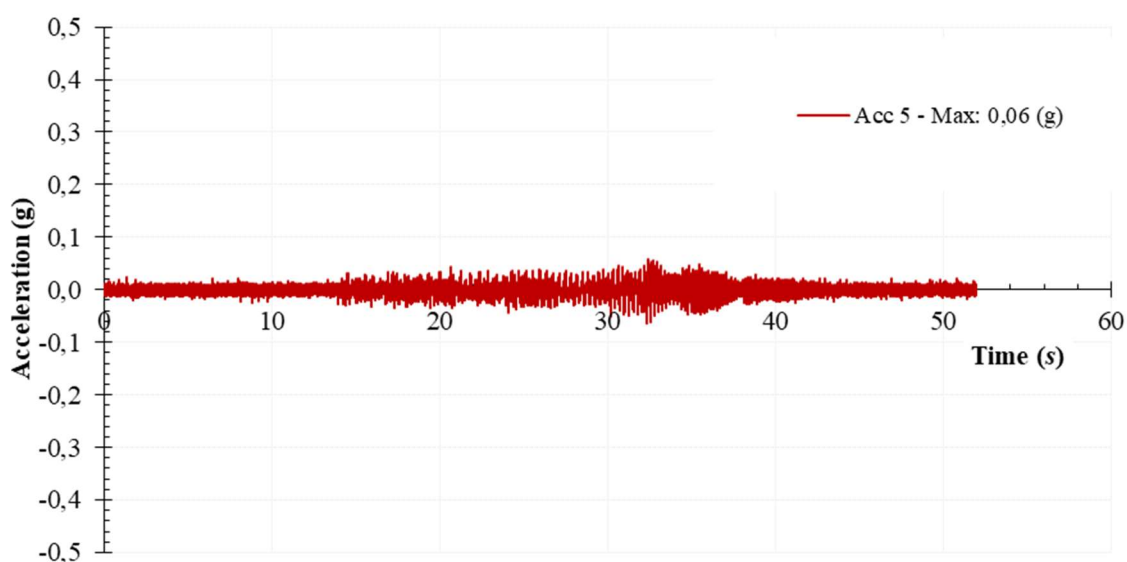


(b)

Figure 3.11.2 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 7 (b) Accelerometer 10

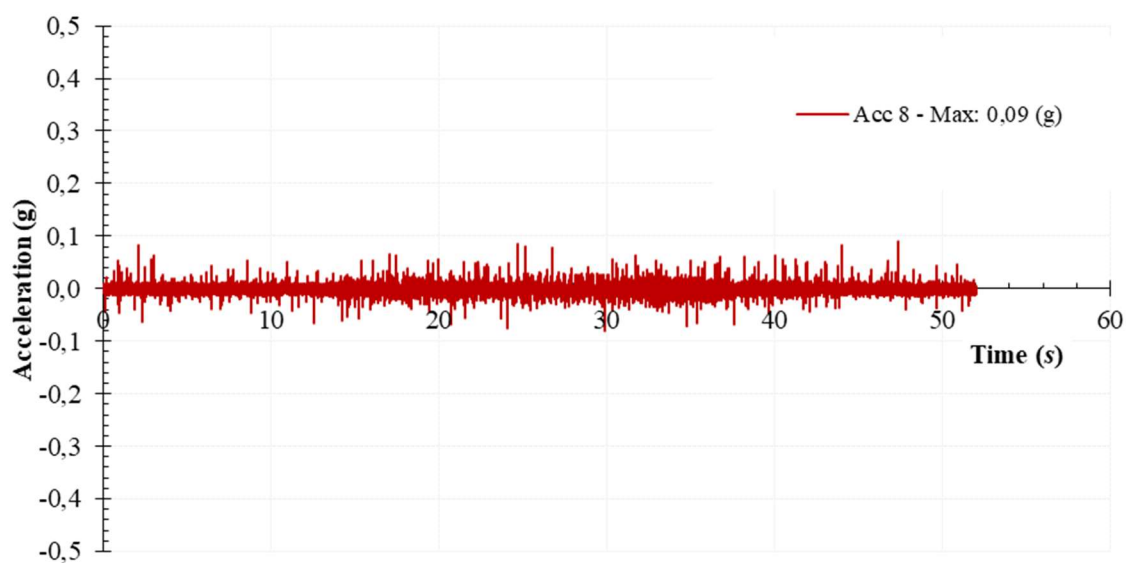


(a)

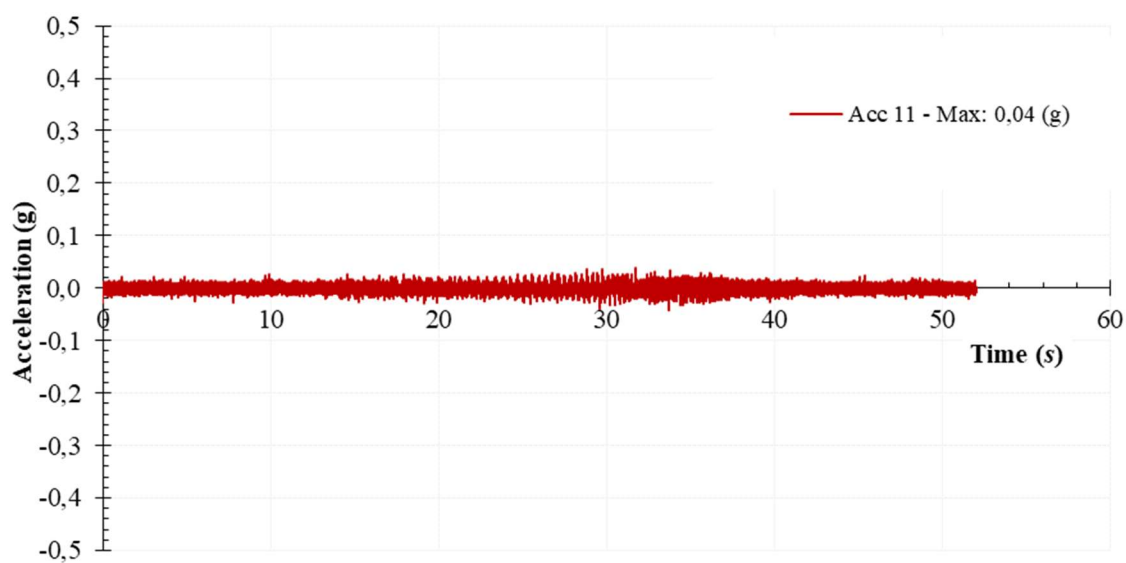


(b)

Figure 3.11.3 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 2 (b) Accelerometer 5

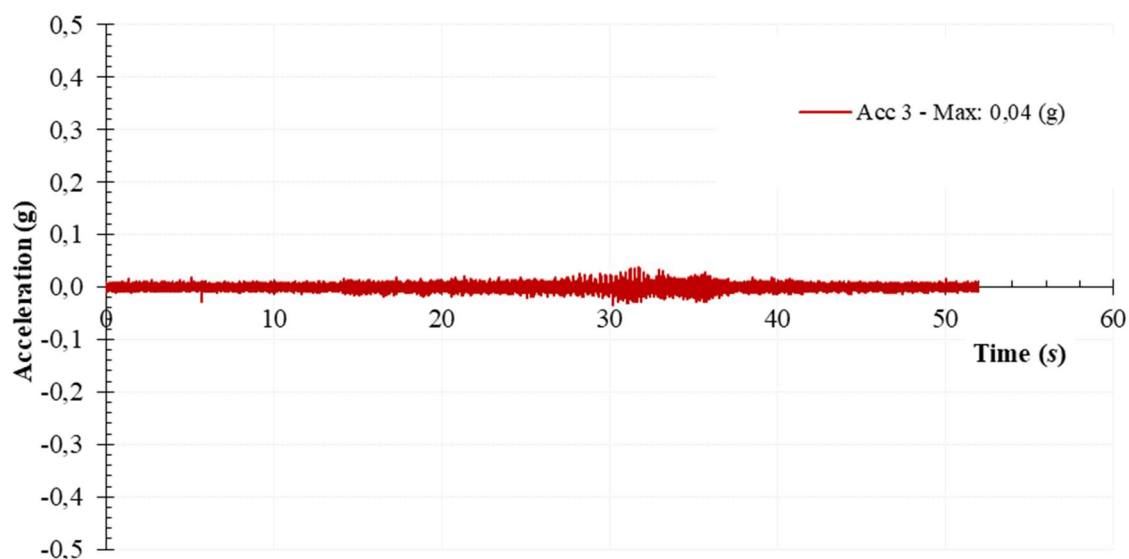


(a)

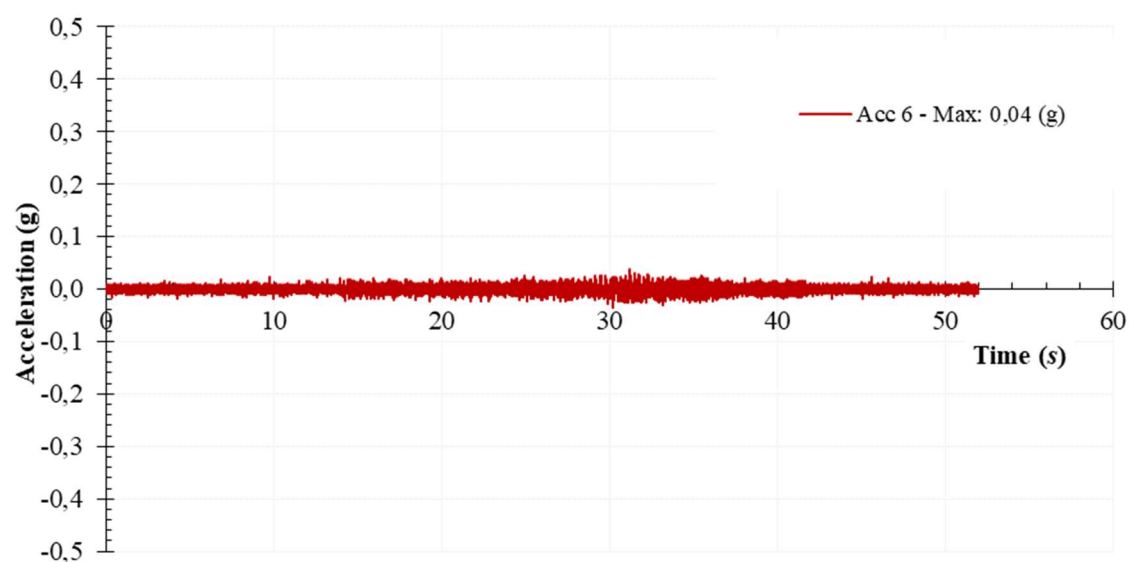


(b)

Figure 3.11.4 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 8 (b) Accelerometer 11

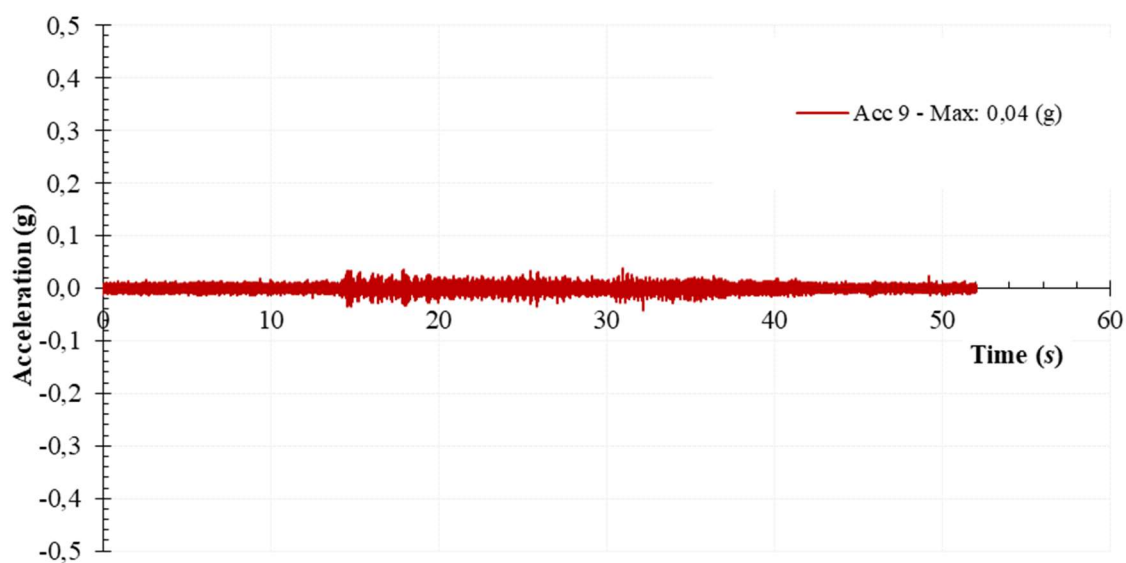


(a)

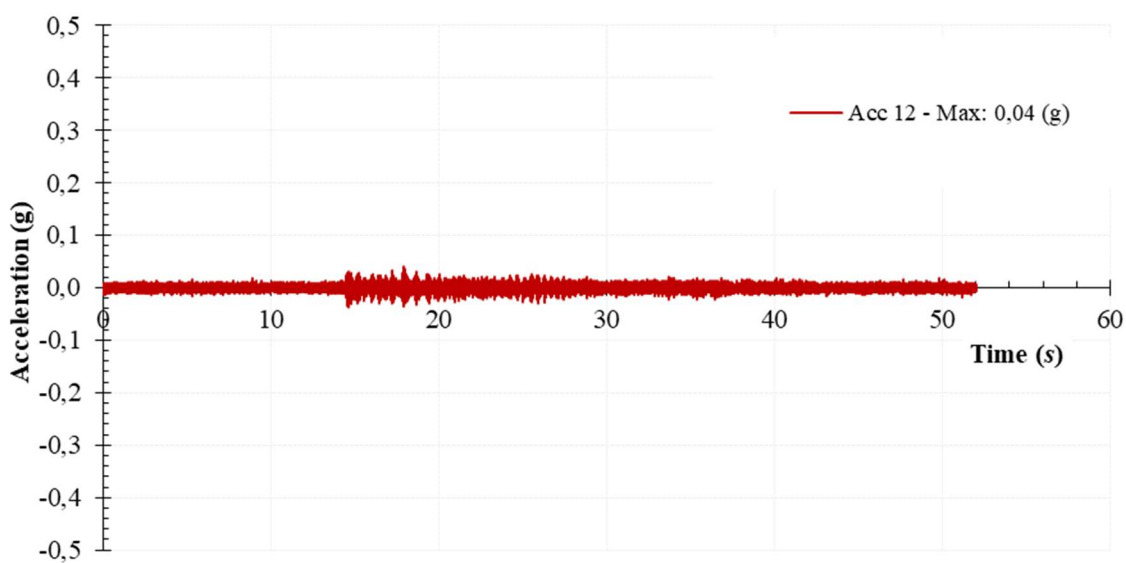


(b)

Figure 3.11.5 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 3
(b) Accelerometer 6

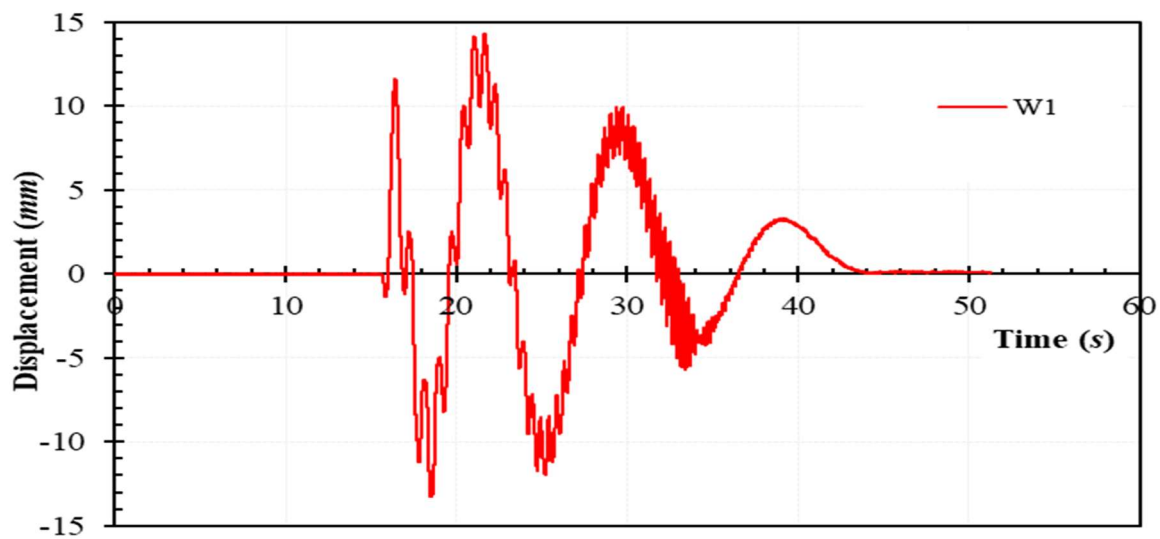


(a)

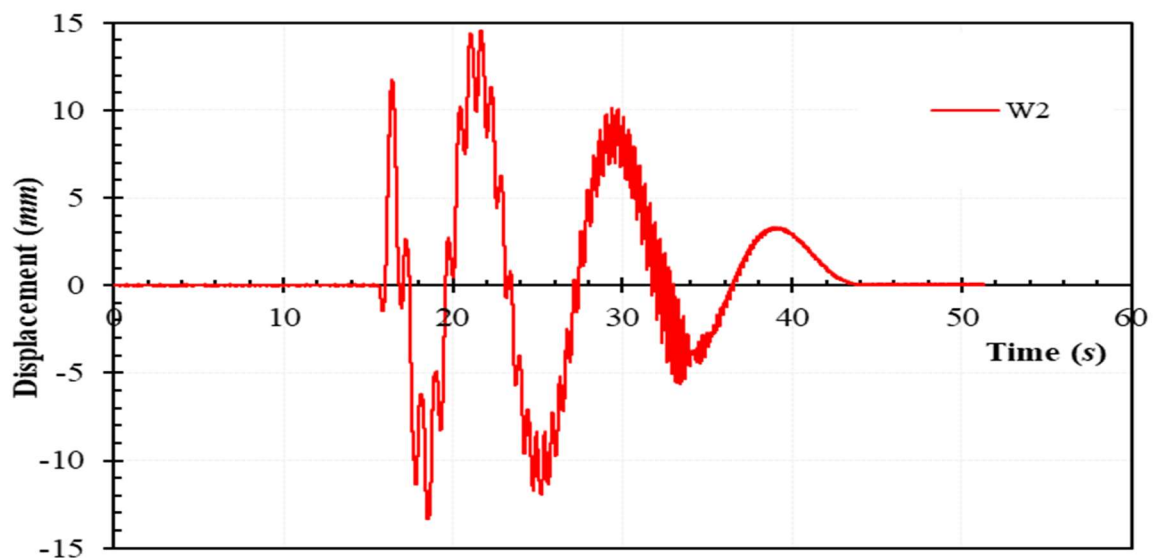


(b)

Figure 3.11.6 Characteristic results for phase A (white noise after 1,1g earthquake): (a) Accelerometer 9 (b) Accelerometer 12



(a)



(b)

Figure 3.11.7 Characteristic results for phase A (white noise after 1,1g earthquake) : (a) Draw wire sensor W1 and (b) Draw wire sensor W2

Figure 3.11.7 shows draw wire sensors W1 and 2. More specifically, draw wire sensor 1 is located on the slab, on the left side and draw wire sensor 2 is located on the slab, on the right side. The maximum movement detected by draw wire sensor 1 is 14,32 mm while the minimum is -13,26 mm. The maximum movement detected by draw wire sensor 2 is 14,56 mm while the minimum is -13,35 mm.

