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SCHOOL OF CIVIL ENGINEERING
LABORATORY OF EARTHQUAKE ENGINEERING
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SEISMIC TEST

OF THE WALL MODEL SYSTEM OF ΚΟΦΙΝΑΣ
NIC. KOFINAS – MICH. KOFINAS PREFABRICATED HOUSES

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TABLE OF CONTENTS

1. ABSTRACT

A single-floor full-scale model, built by the ΚΟΦΙΝΑΣ "NIC. KOFINAS – MICH. KOFINAS Prefabricated Houses" company was experimentally examined using a seismic simulator. The model consists of wood-framed walls with expanded polystyrene insulation and OSB siding. One face of the building was plastered with insulation façade system. The goal of testing was to check the response of this model system under seismic activity.

Initially, the model was excited by a steady sinusoidal pulse shaping acceleration time-history with logarithmic frequency sweeping for determination of its dynamic properties (period and damping ratio). Seismic tests were then carried out during which the model was excited by acceleration time-histories along directions X, Y and Z. These time-histories constituted the elements of a simulated earthquake to range of which encompasses the elastic range of the Greek Seismic Regulation (EAK2000) [1] for Category A ground and maximum ground acceleration of 0.16g (case a). The model was strained by successive escalating simulated seismic excitations. Next, an additional 8Mgr mass was placed in the model and tri-axial seismic excitations were carried out. The range of these excitations corresponded to the elastic range of the Greek Seismic Regulation (EAK2000) [1] for Category B ground and maximum ground acceleration of 0.16g (case b). The model was strained by successive escalating simulated seismic excitations.

In case a, there were 11 seismic tests with escalating excitation accelerating up to 1.50g in direction X, 1.17g in direction Y and 0.87g in direction Z. In case b, there were 5 seismic tests with escalating excitation accelerating up to 0.58g in direction X, 0.54g in direction Y and 0.68g in direction Z.

No visible damage or cracking was noticed throughout the tests (wood frame, wood OSB siding, plastered surface with insulation façade).

The maximum angular deformation of the model in direction X was 4.60‰, corresponded to test 14 with a maximum acceleration of 0.58g in direction X, 0.54g in direction Y and 0.68g in direction Z. The maximum angular deformation of the model in direction Y was 4.28‰ and corresponded to a test with maximum acceleration of 1.50g in direction X, 1.17g in direction Y and 0.87g in direction Z.

2. PREFACE

These seismic tests were carried out further to an agreement with the company ΚΟΦΙΝΑΣ "NIC. KOFINAS – MICH. KOFINAS Prefabricated Houses" and the Laboratory of Earthquake Engineering (LEE) of the National Technical University of Athens (NTUA).

The goal of testing was to explore the response of this model wall system with wood OSB siding, under seismic activity.

The seismic tests were performed on the following model: Single-floor building, full-scale 3.77x3.77m^2 floor plan and 3.12m total height. Figure 1 shows a general view of the model on the seismic simulator. The model consists of four walls assembled in situ on the seismic simulator. The walls of each face are wood framed, all parts are screwed together with reinforced Torx screws, expanded polystyrene, wood OSB siding and gypsum board on the interior side. The eastern, northern and western sides have openings while the southern side is solid (Figure 1-2abc). The height of all walls is 2.80m and they are 0.172m thick (the eastern side fitted with the insulation façade is 0.250m thick). As can be seen in Figure 3, the walls are screwed together with reinforced Torx screws and metal anchors. The roof of the model is made of wood beams in direction A-D and 22mm thick wood OSB siding (Figure 2c). The model was fixed to the seismic simulator with a wood base (Figure 4). The total model mass was 1.38Mgr.

Figures 5 to 7 show the construction plans of the model.

An additional 2Mgr mass was added for the tests, while an additional 6Mgr mass was added during the tests (total additional mass 8Mgr).

The company ΚΟΦΙΝΑΣ "NIC. KOFINAS – MICH. KOFINAS Prefabricated Houses" was responsible for the design and construction of the model. KOFINAS - MICH. KOFINAS Prefabricated Houses". The model was assembled in the Laboratory premises.

The seismic simulator with 6 degrees of freedom installed at the Laboratory of Earthquake Engineering permits full electronic control and data collection with 64 channels. The main properties of the seismic simulator are presented in Paragraph 7, page 8 of this technical report.

The tests were carried out on Friday, 20 November 2009. The tests were observed by seismologist Dr. Gerasimos Houliaras of the Athens Observatory's Geodynamic Institute and the following engineers from ΚΟΦΙΝΑΣ "NIC. KOFINAS – MICH. KOFINAS Prefabricated Houses": Maria Bougiotopoulou: Civil Engineer NTUA, Vasiliki Exarchou: Civil Engineer, Panagiotis Tsantilas: Civil Engineer, Loukas Patis: Architect NTUA, Evgenia Kofina: Pregraduate school of Architecture NTUA, Constantinos Kofinas: Foreman, Andreas Nicolaou: Foreman.

The tests and analysis of results were performed under the supervision of Dr. H. P. Mouzakis, Civil Engineer, Assistant Professor NTUA. The test results were analyzed by L. Karapittas, Civil Engineer. A. Asimakopoulos, Electrical Engineer, G. Mikelis, Mechanical Engineer and technicians K. Hioktouris, M. Koliarakis and D. Hatziroumbis provided their assistance for the tests.