W1

Max: 14,32 mm

Min: -13,26 mm

W2

Max: 14,56 mm

Min: -13,35 mm

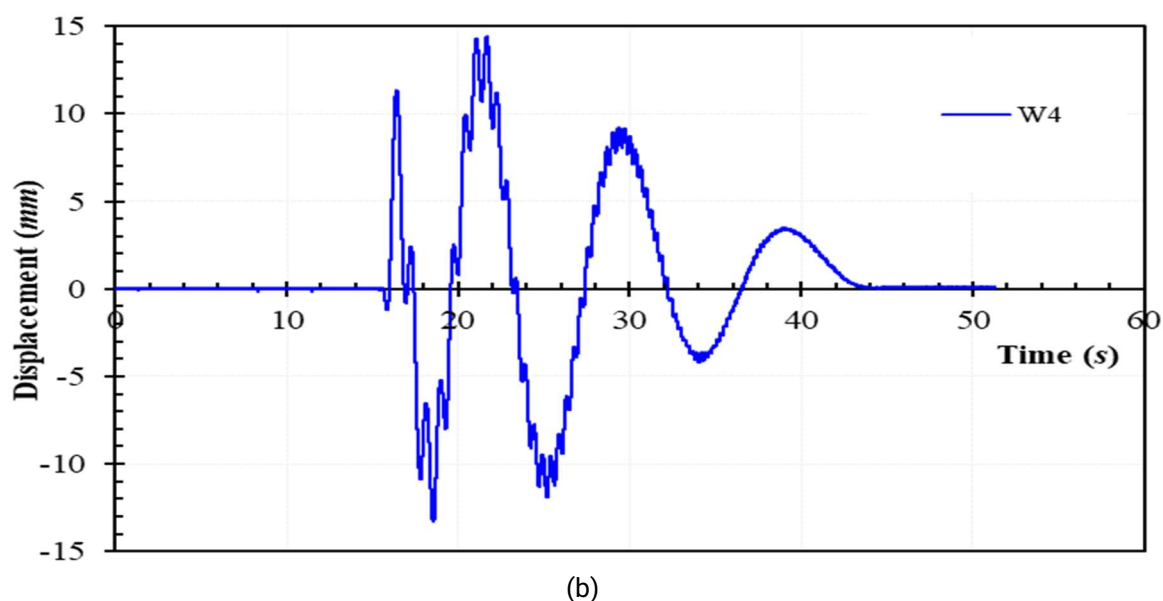
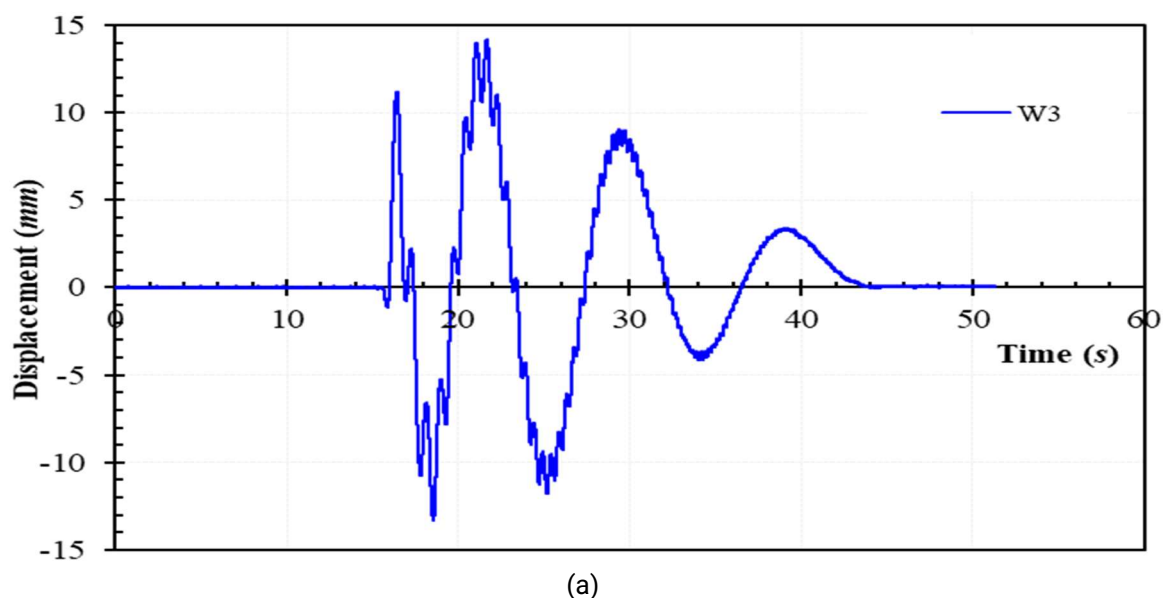


Figure 3.11.8 Characteristic results for phase A (white noise after 1,1g earthquake) : (a) Draw wire sensor 3 and (b) Draw wire sensor 4

Figure 3.11.8 shows draw wire sensors 3 and 4. More specifically, draw wire sensor 3 is located on the foundation, on the left side and draw wire sensor 4 is located on the foundation, on the right side. The maximum movement detected by draw wire sensor 3 is 14,21 mm while the minimum is -13,32 mm. The maximum movement detected by draw wire sensor 2 is 14,41 mm while the minimum is -13,31 mm.

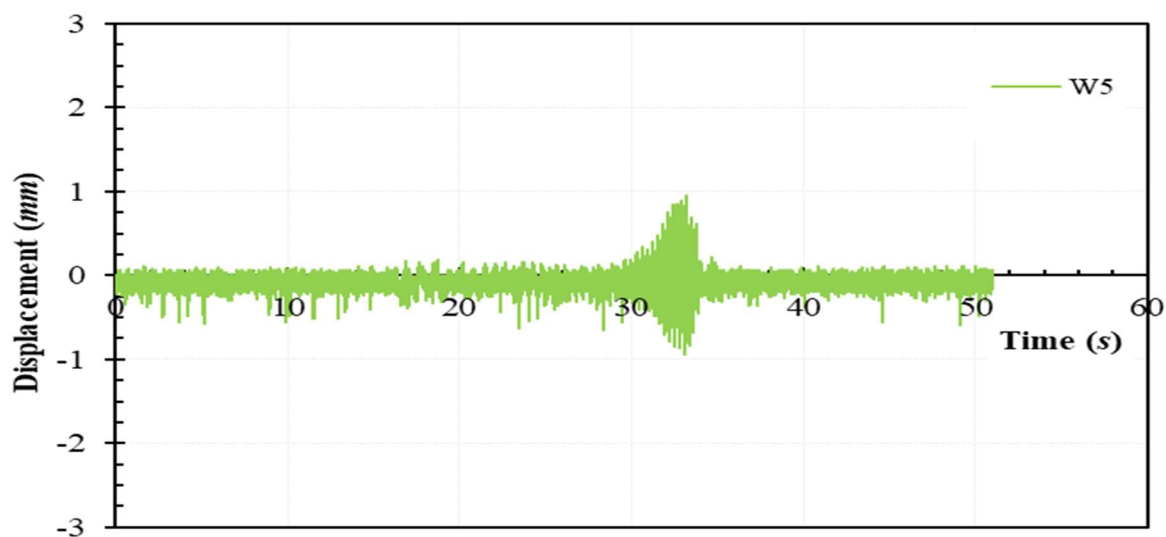
W3

Max: 14,21 mm

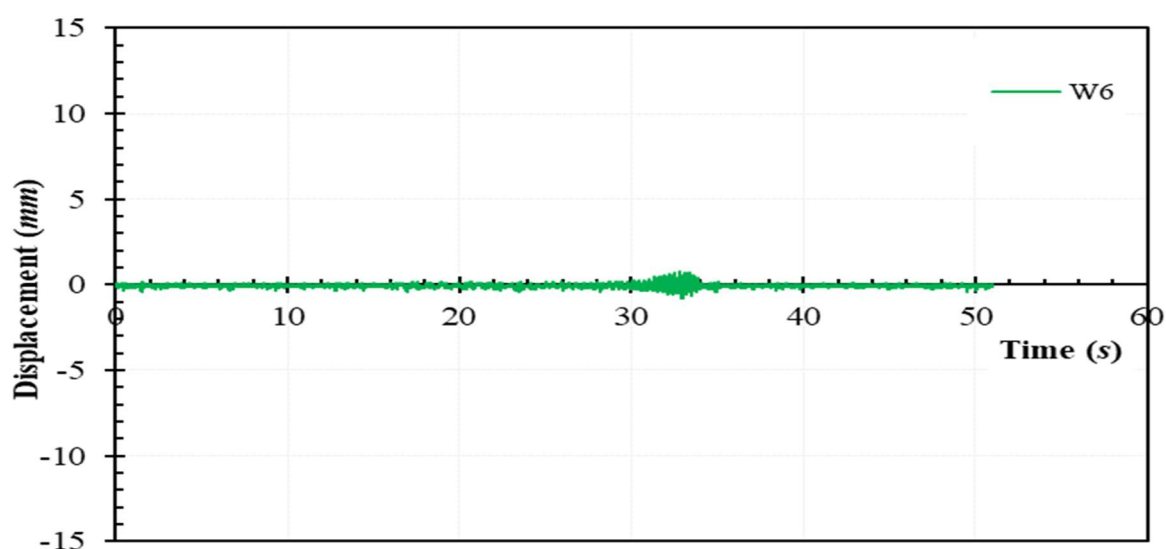
Min: -13,32 mm

W4

Max: 14,41 mm
Min: -13,31 mm



(a)



(b)

Figure 3.11.9 Characteristic results for phase A (white noise after 1,1g earthquake) : (a) Draw wire sensor 5 and (b) Draw wire sensor 6

Figure 3.11.9 shows draw wire sensors 5 and 6. More specifically, draw wire sensor 5 is located along the partial masonry infill diagonal and draw wire sensor 6 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor 5 is 0,95 mm while the minimum is -0,95 mm. The maximum movement detected by draw wire sensor 6 is 0,79 mm while the minimum is -0,83 mm.

W5

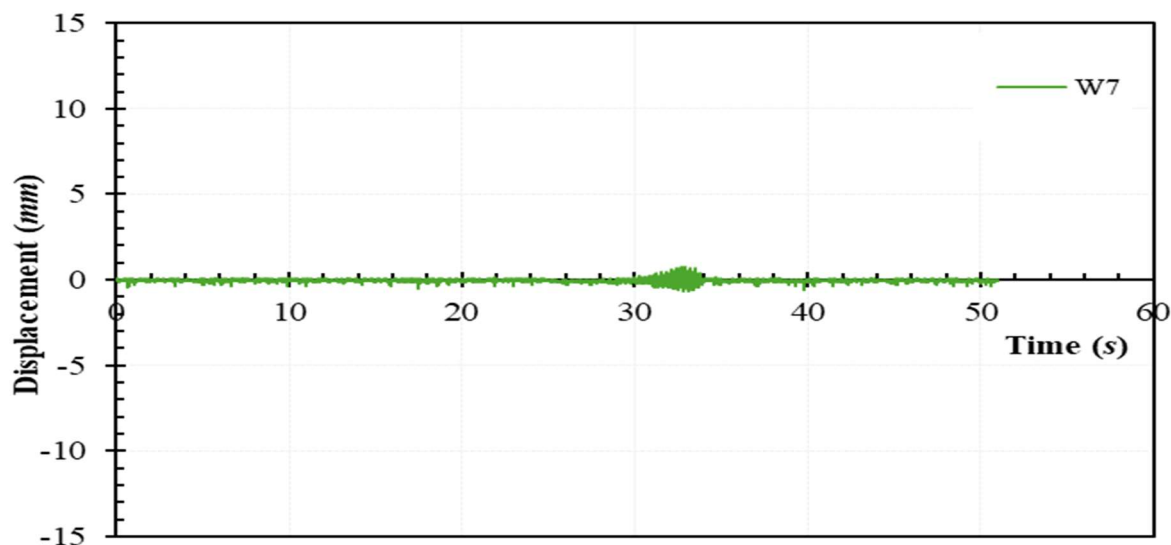
Max: 0,95 mm

Min: -0,95 mm

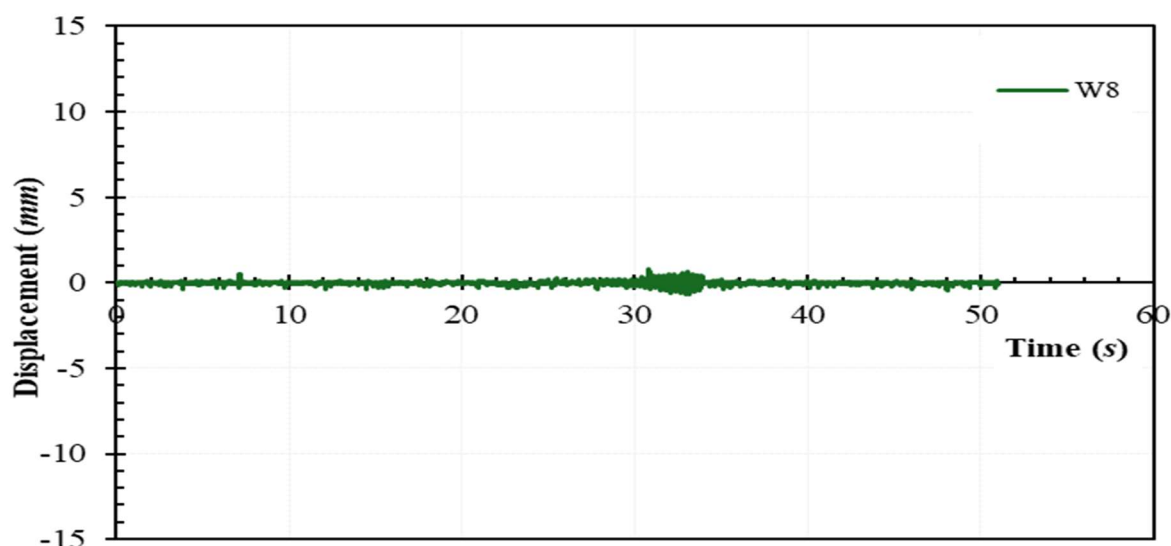
W6

Max: 0,79 mm

Min: -0,83 mm



(a)



(b)

Figure 3.11.10 Characteristic results for phase A (white noise after 1,1g earthquake) : (a) Draw wire sensor 7 and (b) Draw wire sensor 8

Figure 3.11.10 shows draw wire sensors 7 and 8. More specifically, draw wire sensor 7 is located along the partial masonry infill diagonal and draw wire sensor 8 is located along the partial masonry infill diagonal. The maximum movement detected by draw wire sensor 7 is 0,76 mm while the minimum is -0,66 mm. The maximum movement detected by draw wire sensor 8 is 0,79 mm while the minimum is -0,68 mm.

W7

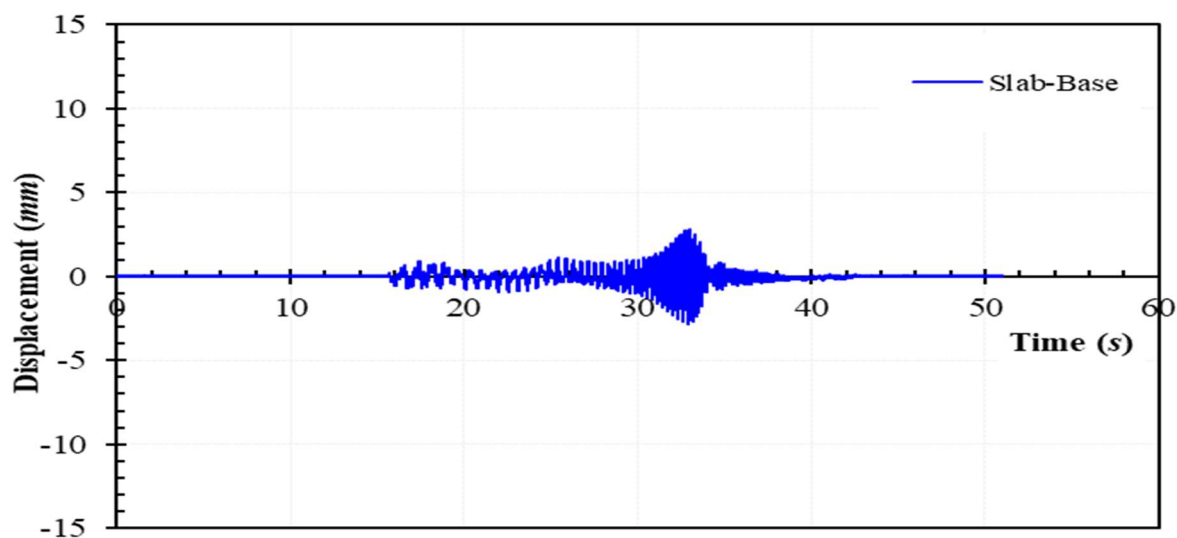
Max: 0,76 mm

Min: -0,66 mm

W8

Max: 0,79 mm

Min: -0,68 mm



(a)

Figure 3.11.11 Characteristic results for phase A (white noise after 1,1g earthquake) : (a) Diagram of displacement Slab – Base

Figure 3.11.11 shows slab – base displacement. More specifically, the maximum drift detected is 2,30 ‰ while the minimum is -2,31 ‰. The residual drift is 0,04 mm.