3. EXPERIMENTAL EXCITATIONS

3.1. Sinusoidal pulse shaping steady acceleration

The model was excited by a steady sinusoidal pulse shaping acceleration of 0.055g with logarithmic frequency sweeping from 1-16Hz. Sweeping speed was one octave per minute. Tests in X and Y directions were performed separately. This test is performed in order to define the dynamic characteristics of the model, period T and damping ration z. Frequency f for this specific excitation in the time filed is provided by the equation:

$$f = 2^{\frac{TIME(sec)}{60}}$$

where TIME(sec) is the maximum model response time. The damping ratio is calculated on the frequency field with the method of half-strip of width power. Table 1 presents the dynamic characteristics of the dominant modeshape of the model in directions X and Y.

Table 1: Period and damping ratio.

Direction	Natural frequency* (Hz)	Period* (sec)	Damping Ratio (%)
X	9.85	0.10	2.07
Y	12.27	0.08	3.29

* Additional mass of 2Mgr on the model.

3.2. Seismic excitations

Two series of tri-axial seismic tests were performed on the model along axis X, Y and Z. In case a, the model had an additional mass of 2Mgr and the time-histories of tri-axial excitation constituted the elements of a simulated earthquake which lasted 2048 sec with a time step every 0.01sec, the range of which encompasses the elastic range of the Greek Seismic Regulation (EAK2000) [1], with the following characteristics:

Seismic Risk Zone: II (A=0.16g)
Magnitude Category: II (γ_I=1.00)
Ground category: A (T_1=0.10 sec, T_2=0.40sec)
Foundation factor θ: 1.00
Damping ζ: 5%

In case b, the model had an 8Mgr additional mass and the time-histories of the tri-axial excitation constituted the elements of a simulated earthquake which lasted 2048 sec with a time step of 0.01sec, the elastic range of the Greek Seismic Regulation (EAK2000), with the following characteristics:

Seismic Risk Zone: II (A=0.16g)
Magnitude Category: II (γ_I=1.00)
Ground category:
Foundation factor θ: 1.00
Damping ζ: 5%

In case a, there were 11 seismic tests with escalating excitation accelerating up to 1.31g in direction X, 1.36g in direction Y and 0.29g in direction Z. In case b, there were 5 seismic tests with escalating excitation accelerating up to 0.58g in direction X, 0.54g in direction Y and 0.68g in direction Z.

Table 2 presents the maximum accelerations of the seismic simulator during the model's tri-axial excitations. Figures 8-9 and 10-11 present the acceleration spectrums of Tests 8 and 18 in the three directions XYZ, which are compared with the Elastic Spectrum of EAK2000 [1] for ground Category A and B respectively and maximum acceleration of 0.36g (maximum ground per EAK2000 [1]). The test acceleration spectrums were calculated for 5% damping.

Table 2: Maximum absolute seismic simulator acceleration values.

Test No.	Maximum acceleration value (m/sec^2)		
	X	Y	Z
3*	0.79	0.69	0.63
4	1.54	1.28	1.12
5	2.39	2.30	1.66
6	3.18	3.10	2.10
7	3.24	3.18	2.09
8	7.58	6.29	4.52
9	10.61	8.38	6.16
10	13.59	10.83	7.88
11	14.94	11.36	8.42
12	14.72	11.51	8.51
13	12.87	13.30	1.86
14**	1.61	1.62	1.55
15	2.36	2.71	2.63
16	3.33	3.81	3.83
17	3.73	4.09	4.41
18	5.66	5.32	6.71

* Additional mass 2Mgr

** Additional mass 8Mgr

4. EXPERIMENTAL LAYOUT

The model was placed on the seismic simulator with an appropriately affixed wooden base which was fixed on the seismic simulator. Fixing of the wooden base was achieved with M30 bolts. Screwing torque of the bolts was 300Nm. Assembly and installation of the model on the seismic simulator was performed by the personnel of ΚΟΦΙΝΑΣ "NIC. KOFINAS – MICH. KOFINAS Prefabricated Houses" in cooperation with Laboratory personnel. The experimental layout of the model on the seismic simulator is presented in Figure 1 while Figure 12 shows the orientation of the model and positive rotations of the seismic simulator axles. General instructions on the experimental and measurement layout are presented in the report [2].

5. MEASUREMENT DEVICES

Figure 13 presents the model acceleration measurement points.
The accelerometers used were made by ENDEVCO/USA.
Table 3 shows the characteristics of accelerometers installed on the roof of the model at measurement points A1X and A2X in direction X and measurement points A3Y and A4Y in direction Y. A tri-axial accelerometer was placed in the middle of the roof at point A5XYZ. Calibration of the accelerometers on the seismic table and accelerometers on the models was performed with an ENDEVCO 28959 DV accelerometer conditioner.

Figures 13 and 14 present the model displacement acceleration measurement points. The cable extension position transducers used were made by CELESCO model PT8101-0050-111-1110. Table 4 presents the characteristics of these potentiometers at measurements point D1 to D8.

Table 3: Accelerometer characteristics.

Measurement Point	Direction	Calibration Value for 1V (m/sec^2)	Type	Reference
A1	X	39.24	Endevco 2262-25	EG993002
A2	X	39.24	Endevco 2262-25	FA5460010
A3	Y	39.24	Endevco 2262-25	EG8100020
A4	Y	39.24	Endevco 2262-25	EG810005
A5	X Y Z	39.24	Endevco 2262-25	FA5460010

Table 4: Transducer characteristics.

Measurement Point	Calibration Value for 1V (mm)	Type	Reference
D1X	68.03	Celesco	3593A
D2X	68.79	Celesco	1796B
D3Y	68.00	Celesco	1797B
D4Y	68.83	Celesco	3594A
D5	67.97	Celesco	A86686
D6	68.18	Celesco	A86683
D7	68.04	Celesco	A86694
D8	68.03	Celesco	A86684

Figures 15-18 show the accelerometers and cable extension position transducers used for the test.