Maximum drift (‰): 2,30 ($2,8175 \text{ m} / 1,225 \text{ m} = 2,30 \text{ ‰}$)

Minimum drift (‰): -2,31

Residual: 0,04 mm

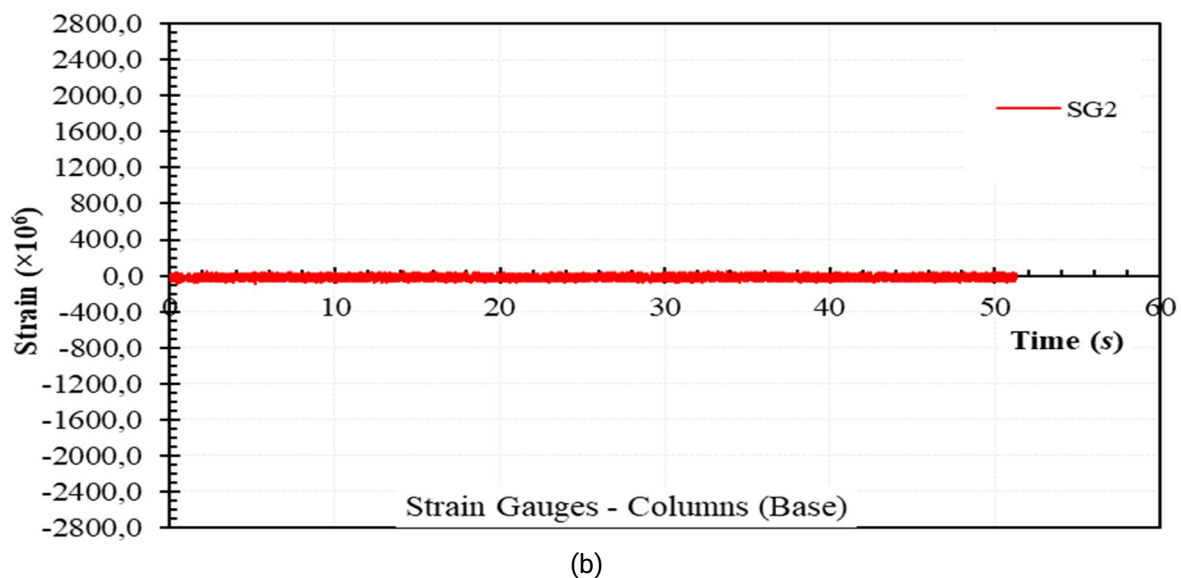
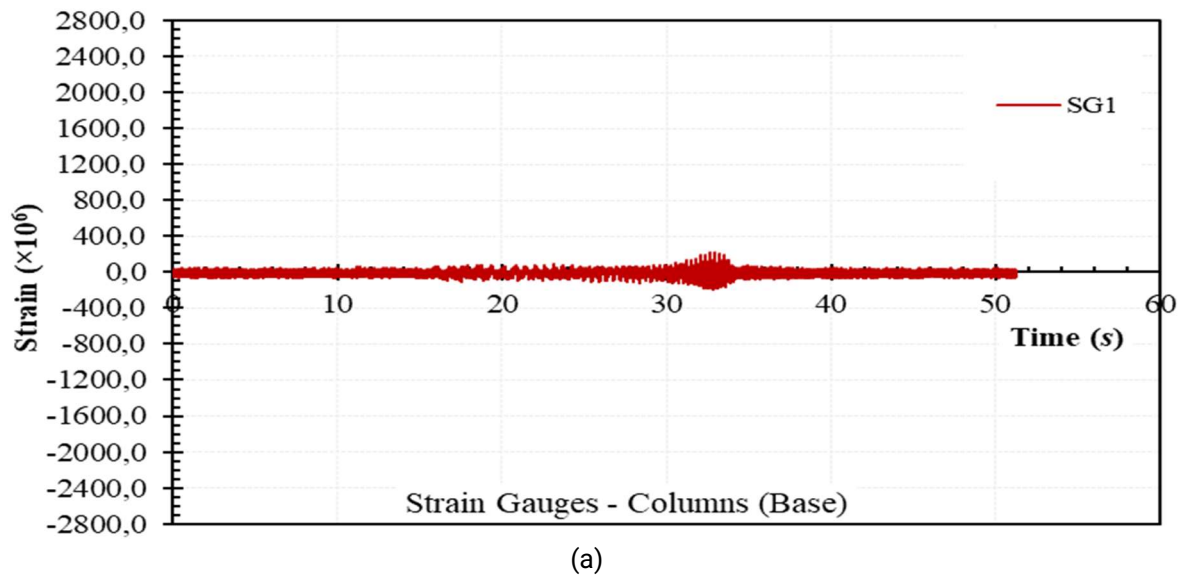


Figure 3.11.12 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 1 and (b) strain gauge 2

Strain gauges detect strain. The strain gauges shown in the figures 3.11.12, 3.11.13, 3.11.14 and 3.11.19 are located in the longitudinal reinforcement, on the underside. More specifically, strain gauge SG1 has maximum strain $213,63\mu\text{strain}$ and minimum strain $-198,37\mu\text{strain}$. The residual strain is $-30,52\mu\text{strain}$. Strain gauge SG2 has maximum deformation $45,78\mu\text{strain}$ and minimum $-91,56\mu\text{strain}$. The residual strain is $15,26\mu\text{strain}$. Strain gauge SG3 has $91,56\mu\text{strain}$ and $-45,78\mu\text{strain}$ maximum and minimum strain respectively. The residual strain is $15,26\mu\text{strain}$. Strain gauge SG4 as we can see in figure 3.11.13 has maximum $183,11\mu\text{strain}$ and minimum $-198,36\mu\text{strain}$ deformation. The residual strain is $-15,26\mu\text{strain}$. Figure 3.11.19 shows strain gauges SG5 and SG6. Strain gauge SG5 has $344,35\mu\text{strain}$ and $-432,74\mu\text{strain}$ maximum and minimum strain respectively. Strain gauge SG5 presents $-1,63\mu\text{strain}$ residual strain. Strain gauge SG6 has $28,42\mu\text{strain}$ maximum strain, $-80,38\mu\text{strain}$ minimum strain and $-2,44\mu\text{strain}$ residual. Finally in figure 3.2.14 see strain gauge SG7 and SG8. Strain gauge SG7 has maximum strain $76,30\mu\text{strain}$ and SG8 has maximum strain $183,11\mu\text{strain}$. Strain gauge

SG7 has $-76,30\mu\text{strain}$ minimum deformation and SG8 has $-198,37\mu\text{strain}$. The residual strain for strain gauge SG7 and SG8 is 0, $-45,78$ respectively.

Sg 1

Max: $213,63\mu\text{strain}$

Min: $-198,37\mu\text{strain}$

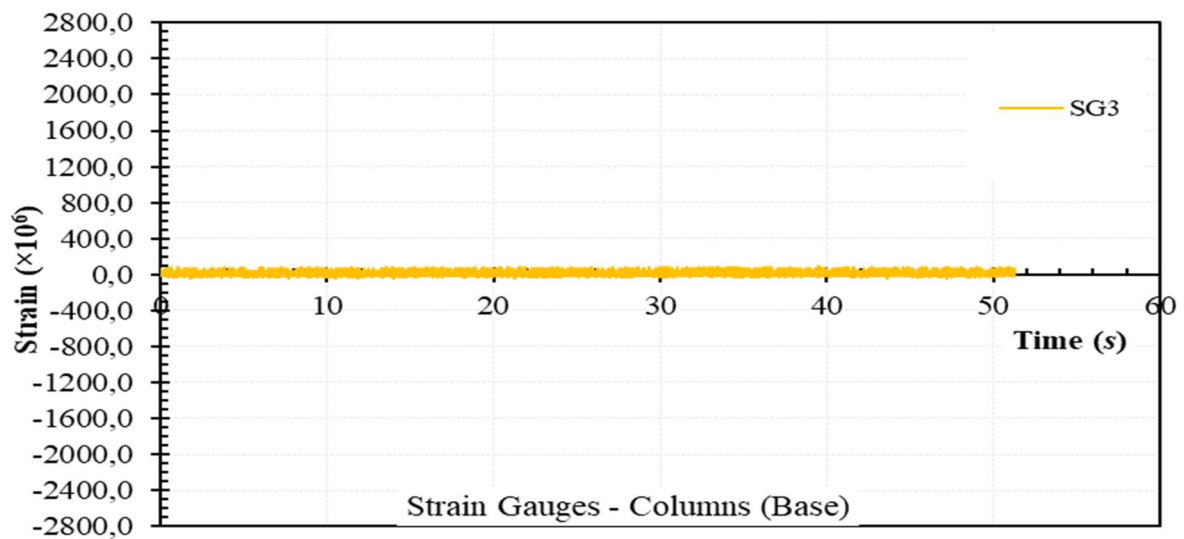
Residual: $-30,52\mu\text{strain}$

Sg 2

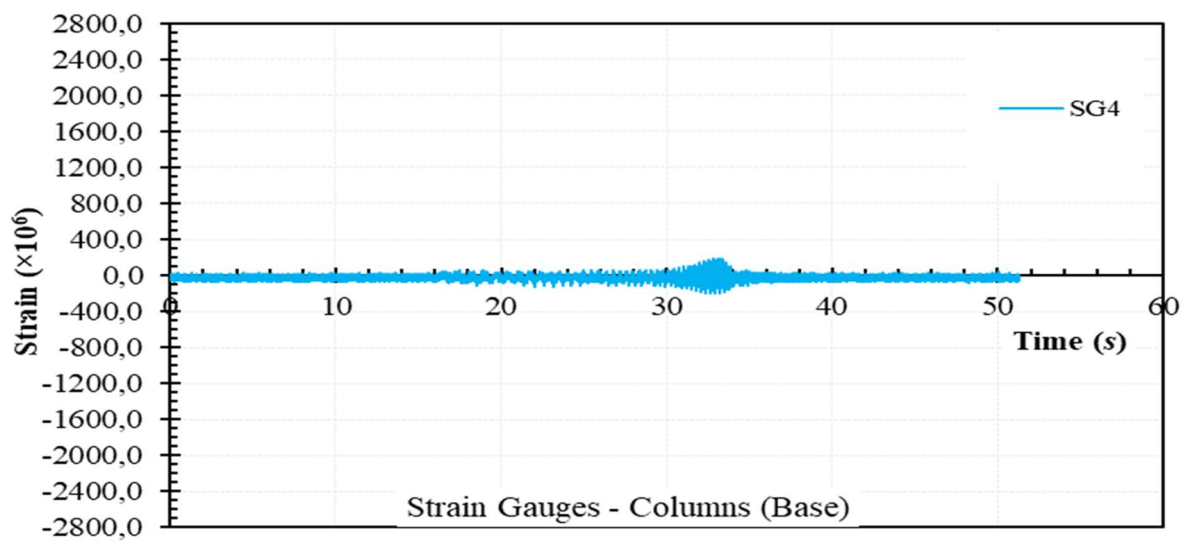
Max: $45,78\mu\text{strain}$

Min: $-91,56\mu\text{strain}$

Residual: $15,26\mu\text{strain}$



(a)



(b)

Figure 3.11.13 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 3 and (b) strain gauge 4

Sg 3

Max: 91,56 μ strain

Min: -45,78 μ strain

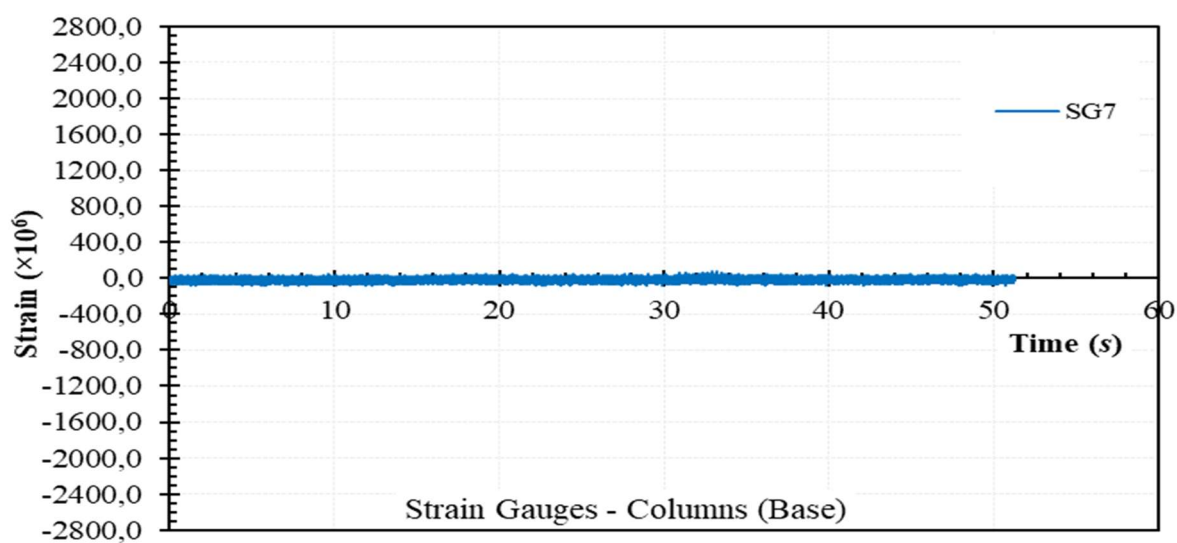
Residual: 15,26 μ strain

Sg 4

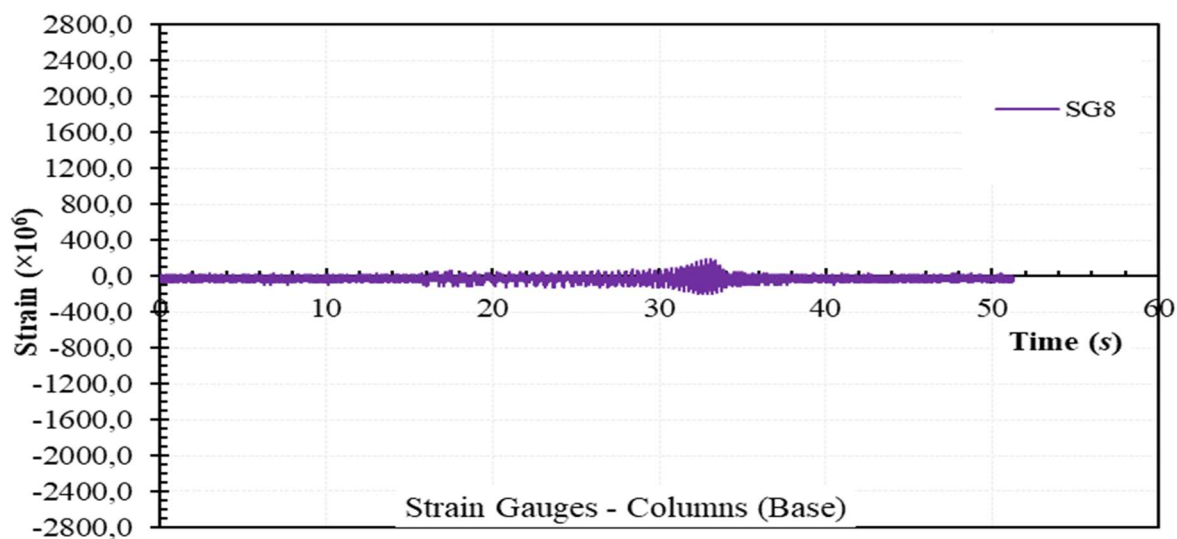
Max: 183,11 μ strain

Min: -198,37 μ strain

Residual: -15,26 μ strain



(a)



(b)

Figure 3.11.14 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 7 and (b) strain gauge 8

Sg 7

Max: 76,30 μ strain

Min: -76,30 μ strain

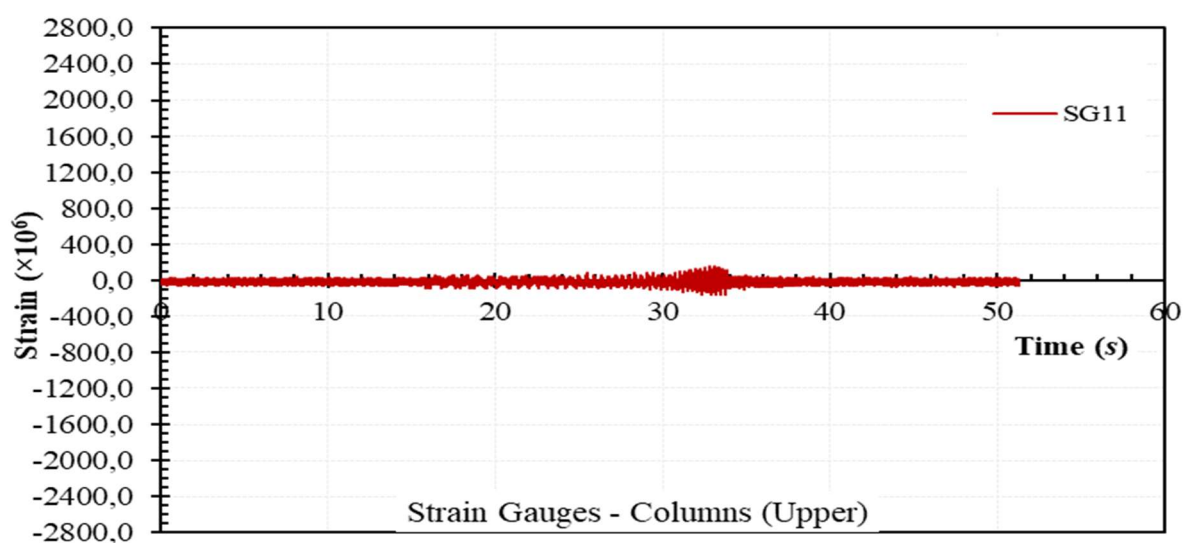
Residual: 0 μ strain

Sg 8

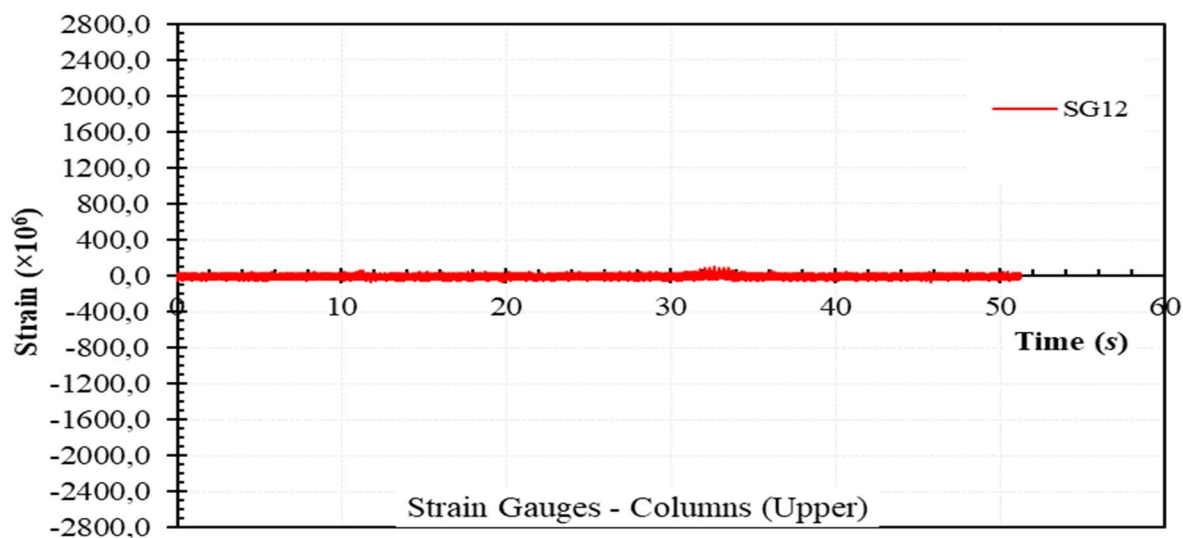
Max: 183,11 μ strain

Min: -198,37 μ strain

Residual: -45,78 μ strain



(a)



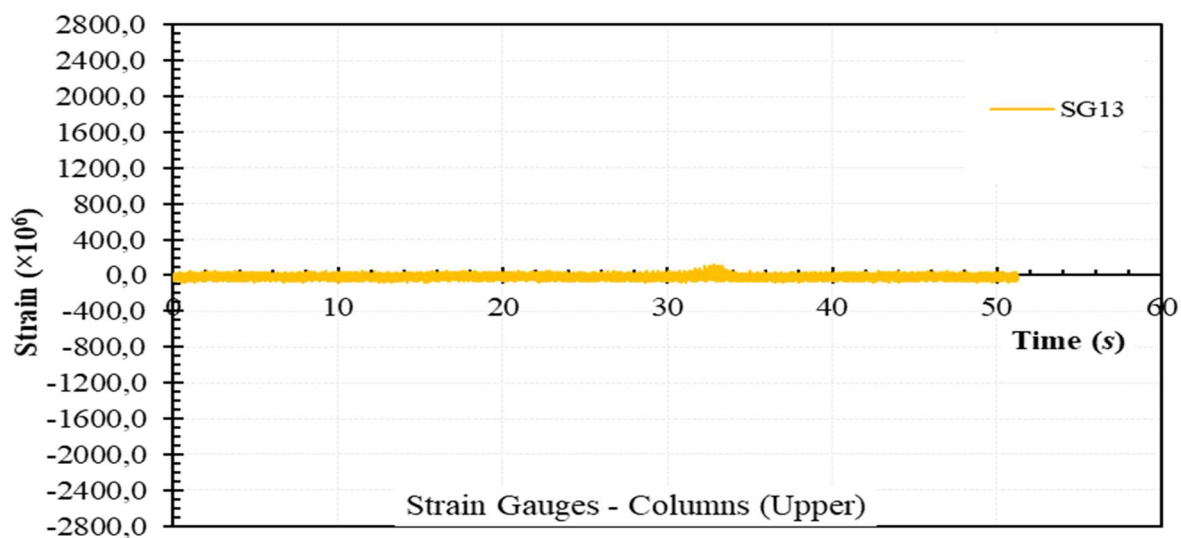
(b)

Figure 3.11.15 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 11 and (b) strain gauge 12

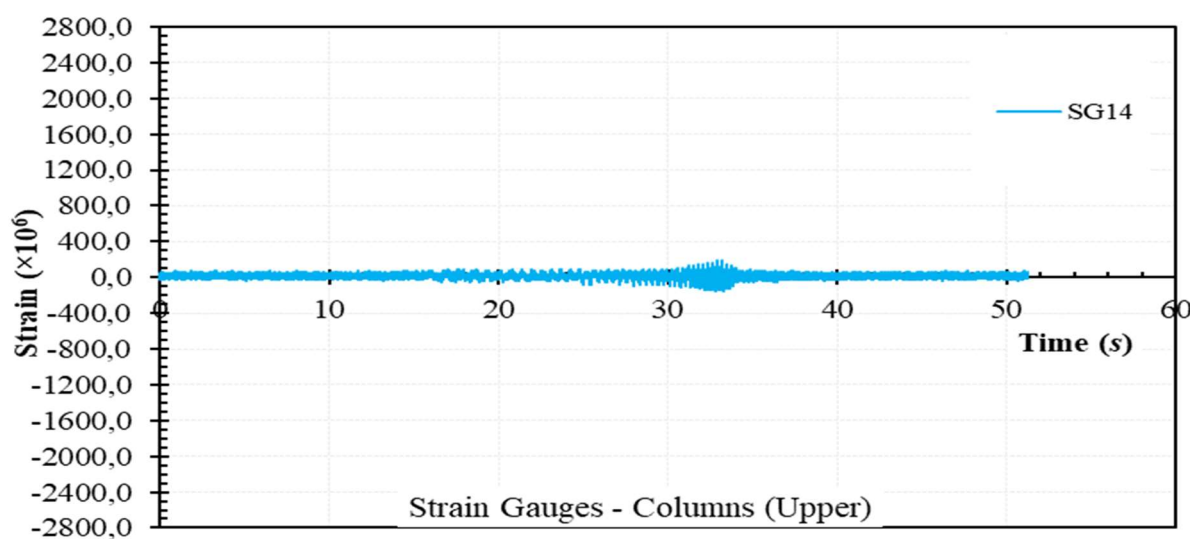
The strain gauges shown in the figures 3.11.15, 3.11.16, 3.11.17 and 3.11.20 are located in the longitudinal reinforcement, on the upper side. More specifically, strain gauge SG9 has 7,32 μ strain

maximum strain, -258,59 μ strain minimum strain and -717,39 μ strain residual. Strain gauge SG10 has 172,32 μ strain maximum strain, -314,26 μ strain minimum strain and -2,44 μ strain residual. Strain gauge SG11 has maximum strain 152,59 μ strain and minimum -152,59 μ strain deformation. The residual strain is -30,52 μ strain for strain gauge SG11. Strain gauge SG12 has maximum strain 106,81 μ strain and minimum strain -76,30 μ strain. The residual value is -15,26 μ strain. Strain gauge SG13 has maximum strain 122,07 μ strain and minimum strain -76,30 μ strain. The residual is -15,26 μ strain. Strain gauge SG14 has maximum strain 183,11 μ strain and minimum strain -152,59 μ strain. The residual is 30,52 μ strain. Finally strain gauges SG15 has maximum strain 183,11 μ strain and minimum strain -152,59 μ strain. The residual is -15,26 μ strain. Strain gauge SG16 has maximum strain 213,63 μ strain, minimum strain -76,30 μ strain and residual strain 15,26 μ strain.

Sg 11Max: 152,59 μ strainMin: -152,59 μ strainResidual: -30,52 μ strain**Sg 12**Max: 106,81 μ strainMin: -76,30 μ strainResidual: -15,26 μ strain



(a)



(b)

Figure 3.11.16 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 13 and (b) strain gauge 14

Sg 13

Max: 122,07 μ strain

Min: -76,30 μ strain

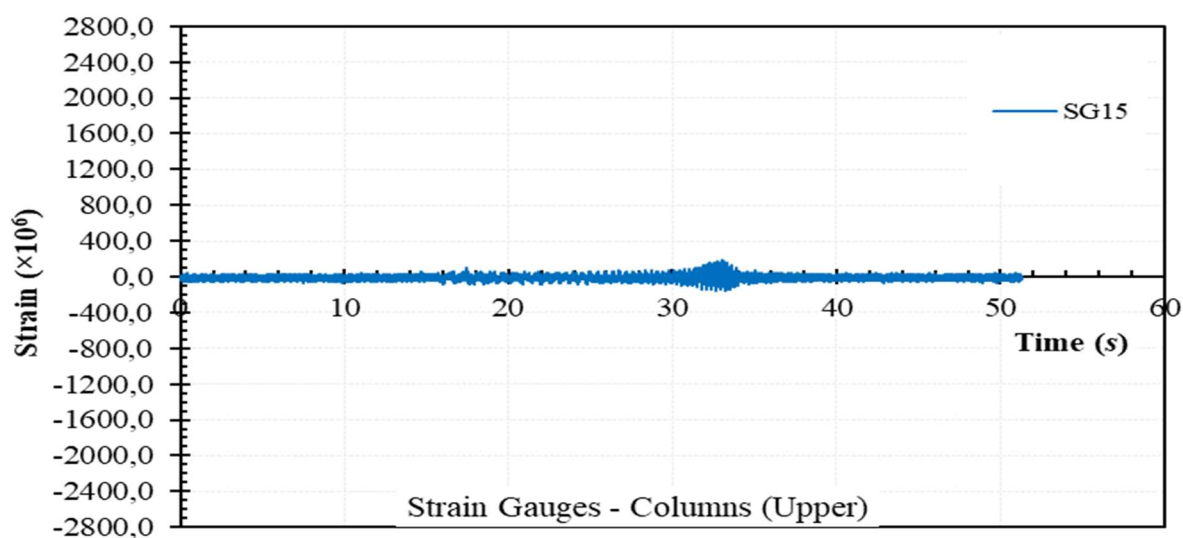
Residual: -15,26 μ strain

Sg 14

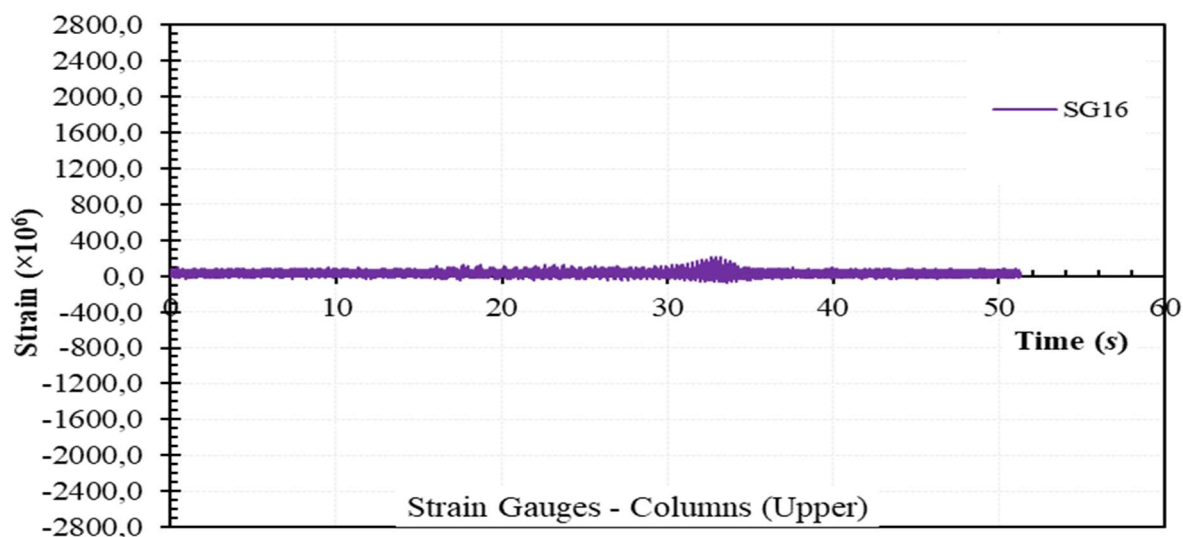
Max: 183,11 μ strain

Min: -152,59 μ strain

Residual: 30,52 μ strain



(a)



(b)

Figure 3.11.17 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 15 and (b) strain gauge 16

Sg 15

Max: 183,11 μ strain

Min: -152,59 μ strain

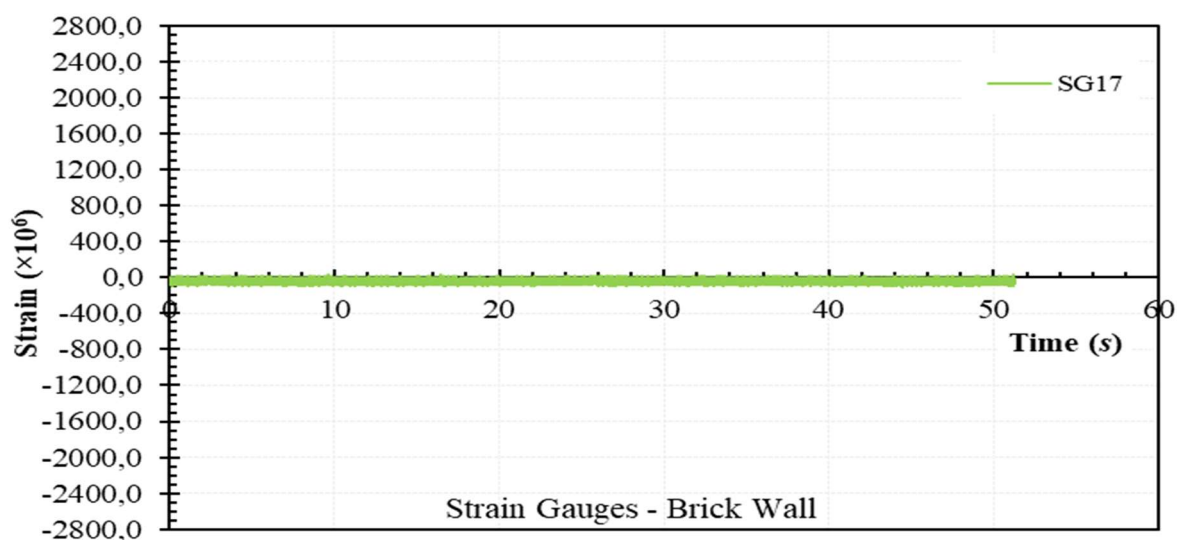
Residual: -15,26 μ strain

Sg 16

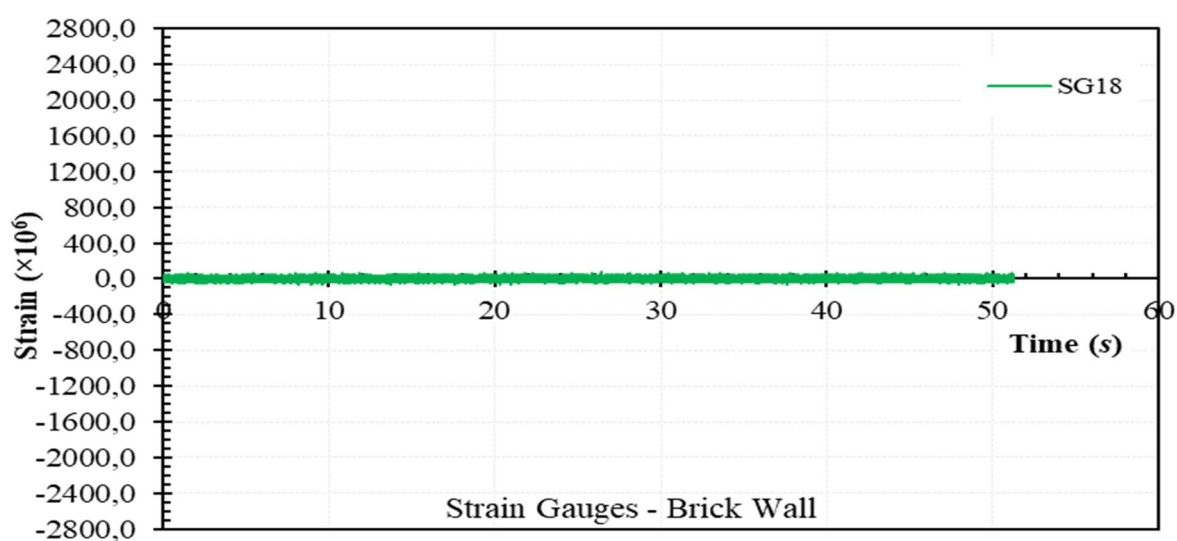
Max: 213,63 μ strain

Min: -76,30 μ strain

Residual: 15,26 μ strain



(a)



(b)

Figure 3.11.18 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 17 and (b) strain gauge 18

Strain gauge SG17 is located on the centre of partial masonry 1 along direction x. Strain gauges SG18 is located on the centre of partial masonry 1 along direction z. More specifically strain gauge SG17 has 30,52 μ strain maximum strain. Strain gauge SG17 has minimum deformation -106,81 μ strain and strain gauge SG18 -61,04 μ strain. Strain gauge SG18 has maximum strain 76,30 μ strain. Finally strain gauge SG17 presents -61,04 μ strain residual. Strain gauge SG18 presents 45,78 μ strain residual.

Sg 17

Max: 30,52 μ strain

Min: -106,81 μ strain

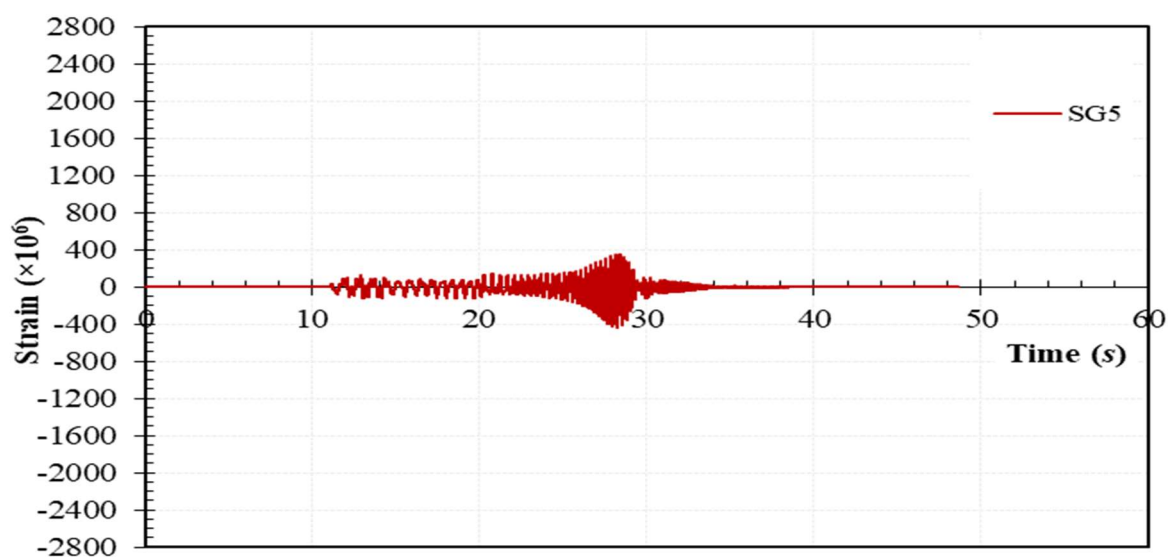
Residual: -61,04 μ strain

Sg 18

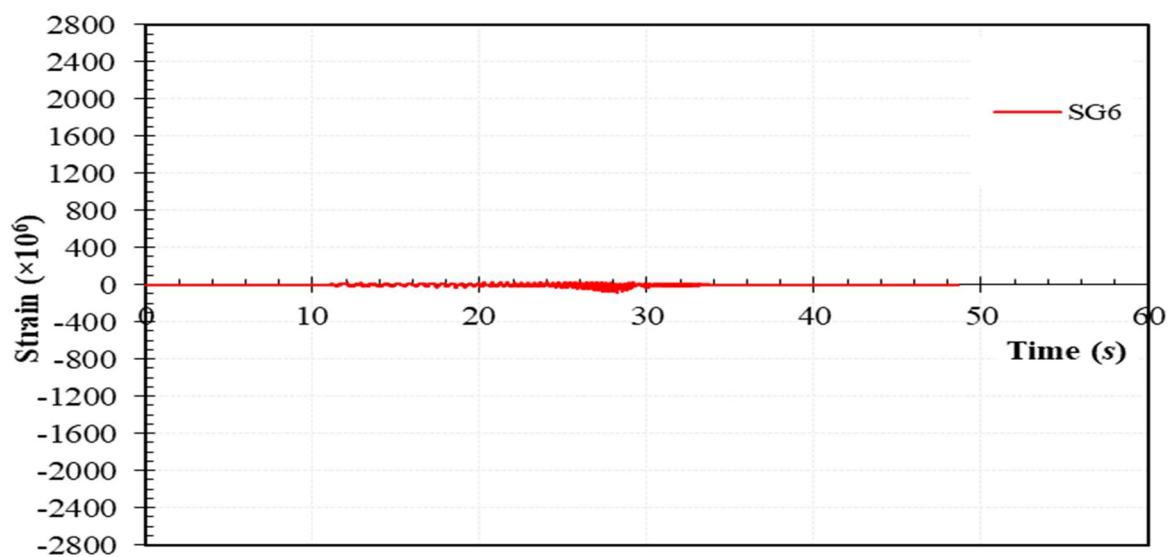
Max: 76,30 μ strain

Min: -61,04 μ strain

Residual: 45,78 μ strain



(a)



(b)

Figure 3.11.19 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 5 and (b) strain gauge 6

Sg 5

Max: 344,35 μ strain

Min: -432,74 μ strain

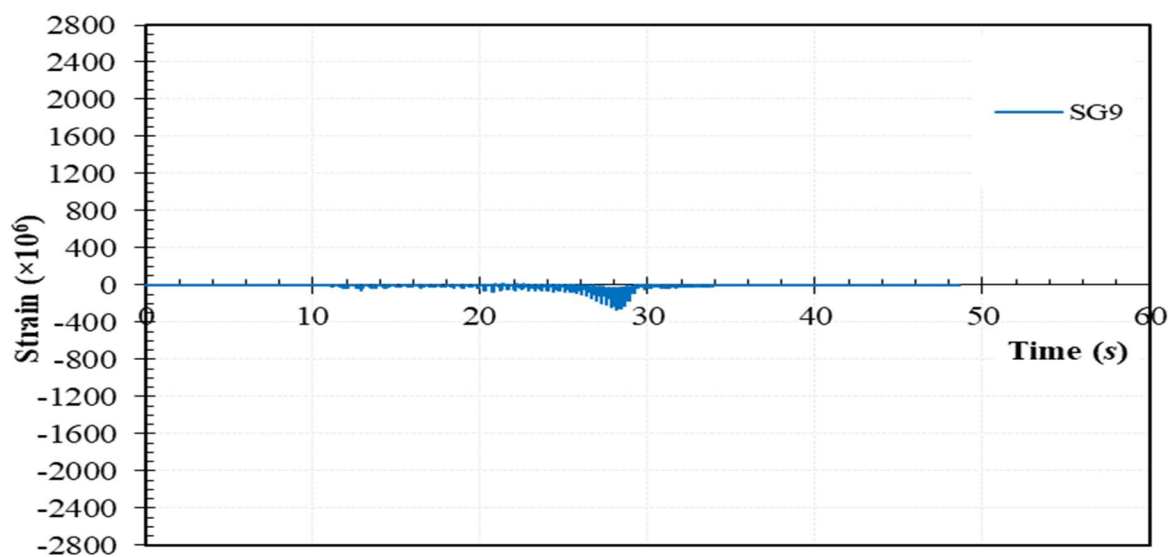
Residual: -1,63 μ strain

Sg 6

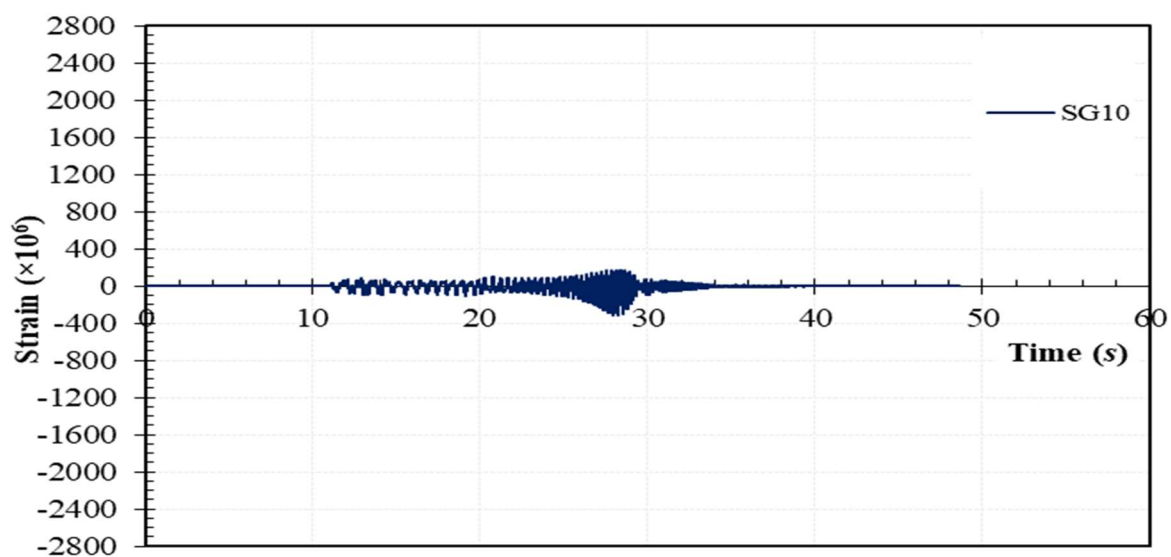
Max: 28,42 μ strain

Min: -80,38 μ strain

Residual: -2,44 μ strain



(a)