6. SEISMIC TEST DATA

The tests were performed in the Laboratory of Earthquake Engineering of NTUA. The Model was placed on the seismic simulator on Wednesday, 18 November 2009. The instruments were calibrated and installed on the model on Thursday, 19 November 2009. The testing time-line can be seen in Table 5.

Table 5: Test time-line

Test Number	Test Description	Acceleration (m/sec^2)			Day	Time
		X	Y	Z		
1*	Frequency sweeping - X	0.55	-	-	20/11	
2	Frequency sweeping - Y	-	0.55	-	20/11	
3	XYZ Seismic excitation	0.79	0.69	0.63	20/11	11:22
4	XYZ Seismic excitation	1.54	1.28	1.12	20/11	11:24
5	XYZ Seismic excitation	2.39	2.30	1.66	20/11	11:26
6	XYZ Seismic excitation	3.18	3.10	2.10	20/11	11:29
7	XYZ Seismic excitation	3.24	3.18	2.09	20/11	11:32
8	XYZ Seismic excitation	7.58	6.29	4.52	20/11	11:34
9	XYZ Seismic excitation	10.61	8.38	6.16	20/11	11:36
10	XYZ Seismic excitation	13.59	10.83	7.88	20/11	11:38
11	XYZ Seismic excitation	14.94	11.36	8.42	20/11	11:40
12	XYZ Seismic excitation	14.72	11.51	8.51	20/11	11:43
13	XYZ Seismic excitation	12.87	13.30	1.86	20/11	12:04
14**	XYZ Seismic excitation	1.61	1.62	1.55	20/11	13:34
15	XYZ Seismic excitation	2.36	2.71	2.63	20/11	13:35
16	XYZ Seismic excitation	3.33	3.81	3.83	20/11	13:37
17	XYZ Seismic excitation	3.73	4.09	4.41	20/11	13:40
18	XYZ Seismic excitation	5.66	5.32	6.71	20/11	13:41

* Additional mass 2Mgr

** Additional mass 8Mgr

6.1. Quality Plan

This paragraph includes the relevant Quality Plan sections prepared for this agreement, which not covered elsewhere. The Quality Plan was drafted in the Greek language and as a controlled document is available for examination at the Laboratory.

SECTION 1 TECHNICAL SPECIFICATIONS

SECTION 2 REGULATIONS AND STANDARDS
GREEK SEISMIC REGULATION (EAK2000), 2000, Earthquake Planning and Protection Organization (OASP).

SECTION 3 WORK INSTRUCTIONS AND PROCEDURES

1. Test results report
2. Calibration of accelerometers
3. Calibration of transducers
4. Transportation – Installation of Models
5. Test preparation and execution

SECTION 4 Special instructions
1. Transportation – Installation of Models
2. Calibration of instruments
3. Photos - Videos

SECTION 5 CERTIFICATES

SECTION 6 SPECIAL EQUIPMENT
1. Accelerometer calibration instrument (Endevco 28969 DV)
2. Torque wrench

7. INSTALLATION

7.1. Location

The address is:
Laboratory of Earthquake Engineering
National Technical University of Athens
Zografou Campus
Zografou, 15700 Athens Greece
Tel: 0030-10-7721180, FAX: 0030-10-7721182

Access to the laboratory facility is easy for long, large vehicles since the facility is next to a motorway and has a large parking area in front.

7.2. Description and calibration of the seismic simulator

Platform-Mechanical characteristics.
Dimensions: 4mx4mx6m
Weight :100 kN Material : Steel
Number of independent degrees of freedom: six (6)
Maximum model weight 100 kN, at 2m height from the seismic simulator. Heavier models must be modified according to the calibration curves.
Maximum Horizontal Force (Direction X, Y): 320 (kN) maximum vertical force (Direction Z): 640 (kN) maximum displacement of seismic simulator in each direction: ±10 (cm)
Maximum rotation per axle: $7X10^{-2}$ (rad)
Maximum horizontal acceleration per axis: (X,Y): 2.0 g maximum vertical acceleration (Z): 4.0 g
Maximum speed per axis: 100 cm/sec
Operational frequencies per degree of freedom: 0.1- 50 Hz
Capacity:1200 kVA

8. TEST METHODS

The tests complied with the following regulations and customer instructions:

- GREEK SEISMIC REGULATION (EAK2000), 2000, Earthquake Planning and Protection Organization (OASP).

- Instructions of ΚΟΦΙΝΑΣ "NIC. KOFINAS – MICH. KOFINAS Prefabricated Houses" for instrument layout and seismic excitations.

9. LITERATURE

[1] GREEK SEISMIC REGULATION (EAK2000), 2000, Earthquake Planning and Protection Organization (OASP).

[2] ΚΟΦΙΝΑΣ NIC. KOFINAS – MICH. KOFINAS Prefabricated Houses" for instrument configuration and seismic excitations

10. TEST RESULTS

Annex A presents all time-histories of signals as these were analyzed at the various measurement points for all tests. Specifically, the following time-histories are presented:

1. Seismic simulator acceleration time-histories along directions X, Y and Z.
2. Acceleration time-histories along direction X at measurement points A1X and A2X.
3. Acceleration time-histories along direction Y at measurement points A3Y and A4Y.
4. Displacement time-histories at points D1X, D2X.
5. Displacement time-histories at points D3Y, D4Y.
6. Displacement time-histories at points D5, D6, D7 and D8.

Table 6: Maximum absolute measurement parameter values.