(b)

Figure 3.11.20 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 9 and (b) strain gauge 10

Sg 9

Max: 7,32 μ strain

Min: -258,59 μ strain

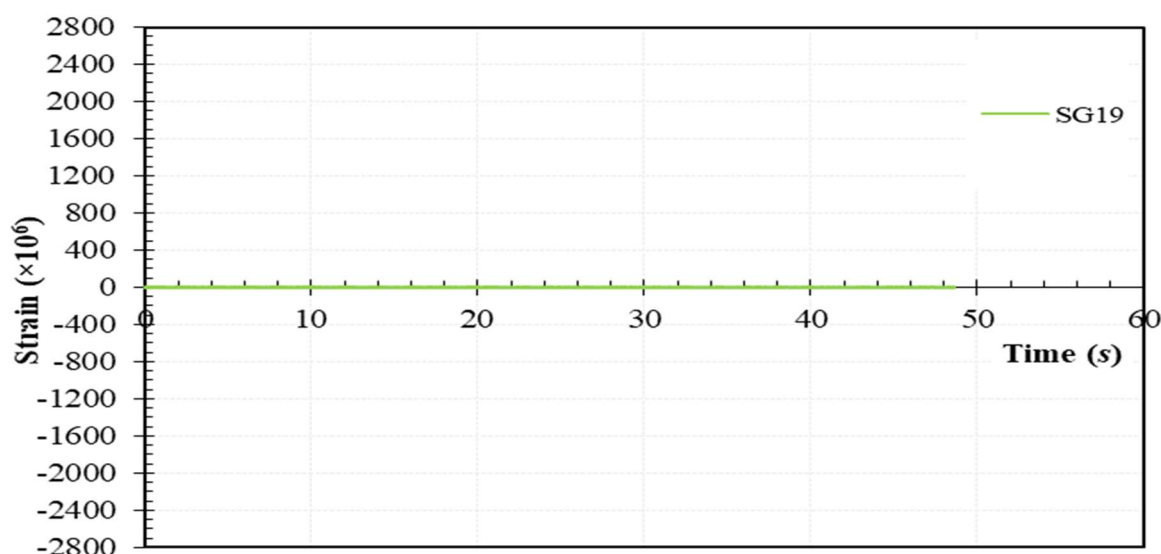
Residual: -717,39 μ strain

Sg 10

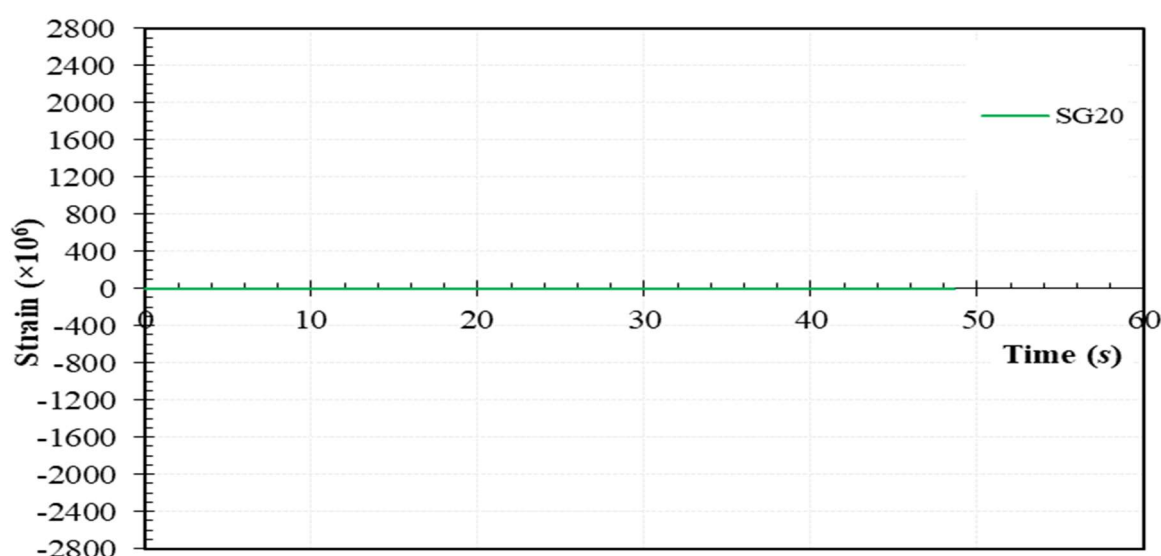
Max: 172,32 μ strain

Min: -314,26 μ strain

Residual: -2,44 μ strain



(a)



(b)

Figure 3.11.21 Characteristic results for phase A (white noise after 1,1g earthquake) (a) strain gauge 19 and (b) strain gauge 20

Strain gauge 19 is located on the centre of partial masonry 2 along direction x. Strain gauges 20 is located on the centre of partial masonry 2 along direction x. More specifically strain gauge SG19 has maximum $1,62 \mu$ strain and minimum $-3,24 \mu$ strain. Strain gauge SG20 has maximum strain $0,81 \mu$ strain and minimum $-4,06 \mu$ strain. The residual strain for strain gauge SG19 is $-2,45 \mu$ strain and residual for strain gauge SG20 is $-2,44 \mu$ strain.

Sg 19

Max: $1,62 \mu$ strain

Min: $-3,24 \mu$ strain

Residual: $-2,45 \mu$ strain

Sg 20

Max: 0,81 μ strain

Min: -4,06 μ strain

Residual: -2,44 μ strain

3.12) Measurements of advanced PZT sensors and characteristic photos

Recorded results of tested as-built structure, PZT measurements

Prompt damage diagnosis of seismically deficient VF buildings necessitates, in addition to the other standard testing measurements, the monitoring and evaluation in a real-time system based on piezoelectric sensors or PZTs (Na and Baek 2018, Sam-Daliri et al. 2016, Sam-Daliri et al. 2021). Structural health monitoring (SHM) for real-time condition and damage assessment plays a crucial role in the testing of VF RC structure (Chalioris et. al. 2015, 2016, 2020, Voutetaki et. al. 2016). This innovative Structural Health Monitoring utilizes an advanced Electro-Mechanical Impedance (EMI) system that integrates PZTs sensors as an embedded-in smart aggregate (SAs) featuring smart properties or piezoelectric patches implementing a network of monitoring the condition of the RC VF structure (Naoum et al. 2023, Voutetaki et al. 2022).

The proposed methodology for real-time damage assessment in RC structures with piezoelectric sensors (PZTs) shows promising potential for incipient damage identification and provides warnings of critical failure before any visible signs appear. This approach can effectively detect damage and assess the structural integrity of VF RC structures subjected to seismic loads.

As mentioned, the EMI method utilizes piezoelectric materials, specifically PZTs, which have the unique ability to generate electric charges on their surface when subjected to mechanical stress. Additionally, they deform mechanically in response to an electric field. Therefore, any changes observed in the electrical impedance of an attached PZT sensor result from variations in the mechanical impedance of the area being tested. Different configurations of PZT patches were evaluated, considering their bonding conditions, locations, and polarization directions, to assess the efficiency of each combination (Naoum et al. 2024).

The PZTs were installed in the tested RC structure in two ways: (a) as embedded PZTs within the mass of the members and (b) as externally bonded PZT patches adhered to the surface of the masonry. A total of 48 piezoelectric sensors were incorporated into the RC structure. Of these, 37 PZTs were placed as SAs inside the mold of the specimens, before casting, while 11 were externally bonded to the surface of the masonries. The Table below provides detailed information on the location and quantity of PZT enabled. Characteristics and locations of all the installed PZT sensors are presented in the following Figure.

Table 3.12.1: Location and amount of PZTs

Location	Amount of PZTs and way of installation
Beams	12 (a)
Columns	12 (a)
Joints	4 (a)
Slab	3 (a)
Cantilever	6 (a)
Masonries	11 (b)
Total	48

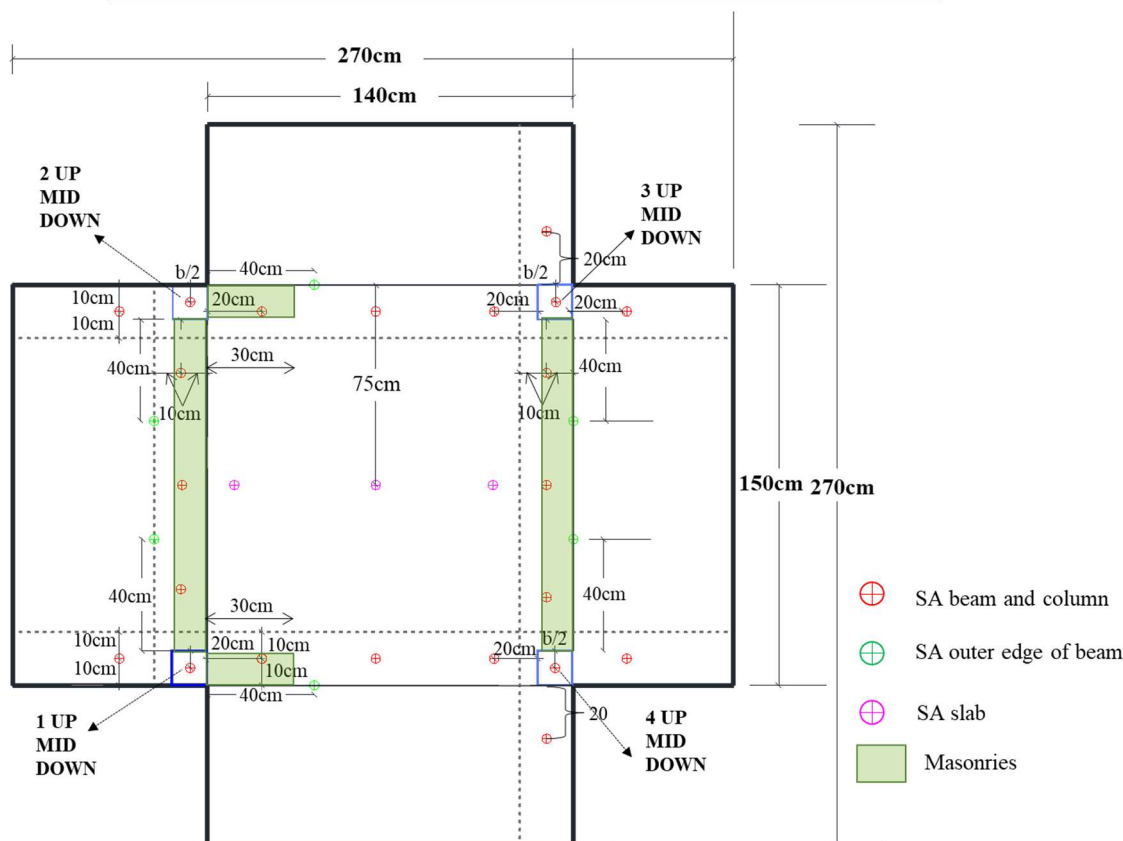


Figure 3.12.1: Location of the masonries.

A group of multiple measurements for each PZT sensor was applied in healthy (initial) conditions to determine the baseline frequency response.

Each SHM device captures the EMI response of a PZT sensor in a predefined frequency range, which was set to 10–250 kHz with a resolution of 1 kHz. As mentioned above, the EMI measured identifies degradation of the mechanical impedance of the monitoring area through the alterations they cause in the EMI response of an installed PZT sensor. Hence, the EMI response of each PZT sensor in the healthy (initial) condition of the specimens was captured and used as a baseline frequency response. For real-time condition and damage assessment in the tested VF RC, the installed PZT patches' EMI response was captured after each loading sequence's end.

The following subsection presents typical PZT sensor voltage signal measurement responses from all PZT groups, as shown in Table 3.12.1.

Beams

Three PZT sensors, referred to as SAs, are installed on each beam, resulting in a total of 12 SAs across four beams of the structure.

The typical voltage signal measurements of the PZT sensors across a range of frequencies, following the loading sequence, are illustrated in the above figures. These figures highlight the frequency response of the PZT sensors for the healthy condition and two final loading sequences that were examined. Some notable observations can be drawn from the displayed voltage signal responses for all SAs. The next figures present the design and code names of the SAs on beams and representative results from the frequency response of the PZTs 3B, 3D, and 3A.

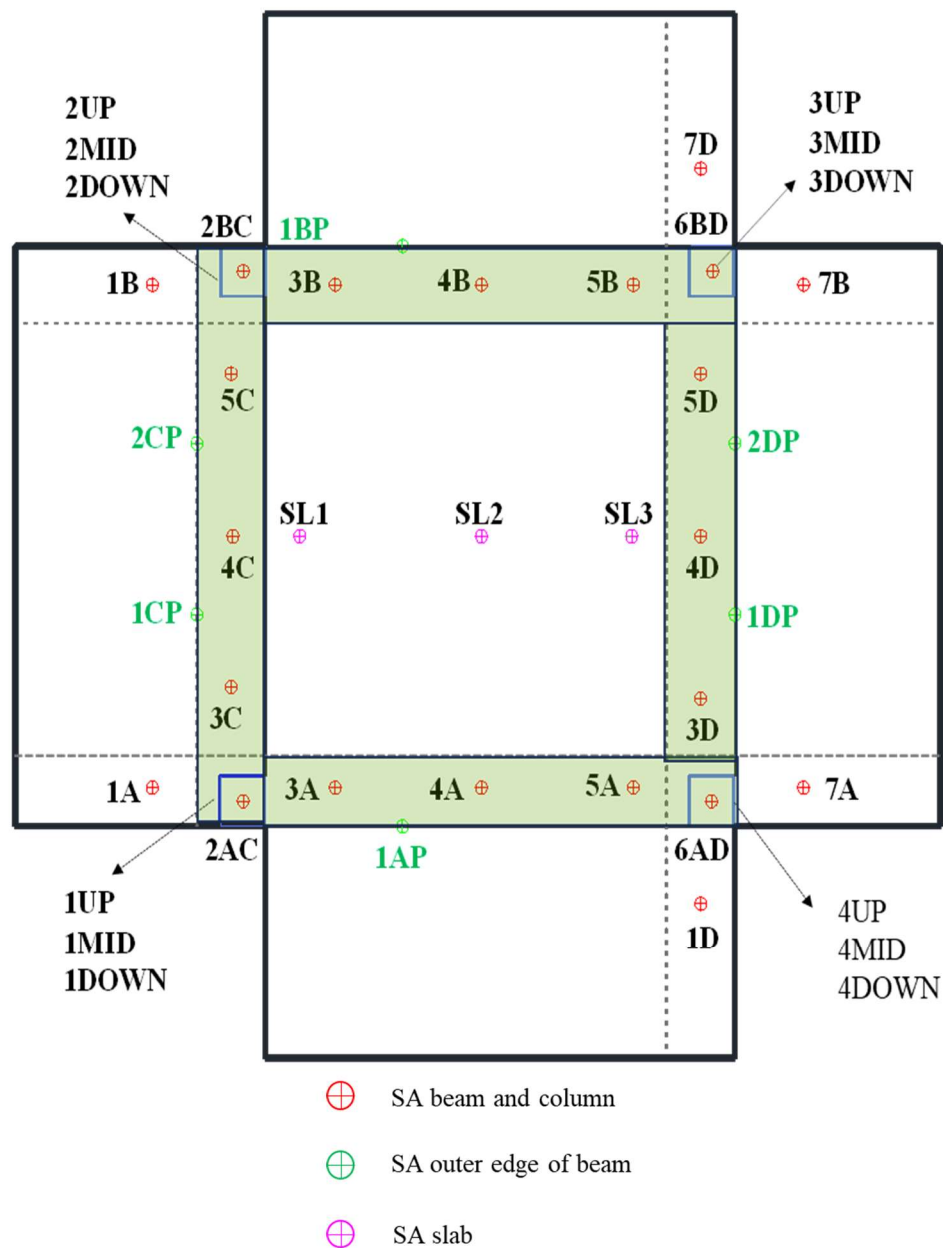


Figure 3.12.2: Design and code names of the SAs on beams (highlighted).

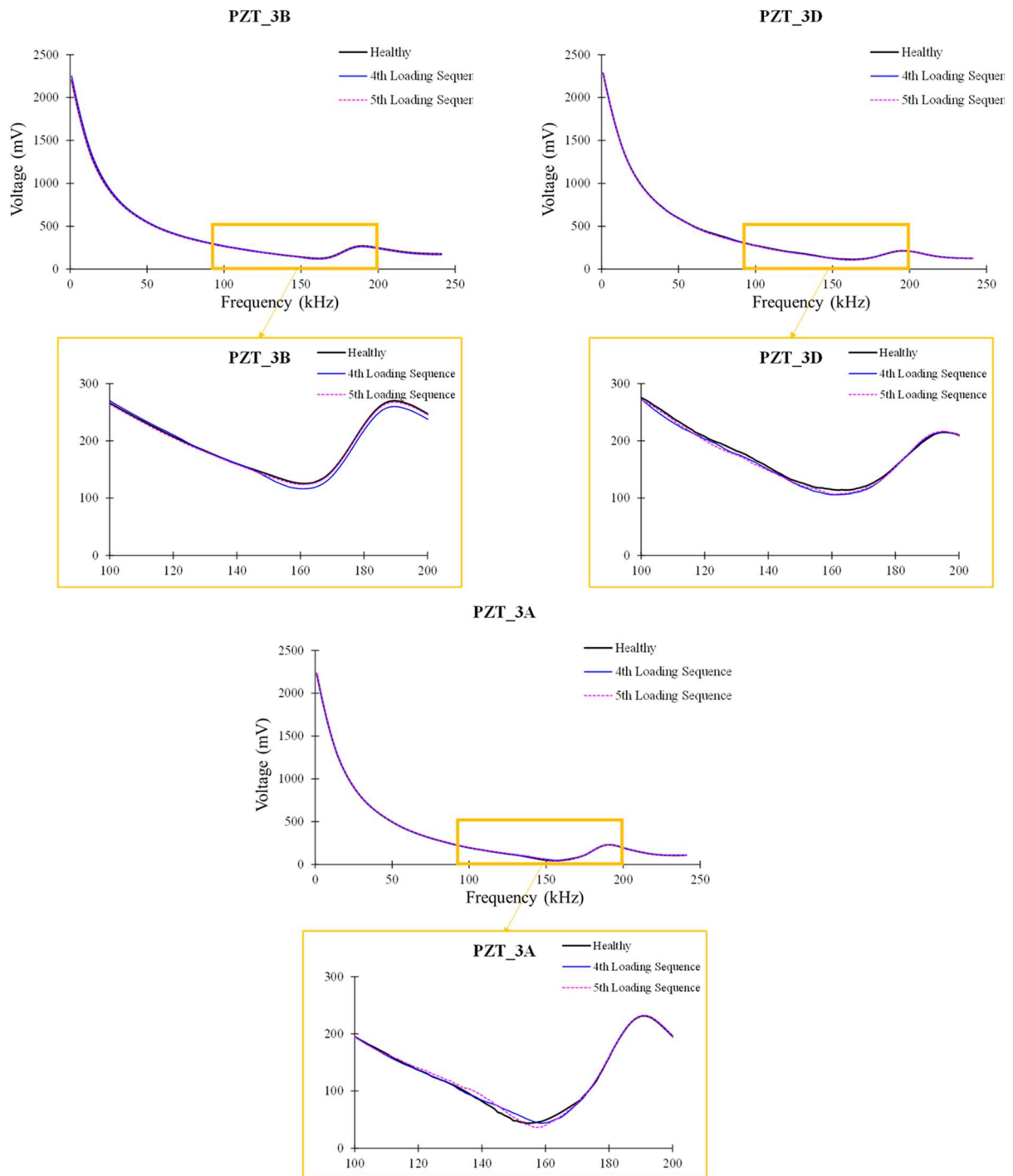


Figure 3.12.3: Voltage frequency response of the PZT sensors 3A, 3B and 3D

Columns

The next three figures present the design and code names of the SAs on columns and representative results from the frequency response of the PZTs, which are located in the middle of columns Y1M, Y2M, and Y3M, Y4M.

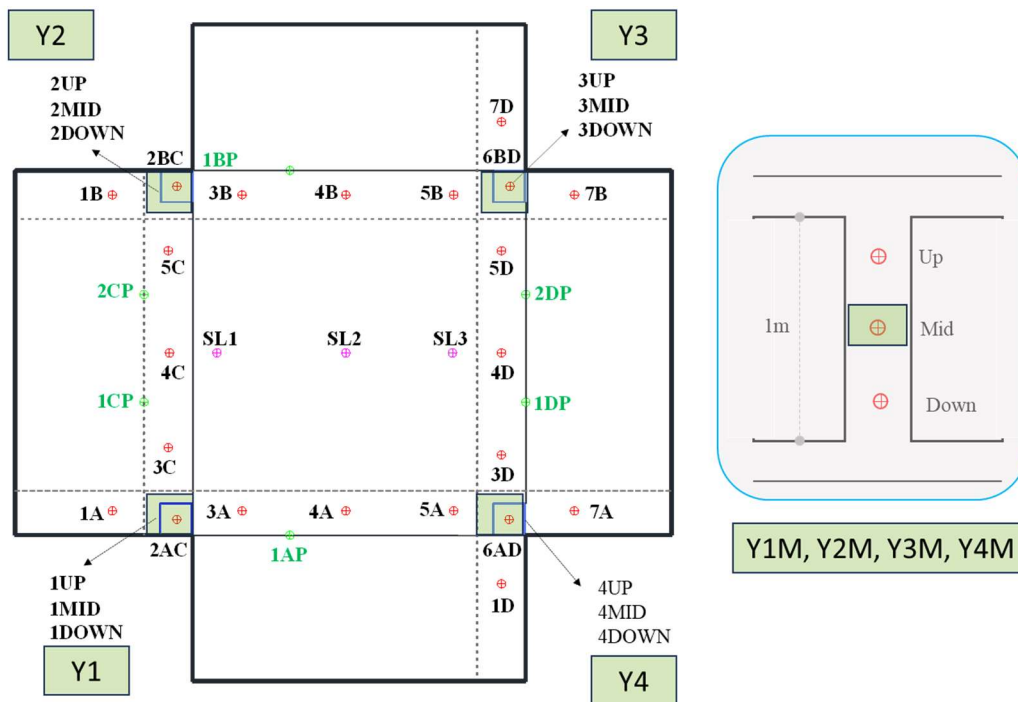


Figure 3.12.4: Design and code names of the SAs on columns (highlighted).

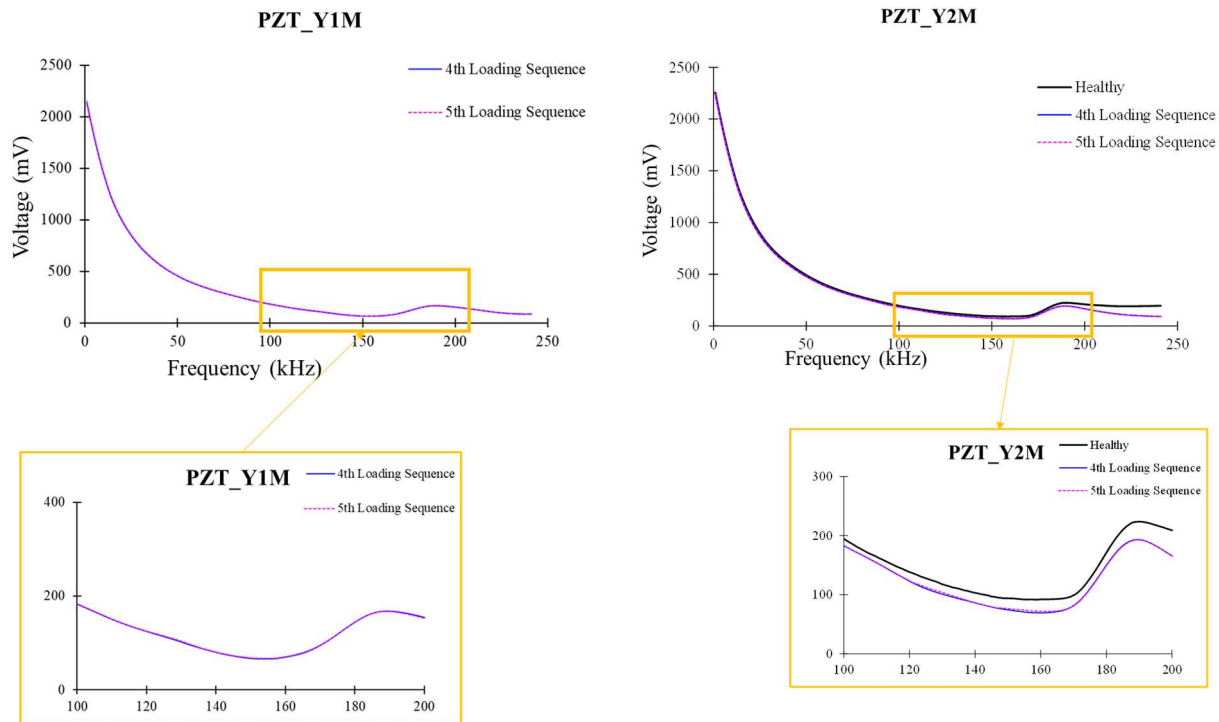


Figure 3.12.5: Voltage frequency responses of the PZT sensors Y1M and Y2M

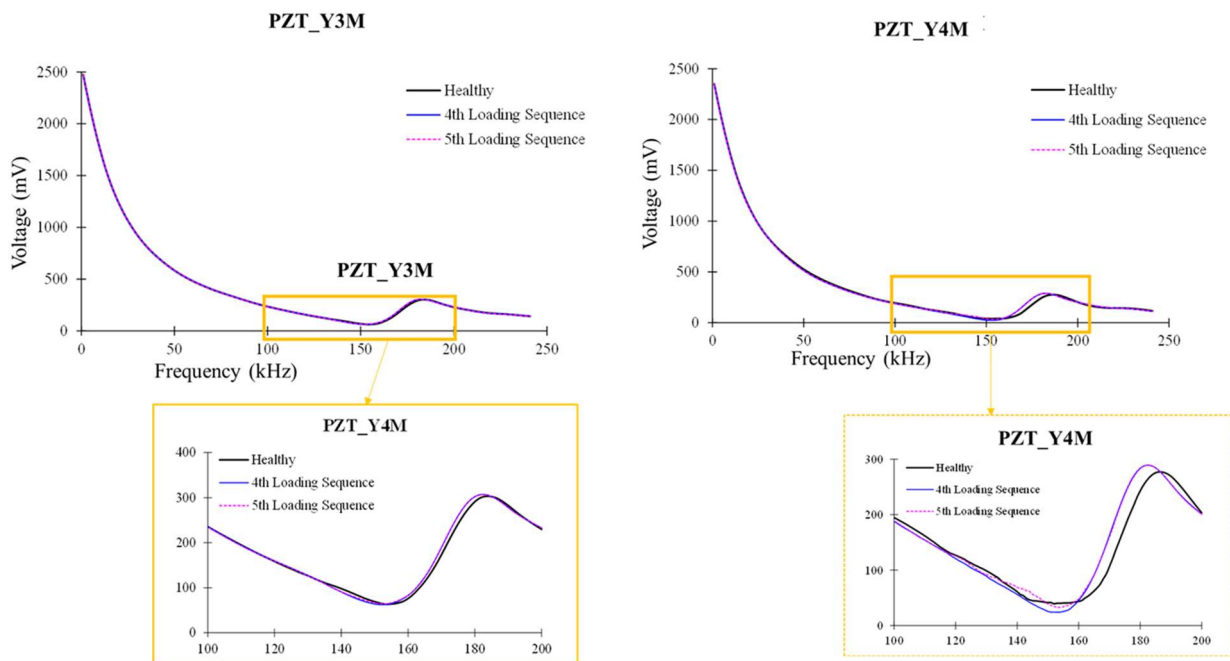


Figure 3.12.6: Voltage frequency responses of the PZT sensors Y3M and Y4M

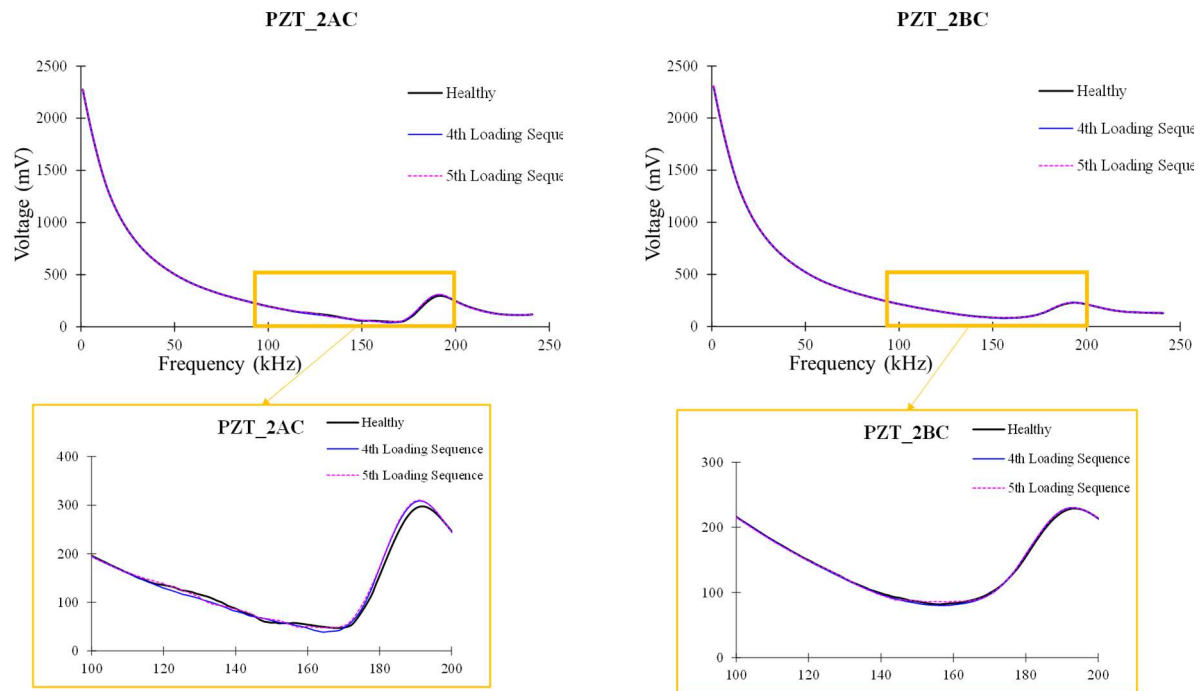


Figure 3.12.8: Voltage frequency responses of the PZT sensors 2AC and 2BC.

Slab

The design and code names of the SAs on the slab and the result for one SA located inside the slab are shown in the above figures, SL1.

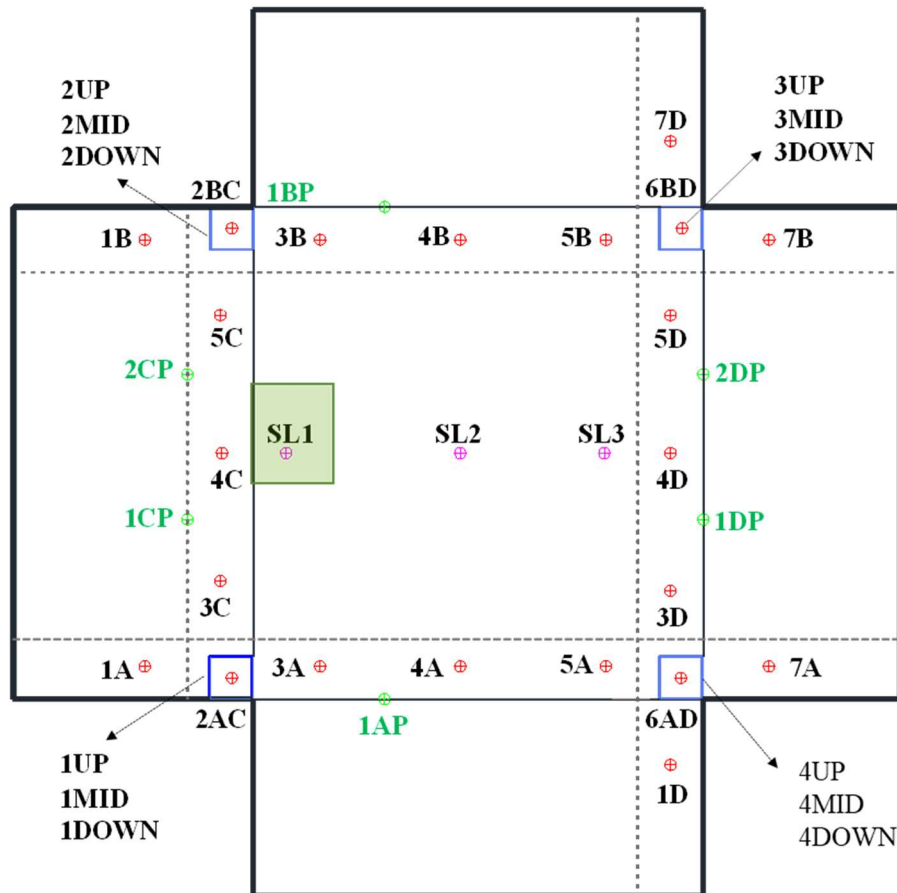


Figure 3.12.9: Design and code names of the SAs on the Slab (highlighted) and voltage frequency response of the PZT sensor SL1

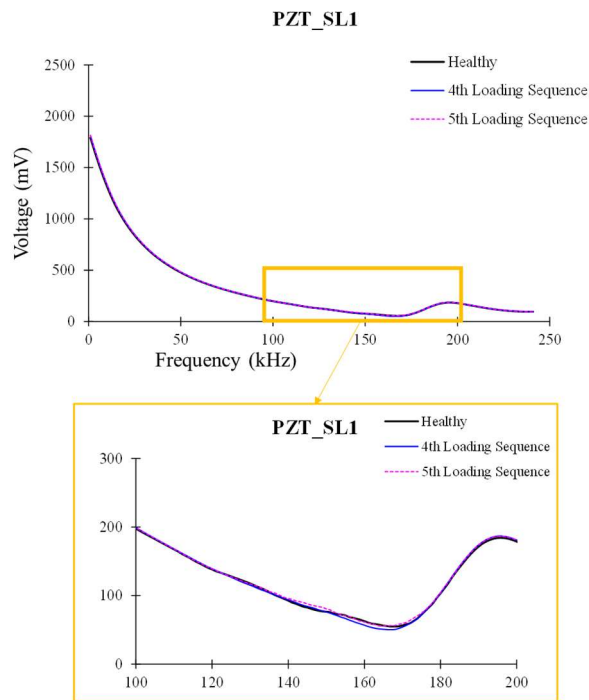
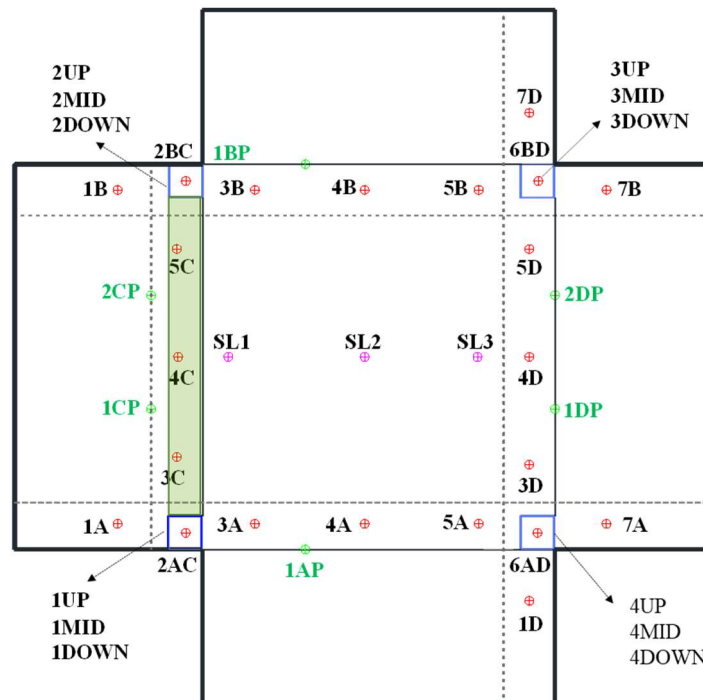


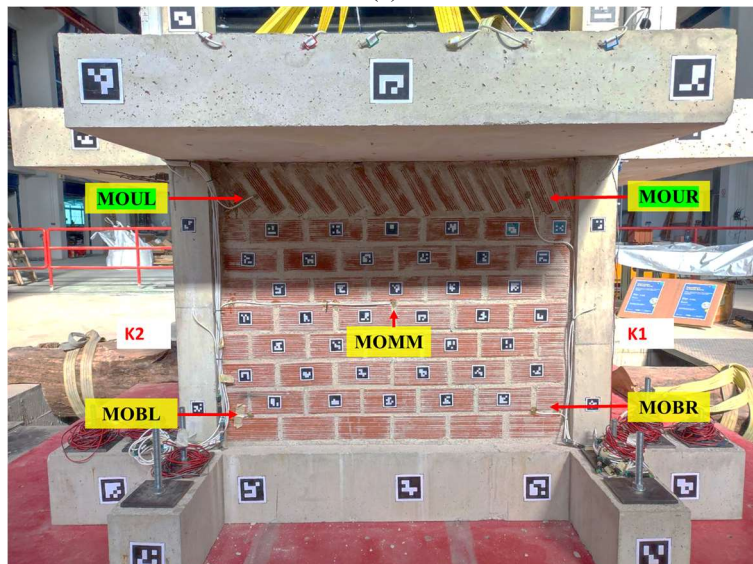
Figure 3.12.10 Voltage frequency responses of the SA sensor SL1

Masonry

In the full-filled masonry, five externally bonded PZTs are located as patches, as depicted in the following figure. The next figure demonstrates the design and code names of the PZTs on masonry. The frequency response of the MOUL PZT sensor (left upper corner of the masonry). and MOUR PZT sensor (right upper corner of the masonry) respectively demonstrated in next two figures.