Parameters		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9
Ac-T-X (m/sec²)	Max	0.76	1.54	2.30	3.18	3.24	7.58	9.76	12.88	13.54
	Min	-0.71	-1.36	-2.39	-2.99	-3.08	-7.27	-10.61	-13.59	-14.94
Ac-T-Y (m/sec²)	Max	0.69	1.28	2.30	3.10	3.18	6.29	8.38	10.83	11.36
	Min	-0.56	-1.20	-1.93	-2.60	-2.64	-6.04	-7.88	-10.22	-10.99
Ac-T-Z (m/sec²)	Max	0.54	1.04	1.56	1.92	1.99	4.52	6.16	7.88	8.42
	Min	-0.63	-1.12	-1.66	-2.10	-2.09	-4.43	-6.02	-7.37	-7.53
D-T-X (mm)	Max	3.62	7.13	13.67	13.16	13.68	26.65	44.73	50.05	51.90
	Min	-3.41	-6.68	-8.84	-14.33	-19.14	-32.68	-42.82	-66.46	-57.71
D-T-Y (mm)	Max	3.26	6.19	9.35	11.37	15.16	24.55	36.62	46.19	46.34
	Min	-2.89	-5.97	-9.54	-12.66	-14.09	-37.22	-41.75	-56.30	-48.54
D-T-Z (mm)	Max	3.30	6.25	8.75	10.66	10.23	21.69	29.41	39.42	37.54
	Min	-1.34	-3.07	-6.63	-8.14	-8.77	-19.57	-26.26	-34.12	-34.68
A1X (m/sec²)	Max	2.39	2.75	3.89	4.91	4.16	9.38	12.99	14.48	14.28
	Min	-2.04	-3.38	-4.55	-6.00	-5.96	-9.77	-12.09	-13.85	-14.24
A2X (m/sec²)	Max	1.26	2.59	3.38	4.55	4.24	6.32	8.44	7.69	8.20
	Min	-1.41	-2.20	-2.55	-3.10	-3.02	-5.73	-7.85	-8.95	-9.22
A3Y (m/sec²)	Max	9.99	3.10	4.83	5.65	5.22	7.65	10.20	13.50	14.44
	Min	-17.59	-3.02	-4.00	-5.06	-4.94	-8.83	-11.46	-14.09	-15.62
A4Y (m/sec²)	Max	1.96	3.34	4.98	6.71	6.59	10.95	12.01	14.56	14.75
	Min	-2.04	-3.57	-4.98	-6.32	-6.04	-11.26	-14.05	-16.68	-17.23
A5X (m/sec²)	Max	2.43	4.04	5.38	7.30	7.93	11.46	13.34	14.56	15.30
	Min	-2.55	-4.20	-4.79	-5.14	-5.10	-10.79	-14.44	-17.82	-19.19
A5Y (m/sec²)	Max	1.88	3.38	4.87	6.04	5.89	10.05	12.16	15.66	16.99
	Min	-2.12	-3.53	-4.91	-6.04	-6.20	-10.63	-12.16	-14.99	-16.32
A5Z (m/sec²)	Max	2.04	2.67	3.96	4.43	4.79	9.30	11.54	14.44	14.28
	Min	-1.61	-2.32	-3.53	-3.81	-4.20	-8.71	-12.20	-14.09	-14.09
D1X (mm)	Max	3.28	7.57	9.76	16.94	21.36	38.37	50.68	77.08	69.46
	Min	-5.36	-8.35	-14.12	-13.27	-13.88	-27.76	-43.95	-49.46	-53.13
D2X (mm)	Max	3.81	7.46	10.29	16.85	21.53	38.32	50.91	77.11	68.03
	Min	-4.24	-7.67	-14.27	-13.07	-13.69	-28.48	-45.13	-50.56	-54.55
D3Y (mm)	Max	5.15	6.48	14.76	14.21	15.61	41.28	45.90	61.40	54.67
	Min	-4.51	-6.51	-10.81	-12.65	-17.58	-28.49	-38.76	-52.16	-50.59
D4Y (mm)	Max	3.87	6.71	10.83	15.42	15.42	40.33	45.84	60.02	56.72
	Min	-4.18	-7.05	-10.30	-12.46	-15.49	-27.19	-37.51	-52.52	-52.86
D5 (mm)	Max	1.84	1.97	1.56	2.04	1.70	1.70	1.56	1.97	1.43
	Min	-1.84	-1.70	-1.43	-1.29	-1.29	-1.63	-1.43	-1.70	-1.56
D6 (mm)	Max	1.57	1.36	1.70	1.77	1.84	1.50	1.71	1.23	1.43
	Min	-1.43	-1.30	-1.98	-1.91	-1.84	-2.45	-1.91	-2.05	-1.57
D7 (mm)	Max	1.63	1.50	1.77	1.57	1.91	1.29	1.63	1.50	1.57
	Min	-1.63	-1.77	-2.18	-1.36	-1.36	-2.04	-2.04	-2.18	-1.43
D8 (mm)	Max	1.84	1.63	1.97	1.70	1.77	1.50	1.63	1.63	1.43
	Min	-1.84	-1.70	-1.97	-1.91	-1.57	-2.11	-2.31	-1.70	-1.91

Annex A also presents the relative displacement time-history at measurement points D1X, D2X, D3Y and D4Y.

Table 6 presents the maximum model responses to strong seismic tests.

Table 6 (continued): Maximum absolute measurement parameter values.

Parameters		Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16
Ac-T-X (m/sec²)	Max	13.72	11.14	1.15	1.73	2.65	3.02	4.61
	Min	-14.72	-12.87	-1.61	-2.36	-3.33	-3.73	-5.66
Ac-T-Y (m/sec²)	Max	11.51	13.30	1.62	2.71	3.81	4.09	5.32
	Min	-10.92	-12.59	-1.40	-2.04	-2.76	-3.12	-4.87
Ac-T-Z (m/sec²)	Max	8.51	1.34	1.55	2.63	3.83	4.41	6.71
	Min	-7.42	-1.86	-1.32	-2.00	-3.12	-3.61	-5.78
D-T-X (mm)	Max	63.48	47.27	7.77	11.54	17.24	19.60	30.18
	Min	-68.55	-50.59	-6.73	-10.34	-15.47	-17.94	-27.53
D-T-Y (mm)	Max	59.33	50.29	7.23	10.45	15.82	18.21	28.12
	Min	-66.80	-61.62	-8.59	-12.06	-18.16	-21.53	-33.06
D-T-Z (mm)	Max	45.35	1.78	8.26	11.35	16.81	19.38	29.22
	Min	-38.30	-0.27	-8.83	-13.21	-20.01	-23.54	-36.55
A1X (m/sec²)	Max	13.81	15.93	2.12	2.98	4.91	5.81	8.32
	Min	-14.36	-16.25	-1.69	-2.39	-3.34	-4.16	-6.24
A2X (m/sec²)	Max	8.20	8.01	1.33	1.65	1.99	1.59	3.49
	Min	-9.22	-10.95	-1.33	-1.81	-2.21	-3.79	-4.36
A3Y (m/sec²)	Max	13.89	17.34	40.54	66.71	73.33	42.91	90.68
	Min	-15.81	-17.50	-54.11	-46.14	-58.28	-98.71	-74.87
A4Y (m/sec²)	Max	14.72	18.60	2.19	3.53	5.49	5.69	8.01
	Min	-16.91	-18.95	-2.01	-2.98	-3.69	-4.47	-6.59
A5X (m/sec²)	Max	14.95	18.05	1.92	2.51	3.30	3.92	6.83
	Min	-18.56	-19.50	-2.32	-2.63	-4.16	-5.06	-8.12
A5Y (m/sec²)	Max	17.03	18.80	1.87	2.51	3.85	4.71	6.63
	Min	-16.48	-18.36	-2.17	-3.45	-5.18	-5.26	-7.53
A5Z (m/sec²)	Max	15.11	5.26	3.30	4.98	5.77	7.10	12.48
	Min	-14.21	-4.71	-2.87	-4.40	-5.73	-6.12	-8.04
D1X (mm)	Max	79.53	60.28	7.17	12.25	18.30	22.25	35.51
	Min	-68.91	-48.64	-10.11	-13.67	-20.89	-22.31	-36.60
D2X (mm)	Max	79.66	60.12	7.46	12.45	18.35	22.77	36.18
	Min	-69.13	-49.05	-9.66	-13.76	-20.24	-22.22	-37.35
D3Y (mm)	Max	75.96	68.48	9.72	14.48	21.49	25.09	39.03
	Min	-62.56	-55.69	-8.23	-12.44	-18.70	-21.01	-32.98
D4Y (mm)	Max	72.96	69.52	10.07	15.07	23.40	25.40	38.89
	Min	-64.49	-56.17	-8.79	-13.49	-20.31	-22.65	-35.10
D5 (mm)	Max	1.77	1.70	1.43	1.84	1.43	1.43	1.77
	Min	-1.90	-1.63	-1.56	-1.84	-1.56	-1.56	-1.90
D6 (mm)	Max	1.43	1.43	1.57	1.64	1.64	1.98	1.64
	Min	-1.57	-1.23	-1.43	-2.05	-1.71	-1.36	-1.36
D7 (mm)	Max	1.77	1.16	1.36	2.11	1.77	1.43	1.43
	Min	-1.57	-1.50	-1.63	-1.23	-1.91	-1.91	-1.23
D8 (mm)	Max	1.91	1.57	1.77	2.18	1.43	1.77	1.43
	Min	-1.43	-1.09	-1.84	-1.77	-1.84	-1.50	-1.84

10.1. Calculation of angular deformation

Angular deformation is the relative building roof displacement ratio to its height. Angular deformation is calculated on direction X with cable extensions position transducers at measurement points D1X, D2X and on direction Y with cable extensions position transducers at measurement points D3Y, D4Y. The height is equal to the height at which the cable extensions position transducers were placed (in the middle height of the wood roof beam 2.95m). Table 7 presents the maximum absolute relative displacement value at positions D1X, D2X and the corresponding angular deformation values for Tests 6 – 16. In Table 8, the corresponding values are given for direction Y.

Table 7: X direction: Relative Displacement – Angular Deformation

Test	RD1X (mm)	RD2X (mm)	Angular Deformation D1X/h (=2.95m) (‰)	Angular Deformation RD2X/h (=2.95m) (‰)
6*	2.51	2.68	0.85	0.91
7	2.51	2.64	0.85	0.89
8	5.09	5.33	1.73	1.81
9	7.08	7.47	2.40	2.53
10	10.23	10.12	3.47	3.43
11	11.06	10.65	3.75	3.61
12	13.40	11.39	4.50	3.86
13	9.05	10.28	3.07	3.49
14**	2.79	2.53	0.95	0.86
15	4.26	4.20	1.44	1.42
16	6.94	5.76	2.35	1.95
17	6.72	6.76	2.28	2.29
18	13.17	13.57	4.46	4.60