(a)



(b)

Figure 3.12.11: Design and code names of the PZTs on Masonry, MOUR and MOUL (highlighted)

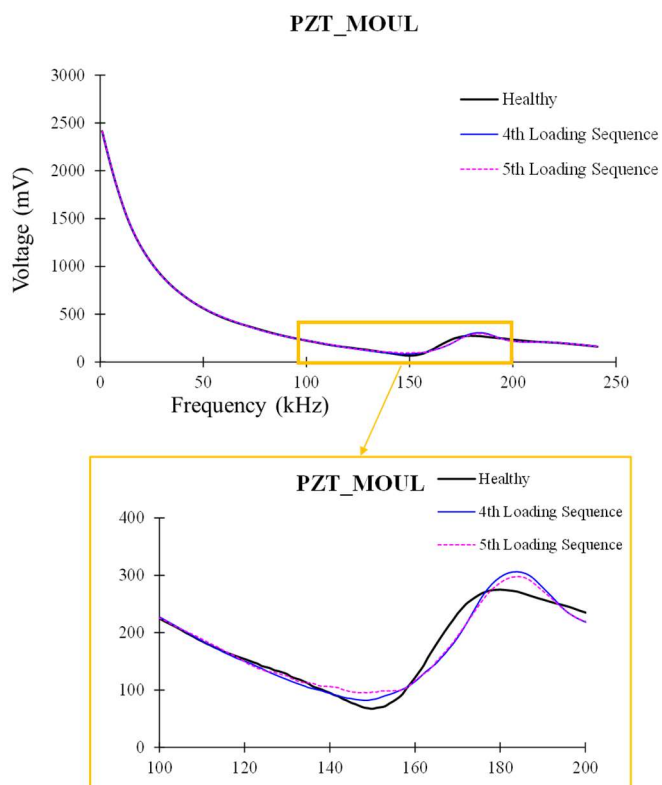


Figure 3.12.12: Voltage frequency responses of the PZT sensor MOUL

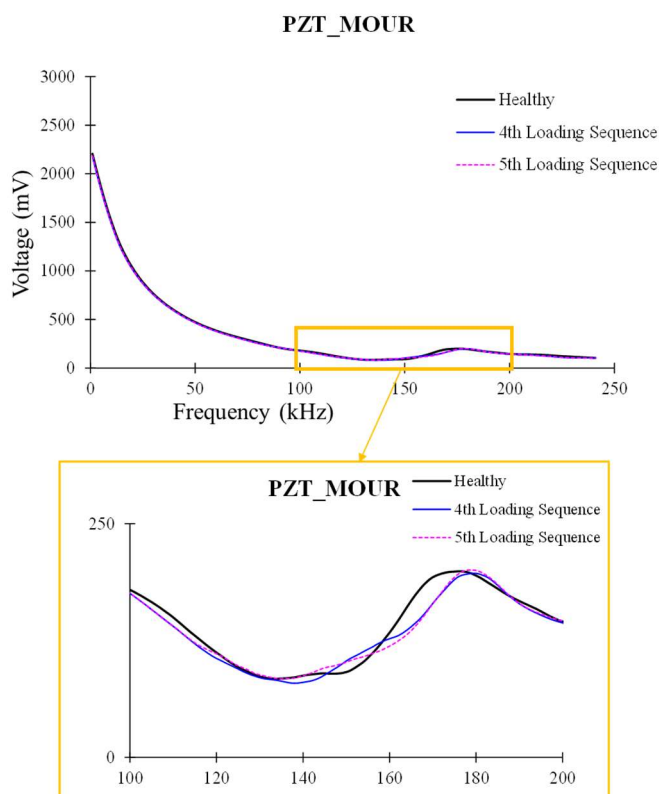


Figure 3.12.13: Voltage frequency responses of the PZT sensor MOUR



Cantilevers

The results for the SAs 1AP and 1CP, located inside the cantilever's or outer edge of the beam, are shown in the above figures.

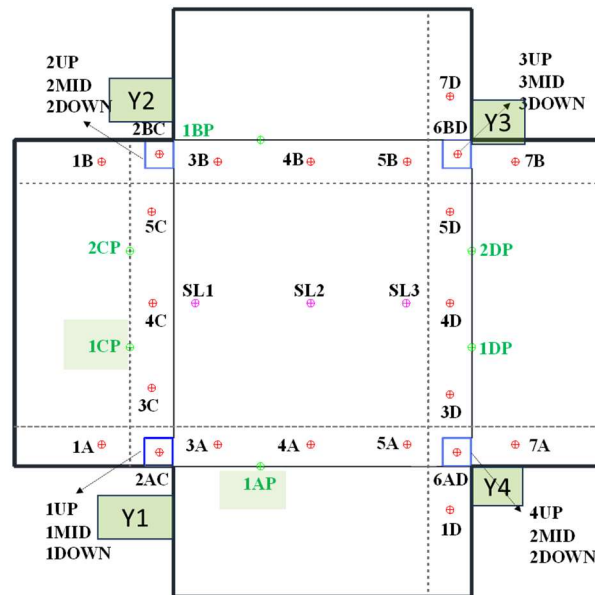


Figure 3.12.14: Design and code names of the SAs on Cantilevers, 1AP and 1CP (highlighted)

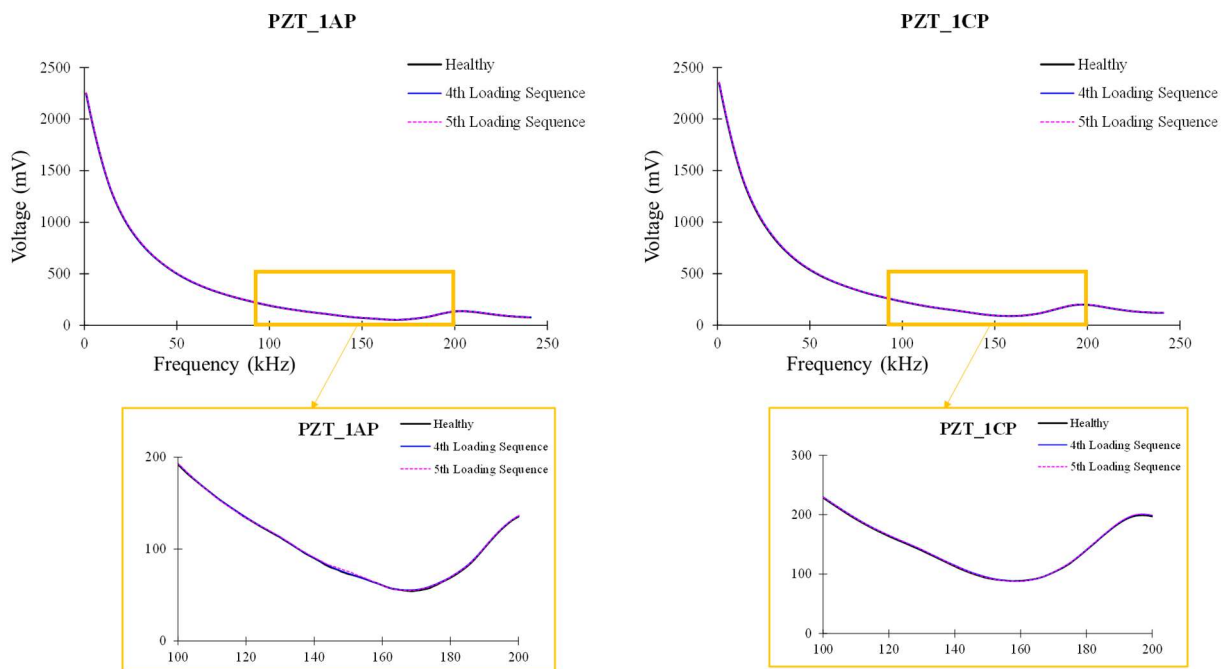


Figure 3.12.15: Voltage frequency responses of the PZT sensors 1AP and 1CP

3.13) Characteristic photos

Indeed, the structure presented debonding of the full Infill wall between columns 1-2 and 3-4 from the top slab and the adjacent columns' surfaces (Figures 3.13.1-3). The bottom infill-tie beam interface seems intact in most cases. Histories of recorded accelerations on infill 3-4 as well as PZT measurements coincide with photographic validation and observations.

Further, concrete columns 3 and 4 suffered minor cracking at the edge of the section at the bottom and at the top respectively. Again, the PZT measurements agree well with the observed minor cracks.

The columns developed maximum steel strain as high as 2000-2350 μ strain, well below the yield strain of the B500C steel (2890 μ strain, see section 4.1).

Therefore, the first phase of the seismic testing is completed successfully, based on the SLS level damages of the as-built structure after the execution of 11 dynamic tests, including 5 levels of earthquake excitations.

In particular, the results from the PZTs demonstrate the ability of the PZT-enabled SHM system to detect changes in the health condition at different locations after each loading sequence.



Figure 3.13.1 View of masonry 3-4 (a) transverse to the direction of movement of the seismic table and (b) of masonry 4-1 parallel to the direction of movement of the seismic table



(a)



(b)

Figure 3.13.2 View of masonry 2-3 parallel to the direction of movement of the seismic table (a) with PZTs and (b) wall infill-column and slab debonding



(a)

Figure 3.13.3 Interior side of masonry 3-4, transverse to the direction of movement of the seismic table

4) Mechanical properties of materials

4.1 Concrete and steel

The 3d structure was cast in four phases; the tie beams, the columns, the slab and the top half-columns. During concrete pouring, cylindrical specimens with dimensions of $\varnothing 150 \times 300$ mm were cast to assess the mechanical properties of the concrete. These cylinders were cured under the same conditions as the tested 3d structure. To determine the compressive strength, at least three cylinders were tested per casting batch, while an additional three specimens were used for the split tensile strength evaluation. The cylinders were tested in accordance with EN 12390-3:2019 and EN 12390-6:2023 standards to determine compressive strength and splitting tensile strength, respectively. The tests were conducted during the testing of the 3d as-built structure. Figures 4.1 and 4.2 illustrate the experimental setup for the compressive and splitting tensile tests, respectively, along with the typical failure modes of the cylinders. The mean compressive strength and standard deviation of the concrete were 36.7 MPa and 0.9 MPa for the tie beam, 25.5 MPa and 1.4 MPa for the columns, and 31.6 MPa and 0.9 MPa for the slab. The average tensile strength and standard deviation were 2.37 MPa and 0.16 MPa for the tie beam, 2.26 MPa and 0.11 MPa for the columns, and 2.64 MPa and 0.14 MPa for the slab. The detailed results of the compressive and splitting tensile tests are presented in Tables 4.1 and 4.2, respectively.



(a)



(b)

Figure 4.1 Concrete compressive strength test: (a) standard test setup (b) typical failure mode



(a)



(b)

Figure 4.2 Split tensile test: (a) standard test setup (b) typical failure mode

Table 4.1: Summary of compressive strength test results.

Cylinder Number	Maximum Load (kN)			Loading Area (mm ²)	Maximum Compressive Strength (MPa)		
	Cylinder	Average	St. Dev.		Cylinder	Average	St. Dev.
Tie Beam							
1	637.22	649.66	16.07	17,671	36.1	36.7	0.9
2	643.96				36.4		
3	667.80				37.8		
Column							
1	433.22	451.29	25.32	17,671	24.5	25.5	1.4
2	444.06				25.1		
3	488.68				27.7		
4	439.19				24.9		
Slab							
1	567.86	559.03	16.16	17,671	32.1	31.6	0.9
2	542.20				30.7		
3	580.79				32.9		
4	544.58				30.8		
5	559.72				31.7		

Table 4.2: Summary of split tensile test results.

Cylinder Number	Maximum Load (kN)			Loading Area (mm ²)	Maximum Tensile Split Strength (MPa)		
	Cylinder	Average	St. Dev.		Cylinder	Average	St. Dev.
Tie Beam							
1	175.14	168.04	11.32	70,686	2.478	2.37	0.16
2	173.99				2.461		
3	154.99				2.193		
Column							
1	152.60	159.77	7.77	70,686	2.159	2.26	0.11
2	168.03				2.377		
3	158.70				2.247		
Slab							
1	183.55	186.88	9.94	70,686	2.597	2.64	0.14
2	179.03				2.533		
3	198.05				2.802		

The longitudinal steel bars used in columns, tie-beams and slab was of B500C quality. The experimentally derived mechanical properties under direct tension were measured with 2 strain gauges and 1 laser meter (Figure 4.3). The average values were as follows: yield stress $f_{su} = 564$ MPa, maximum stress $f_{smax} = 663$ MPa and ultimate stress $f_{su} = 652$ MPa. Yield strain $\epsilon_{sy} = 0,00289$, strain at initiation of hardening $\epsilon_{sp} = 0,027$ and strain at ultimate $\epsilon_{su} = 0.143$. Modulus of elasticity of the steel was $E_s = 195$ GPa.

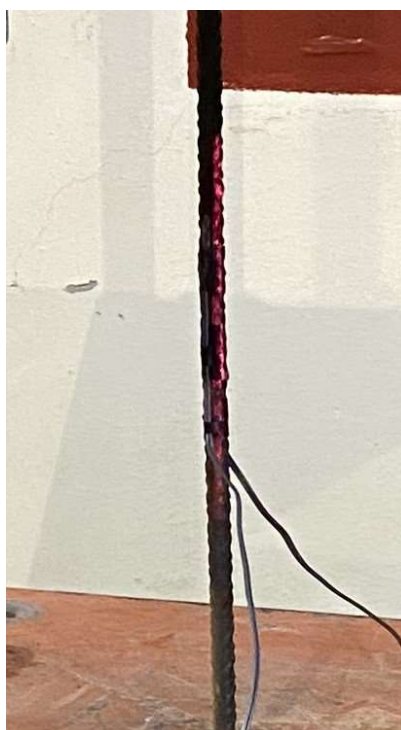


Figure 4.3 Instrumentation of steel bar under direct tension

4.2 Hollow clay bricks, binding mortar and brick wall interface of triplets

Uniaxial compression test of hollow clay bricks parallel to the holes.

Seven hollow clay brick units for infill with dimensions 60/90/190 mm (width/height/length), weight of about 1.2 kg brick, and vertical holes covering the 55% of the total brick volume, were tested in uniaxial compression until failure (Figure 4.4, EN772-1). The test results are presented in Table 4.3. In the first column is the code of the bricks, with the letter B from the initial letter of the name “Brick” and “V” from the word “Vertical”. In the second column is the value of the failure load P . In the third column is the loading area taking into account the holes, called the gross loading area, and in the fourth, the net loading area subtracting the holes’ area. In the two last columns, the clay bricks’ compressive strength of gross loading area and of net loading area are presented, respectively. The nominal average axial compressive strength of bricks with vertical holes appears to be approximately 9.8 MPa and 21.7 MPa if we remove the percentage of holes.

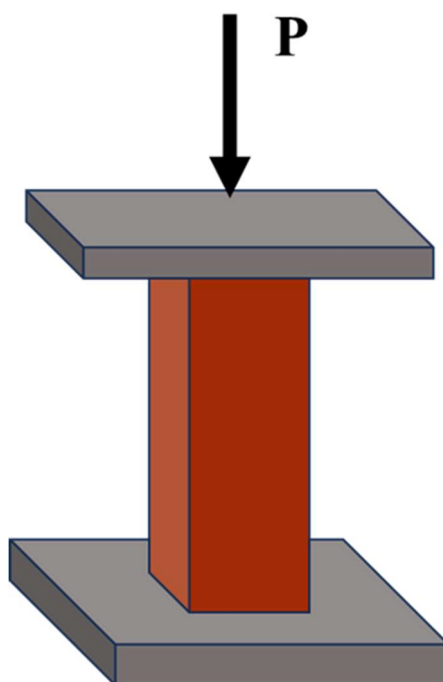
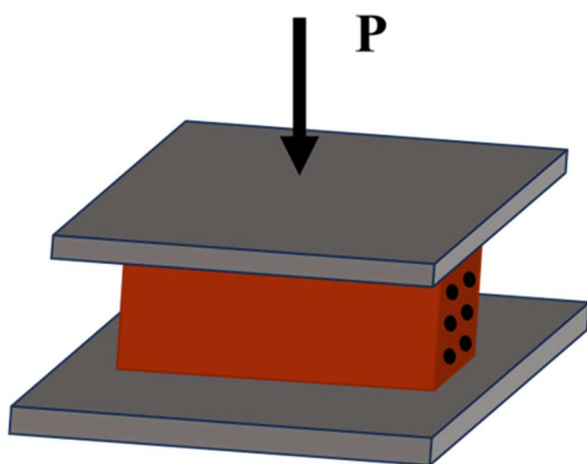


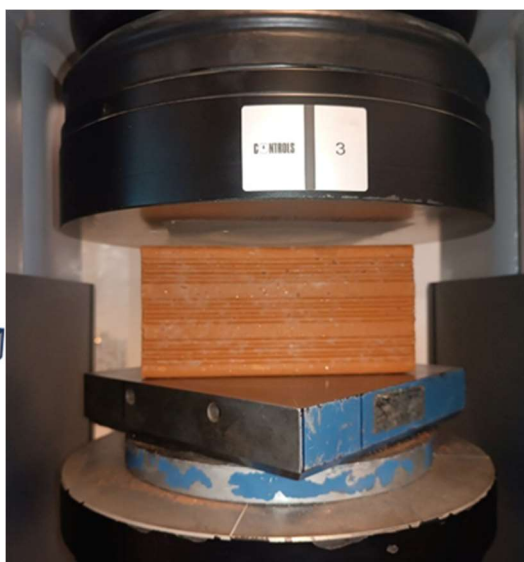
Figure 4.4: Brick compression test setup parallel to the holes.

Table 4.1: Compressive strength of clay bricks with loading direction parallel to the holes.

Brick code	Load	Gross Loading Area	Net Loading Area	Compressive strength (gross loading area)	Compressive strength (net loading area)
	P (N)	A (mm ²)	0.45*A (mm ²)	σ (MPa)	σ (MPa)
BV_1	53690	5400	2430	9.9	22.1
BV_2	51220			9.5	21.1
BV_3	53360			9.9	22.0
BV_4	51740			9.6	21.3
BV_5	51090			9.5	21.0
BV_6	55100			10.2	22.7
BV_7	53690			9.9	22.1
Average	52841			9.8	21.7



(a)



(b)

Figure 4.5: Clay brick compression test setup perpendicular to the holes.

Seven bricks with vertical holes were tested in compressive stress until failure. The test results are presented in Table 4.4. In the first column, the code of the bricks is listed, with the letter B from the initial letter of the name “Brick” and “L” from the word “Lateral”. In the second column is the value of the failure load P. In the third column, the area of the loading surface is listed, while in the fourth column,

the compressive strength of the bricks is calculated. The nominal average axial compressive strength of bricks, with the loading direction perpendicular to the holes, appears to be approximately 2.1 MPa for the gross loading area.

Table 4.2: Compressive strength of bricks for infill masonry with the loading direction perpendicular to the holes.

Brick code	Load	Gross Loading Area	Compressive strength (gross loading area)
	P (N)	A (mm ²)	σ (MPa)
BL_1	22670	11400	2.0
BL_2	21620		1.9
BL_3	20110		1.8
BL_4	26780		2.4
BL_5	24550		2.2
BL_6	25400		2.2
BL_7	23860		2.1
Average	23146		2.1

Experimental determination of lime-cement mortar strength.