* Additional mass 2Mgr

** Additional mass 8Mgr

Table 8: Y Direction: Relative Displacement – Angular Deformation

Test	RD3Y (mm)	RD4Y (mm)	Angular Deformation D3Y/h (=2.95m) (‰)	Angular Deformation RD4Y/h (=2.95m) (‰)
6*	2.71	2.59	0.92	0.88
7	2.65	2.63	0.90	0.89
8	4.27	4.85	1.45	1.64
9	6.12	6.66	2.07	2.26
10	12.00	9.77	4.07	3.31
11	10.07	9.85	3.41	3.34
12	12.62	10.73	4.28	3.64
13	8.76	10.31	2.97	3.49
14**	2.65	2.59	0.90	0.88
15	3.96	4.50	1.34	1.53
16	4.98	8.99	1.69	3.05
17	5.86	8.43	1.99	2.86
18	10.59	12.50	3.59	4.24

* Additional mass 2Mgr

** Additional mass 8Mgr

The maximum angular deformation of the model in direction X was 4.60‰, corresponded to test 18 with a maximum acceleration of 0.58g in direction X, 0.54g in direction Y and 0.68g in direction Z. The maximum angular deformation of the model in direction Y was 4.28‰ and corresponded to test 12 with maximum acceleration of 1.50g in direction X, 1.17g in direction Y and 0.87g in direction Z.

11. CONCLUSIONS

Two series of tests were performed on the model. In case a, the additional mass of 2Mgr on the model and seismic excitation time-histories corresponded to the elastic spectrum per Greek Seismic Regulation (EAK2000) [1], for Ground category A and ground acceleration 0.16g. In case b, the additional mass of 8Mgr on the model and seismic excitation time-histories corresponded to the elastic spectrum per Greek Seismic Regulation (EAK2000) [1], for Ground category A and ground acceleration 0.16g.

In case a, there were 11 seismic tests with escalating excitation accelerating up to 1.50g in direction X, 1.17g in direction Y and 0.87g in direction Z. In case b, there were 5 seismic tests with escalating excitation accelerating up to 0.58g in direction X, 0.54g in direction Y and 0.68g in direction Z.

No visible damage or cracking was noticed throughout the tests (wood frame, wood OSB siding, plastered surface with insulation façade).

The maximum angular deformation of the model in direction X was 4.60‰, corresponded to a test with maximum acceleration of 0.58g in direction X, 0.54g in direction Y and 0.68g in direction Z. The maximum angular deformation of the model in direction Y was 4.28‰ and corresponded to a test with maximum acceleration of 1.50g in direction X, 1.17g in direction Y and 0.87g in direction Z.

Athens, November 2009

The Engineer who
performed the test and drafted the report

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. Civil Engineer, Assistant Professor NTUA

The Laboratory Director:

Dr. K. Spyrakos
. Civil Engineer, Professor NTUA

Figure. 1: Experimental layout of the model on the seismic simulator.

(a)

(b)

(c)

Figure. 2: Assembly of the model: (a) Western – Southern face (b): Northern face and (c): Eastern – Northern face, roof.

Figure. 3: Connection of walls with screws.

Figure. 4: Wood base to fix model on the seismic simulator.

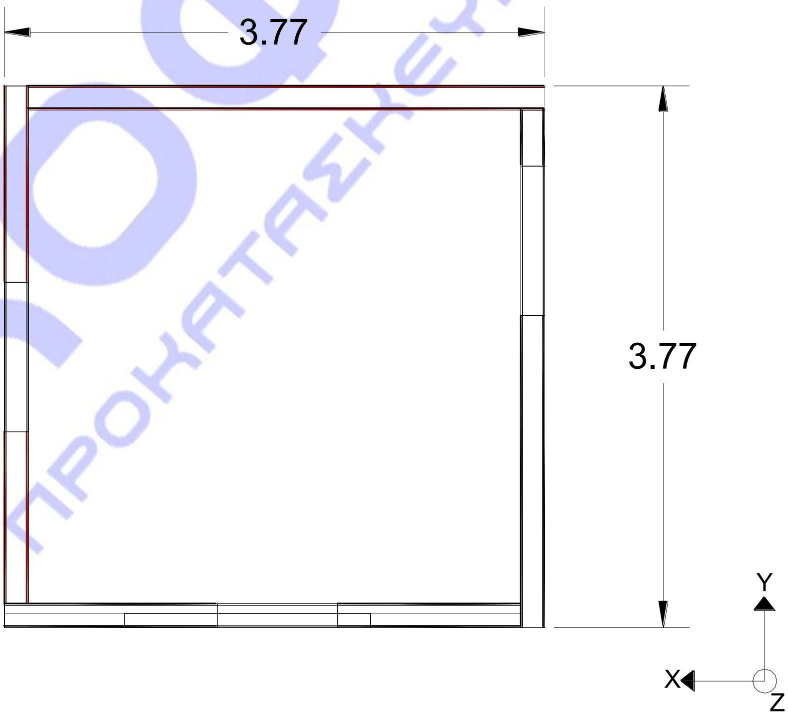


Figure. 5: Model floor plan.

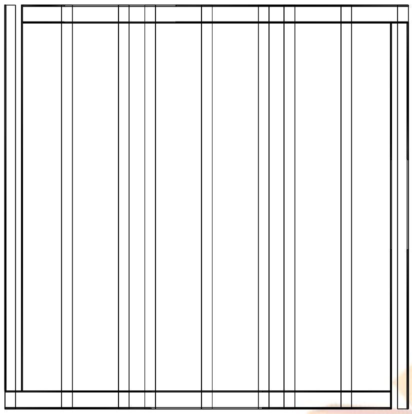


Figure. 6: Transverse beams of model.

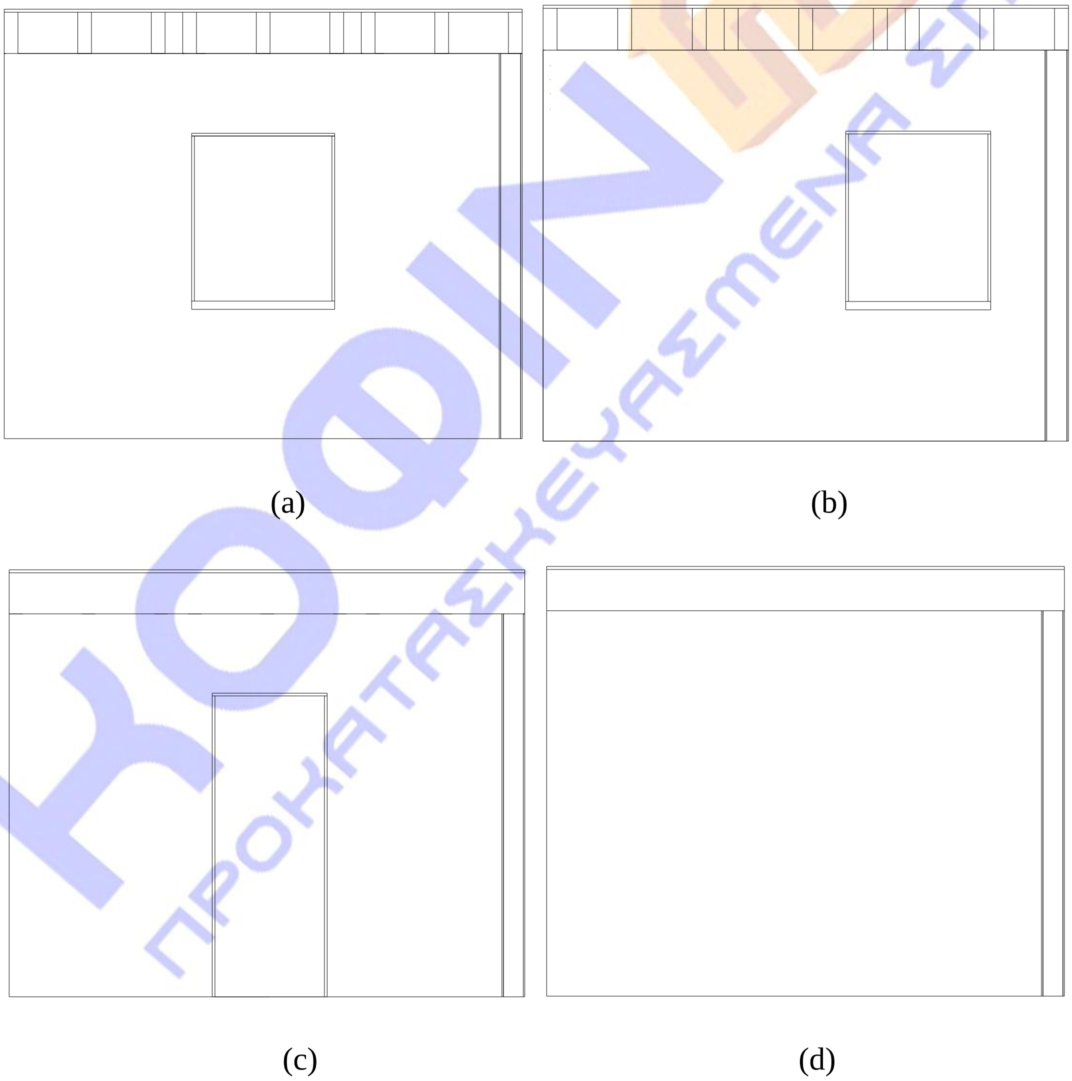
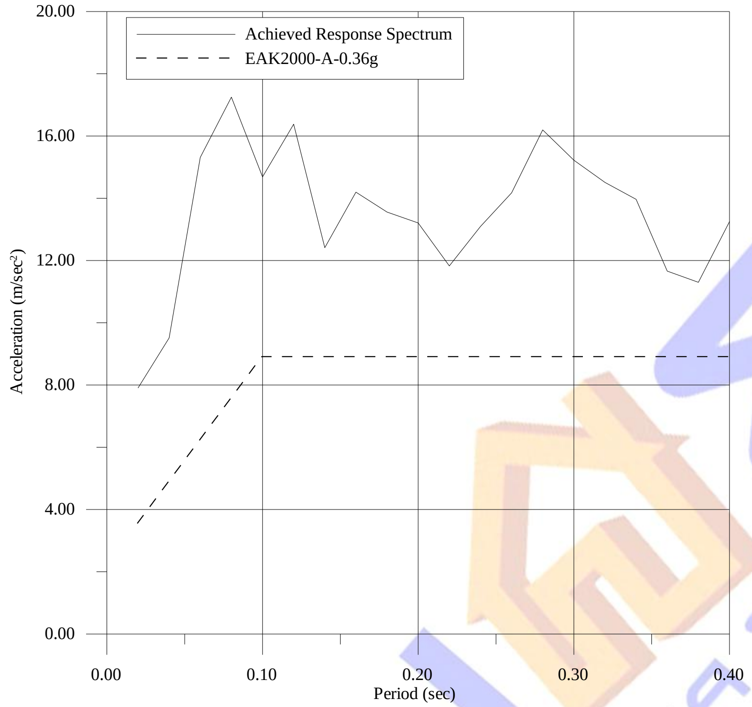
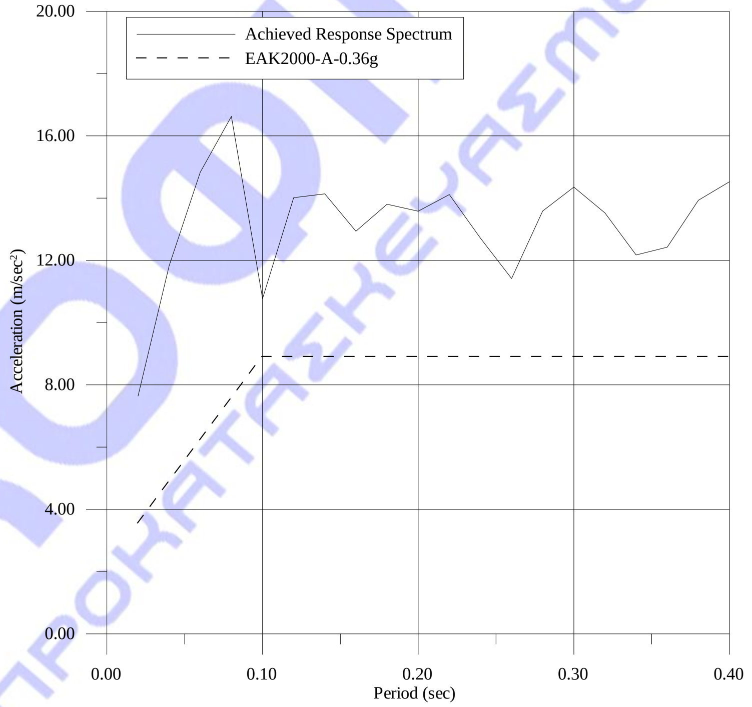