The flexural tensile strength of the lime-cement binder is determined with three-point flexural tests on prismatic specimens and their compressive strength is estimated by 28-day compression tests of the binder mortar obtained by testing 40 × 40 × 160 mm³ mortar prisms according to EN 1015-11 (1999) (see also earlier tests on smart mortars and novel bricks by Thomoglou et al. 2023, 2024). A lime-cement mortar was used for the construction of all brick infill walls, with a nominal mortar thickness between the bricks of 10 mm. The lime-cement mortar was studied by taking 9 prisms, which immediately after construction, the prisms remained in ambient conditions.

a) Results of three-point bending tests of lime mortar prisms

To investigate the tensile strength the prisms were subjected to three-point bending (Figure 4.6). Specifically, nine mortar prisms were tested (Table 4.3). The tensile strength of the mortar is 2.7 MPa.

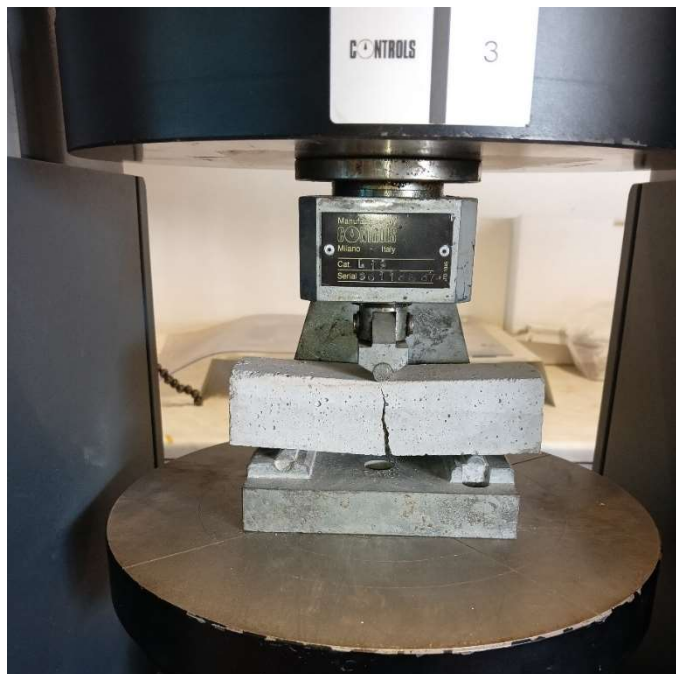


Figure 4.6: Experimental setup for three-point bending of a lime-cement mortar prism and failure mode after the test.

Table 4.3: Experimental results of three-point bending test of lime-cement mortar prisms.

Mortar code	Load	Flexural strength
	P (N)	σ (MPa)
MO_1	1210	2.8
MO_2	1230	2.9
MO_3	1090	2.6
MO_4	1430	3.4
MO_5	1200	2.8
MO_6	980	2.3
MO_7	1220	2.9
MO_8	930	2.2
MO_9	1080	2.5
Average	1152	2.7
Stdev	151	0.4

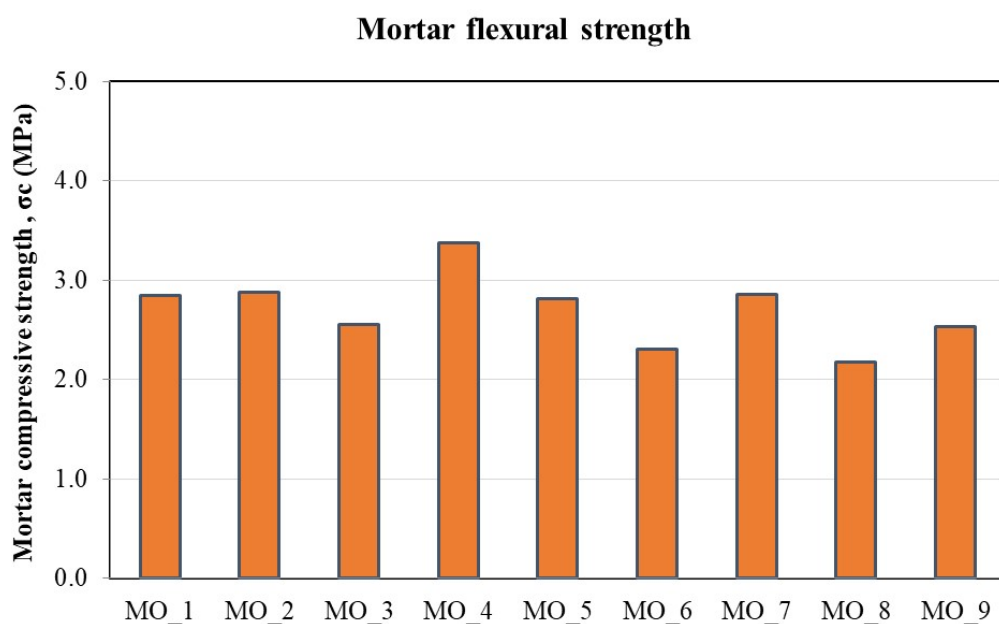


Figure 4.7: Experimental results of three-point bending tests of lime-cement mortar prisms.



Figure 4.8: Failure modes of three-point bending tests of lime-cement mortar prisms.

The failure mode of the lime-cement mortar prisms from three-point bending is presented in Figures 4.8. The typical behavior of the prisms in the three-point bending test is shown by the opening of a wide crack.

b) Results of compression tests of lime-cement mortar prisms

Figure 4.9 shows the test setup, Table 4.4 the list of the results and figure 4.10 the typical mode of failure. The compressive strength of the mortar is 11.6 MPa.



Figure 4.9: Experimental compression test setup of lime-cement mortar prism.



Figure 4.10: Failure mode of compression tests of lime-cement mortar prism piece.

Table 4.4: Experimental results of compression test of lime-cement mortar prisms' pieces.

Mortar code	Load	Loading Area	Compressive strength
	P (N)	A (mm ²)	σ (MPa)
MO_1a	17960	1600	11.2
MO_1b	19340		12.1
MO_2a	19960		12.5
MO_2b	18110		11.3
MO_3a	17680		11.1
MO_3b	18350		11.5
MO_4a	18820		11.8
MO_4b	18640		11.5
MO_5a	17760		11.1
MO_5b	16180		10.1
MO_6a	17340		10.8
MO_6b	17320		10.8
MO_7a	17360		10.9
MO_7b	16980		10.6
MO_8a	17810		11.1
MO_8b	16300		10.2
MO_9a	16190		10.1
MO_9b	18497		11.6
Average	18603		11.6
Stdev	1043		0.7

Mortar compressive strength

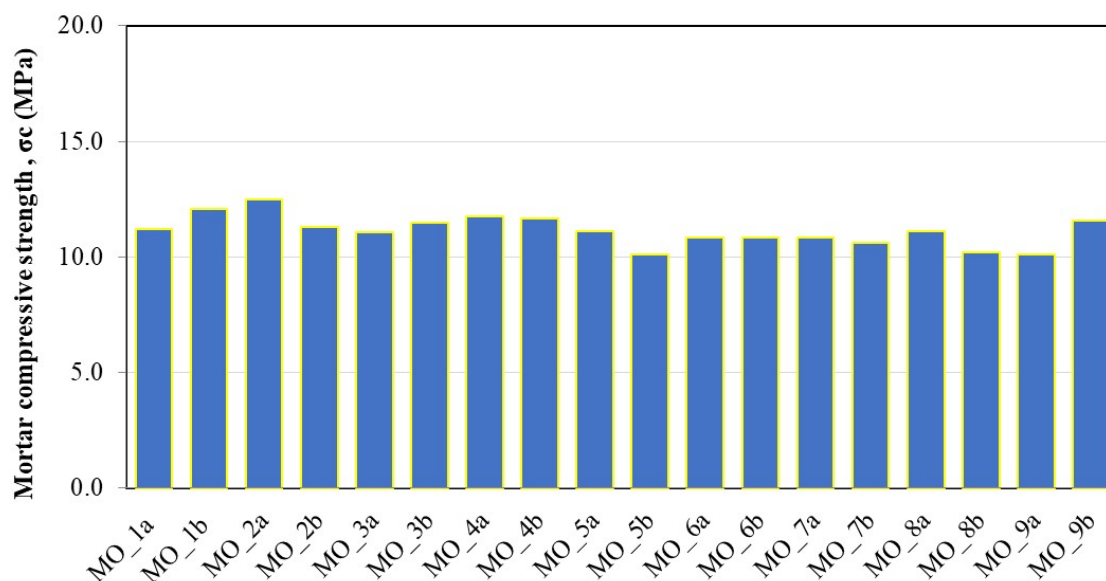


Figure 4.11: Experimental results of compression tests of lime-cement mortar.

Direct shear test on a triplet of clay bricks with an intermediate connecting joint of 10 mm.

Masonry triplets are adopted in this project to evaluate the shear strength along masonry joints between clay bricks and mortar. The brick triplet test, defined by EN 1052-3, contributes to the determination of the shear strength (f_v) of the joint, i.e the bond of the interface between the brick and the binder. For this test, at least six specimens were constructed, each consisting of three bricks and two mortar joints. The nominal dimensions of the specimens are 290mm (length) x 60mm (width) x 190mm (height). The joints are made of binding lime-cement mortar of 10 mm thickness.

The experimental loading setup of the triplet of bricks with holes is illustrated in Figure 4.12. The shear strength is equal to the ratio of the reaction of the support equal to force $P/2$ divided by the area of the joint. Based on the roller supports the lateral force is zero.

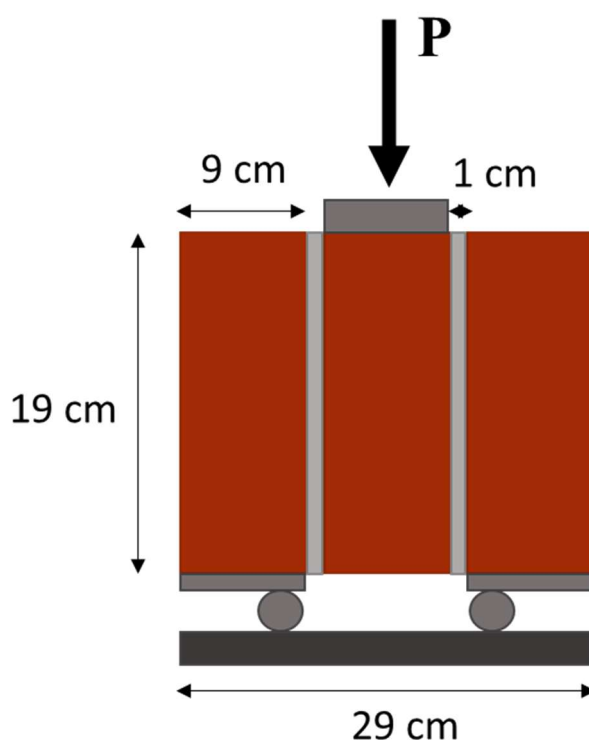


Figure 4.12: Triplet of clay bricks for the direct shear test with an intermediate connecting lime-cement mortar joint of 10 mm.



Figure 4.13: Experimental direct shear test setup of clay bricks triplet.

The experimental results of the direct shear test of triplet clay bricks are summarized in Table 4.11. The first column indicates the specimen code, where tr is the initials of the words "triplet", the second the maximum shear sliding load, the third the area of the joint surface A , while the fourth, calculates the shear strength of each specimen resulting from the ratio of $P/2$ to the area of the triplet joint. The fifth column calculates the value of the average initial shear strength (f_{v0}) with an average of 0.25 MPa. The sixth column shows the value of the characteristic initial shear strength (f_{v0k}) of the triplet specimen 0.2 multiplied by the correction factor 0.8, while the last column shows the failure mode of each triplet specimen.

Table 4.5: Experimental results of the direct shear test of clay bricks triplet.

Triplet Code	Load	Area	Shear strength	Average initial shear strength	Characteristic initial shear strength	Failure Mode
	F_{imax} (N)	A_i (mm ²)	$f_{voi} = F_{imax} / 2A_i$ (MPa)	f_{vo} (MPa)	$f_{vok} = 0.8 f_{voi}$ (MPa)	
tr_1	5280	11400	0.23	0.25	0.20	A2
tr_2	5290		0.23			A2
tr_3	5900		0.26			A2
tr_4	6680		0.29			A2

Shear failure modes of clay brick triplets

Four different failure modes (A, B, C, D) may be identified according to the EN 1052-3 specifications without lateral compression for the shear tests, as illustrated in Figure 4.14. Specifically, in the first two failure modes (A1 and A2), failure occurs by the separation of the mortar from the brick, due to the weakness of the interface between the two materials. For each specimen, its failure mode is listed in detail, which is type A2 as shown in Table 4.5.

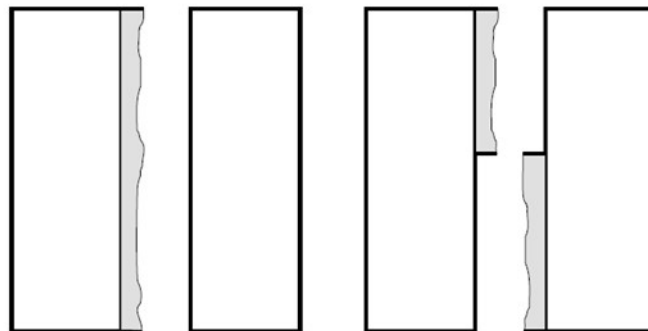


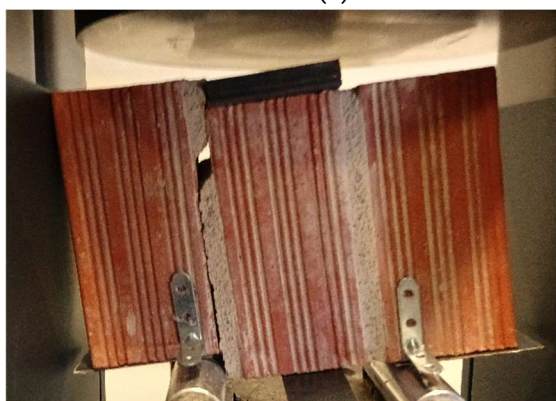
Figure 4.14: Types of failure modes of brick triplets subjected to shear test. Shear failure at the brick/mortar interface (A1) at one or (A2) between two interfaces.



(a)



(b)



(c)



(d)



(e)



(f)

Figure 4.15: Failure modes of brick triplets subjected to shear testing. Shear failure at the brick/mortar interface (A1) at one or (A2) between two interfaces (a)-(f).

Four specimens failed when the mortar failed and separated in the two brick surfaces and two specimens failed by delamination of the interface with brittle failure as shown in Figure 4.15 (see also earlier tests on novel bricks by Thomoglou et al. 2024)

References

Chalioris, C.E.; Karayannis, C.G.; Angeli, G.M.; Papadopoulos, N.A.; Favvata, M.J.; Providakis, C.P. Applications of Smart Piezoelectric Materials in a Wireless Admittance Monitoring System (WiAMS) to Structures-Tests in RC Elements. *Case Stud. Constr. Mater.* 2016, 5, 1-18, doi:10.1016/j.cscm.2016.03.003.

Chalioris, C.E.; Papadopoulos, N.A.; Angeli, G.M.; Karayannis, C.G.; Liolios, A.A.; Providakis, C.P. Damage Evaluation in Shear-Critical Reinforced Concrete Beam Using Piezoelectric Transducers as Smart Aggregates. *Open Eng.* 2015, 5, 373-384, doi:10.1515/eng-2015-0046.

Chalioris, C.E.; Voutetaki, M.E.; Liolios, A.A. Structural health monitoring of seismically vulnerable RC frames under lateral cyclic loading. *Earthq. Struct.* 2020, 19, 29-44.

EN 1015-11. Methods of test for mortar masonry - Part 11: determination of flexural and compressive strength of hardened mortar. CEN, Brussels; 1999.

EN 1052-3:2002; Methods of Test for Masonry—Part 3: Determination of Initial Shear Strength. BSI: London, UK, 2002

EN 772-1. Methods of test for masonry units. Part 1: determination of compressive strength. CEN, Brussels, Belgium, 2000.

EN 12390-3: Testing hardened concrete - Part 3: Compressive strength of test specimens. CEN, Brussels, 2019.

EN 12390-6: Testing hardened concrete - Part 6: Tensile splitting strength of test specimens. CEN, Brussels, 2023.

EN 10002-1: Metallic materials - Tensile testing - Part 1: Method of test at ambient temperature. CEN, Brussels, 2001.

Na, W.S.; Baek, J., A Review of the Piezoelectric Electromechanical Impedance Based Structural Health Monitoring Technique for Engineering Structures, *Sensors* 2018, 18(5), 1307; doi:10.3390/s18051307.

Naoum, M.C.; Papadopoulos, N.A.; Sapidis, G.M.; Voutetaki, M.E. Efficacy of PZT Sensors Network Different Configurations in Damage Detection of Fiber-Reinforced Concrete Prisms under Repeated Loading. *Sensors* 2024, 24, 5660. <https://doi.org/10.3390/s24175660>.

Naoum, M.C.; Papadopoulos, N.A.; Voutetaki, M.E.; Chalioris, C.E. Structural Health Monitoring of Fiber-Reinforced Concrete Prisms with Polyolefin Macro-Fibers Using a Piezoelectric Materials Network under Various Load-Induced Stress. *Buildings* 2023, 13, 2465. <https://doi.org/10.3390/buildings13102465>.

Rousakis T, Ilki A, Kwiecien A, Viskovic A, Gams M, Triller P, Ghiassi B, Benedetti A, Rakicevic Z, Colla C, Halici OF, Zajac B, Hojdis Ł, Krajewski P, Rizzo F, Vanian V, Sapalidis A, Papadoulis E, Bogdanovic A. Deformable Polyurethane Joints and Fibre Grids for Resilient Seismic Performance of Reinforced Concrete Frames with Orthoblock Brick Infills. *Polymers* 2020; 12(12). DOI: <https://doi.org/10.3390/polym12122869>. Thomoglou, A.K.; Falara, M.G.; Gkountakou, F.I.; Elenas, A.; Chalioris, C.E. Smart Cementitious Sensors with Nano-, Micro-, and Hybrid-Modified Reinforcement: Mechanical and Electrical Properties. *Sensors* 2023, 23, 2405. <https://doi.org/10.3390/s23052405>.

Sam-Daliri, O.; Faller, L.M.; Farahani M.; Roshanghias, A.; Araee, A.; Baniassadi, M.; Oberlercher, H.; Zangl, H., Impedance analysis for condition monitoring of single lap CNT-epoxy adhesive joint. International Journal of Adhesion and Adhesives, 88, 59-65, doi:10.1016/j.ijadhadh.2018.11.003.

Sam-Daliri, O.; Faller, L.M.; Farahani M.; Zangl, H., Structural health monitoring of adhesive joints under pure mode I loading using the electrical impedance measurement. Engineering Fracture Mechanics, 245, 107585, doi:10.1016/j.engfracmech.2021.107585. Thomoglou, A.K.; Voutetaki, M.E.; Fantidis, J.G.; Chalioris, C.E. Novel Natural Bee Brick with a Low Energy Footprint for “Green” Masonry Walls: Mechanical Properties. Eng. Proc. 2024, 60, 9. <https://doi.org/10.3390/engproc2024060009>.

Voutetaki, M.E.; Papadopoulos, N.A.; Angeli, G.M.; Providakis, C.P. Investigation of a New Experimental Method for Damage Assessment of RC Beams Failing in Shear Using Piezoelectric Transducers. Eng. Struct. 2016, 114, 226-240, doi:10.1016/j.engstruct.2016.02.014

Voutetaki, M.E.; Naoum, M.C.; Papadopoulos, N.A.; Chalioris, C.E. Cracking Diagnosis in Fiber-Reinforced Concrete with Synthetic Fibers Using Piezoelectric Transducers. Fibers 2022, 10, 5. <https://doi.org/10.3390/fib10010005>.