Figure. 7: Model elevations: (a) Eastern, (b); Western, (c): Northern and (d): Southern.



(a)



(b)

Figure. 8: Test 8: Comparison of test acceleration Spectrum with Elastic Spectrum EAK2000 for ground A and maximum ground acceleration of 0.36g, (a): Direction X and (b): Direction Y.

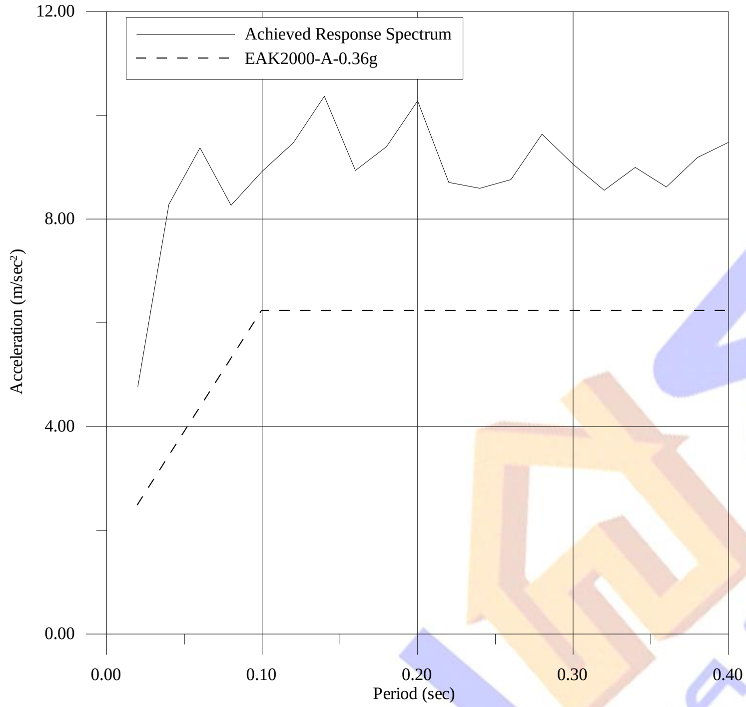
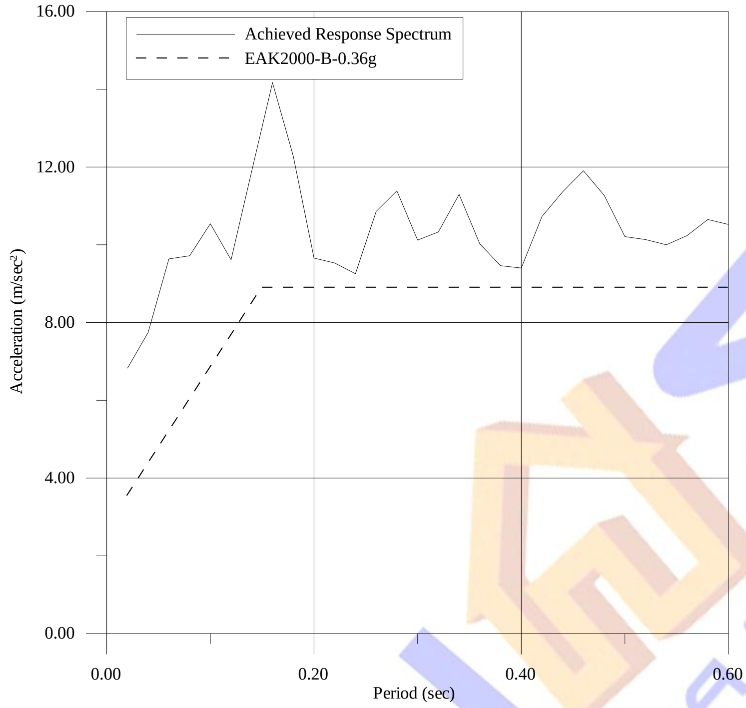


Figure. 9: Test 8: Comparison of test acceleration Spectrum with Elastic Spectrum EAK2000 for ground A and maximum ground acceleration of 0.36g, Direction Z.



(a)

(a)

(b)

Figure. 10: Test 18: Comparison of test acceleration Spectrum with Elastic Spectrum EAK2000 for ground B and maximum ground acceleration of 0.36g, (a): Direction X and (b): Direction Y.

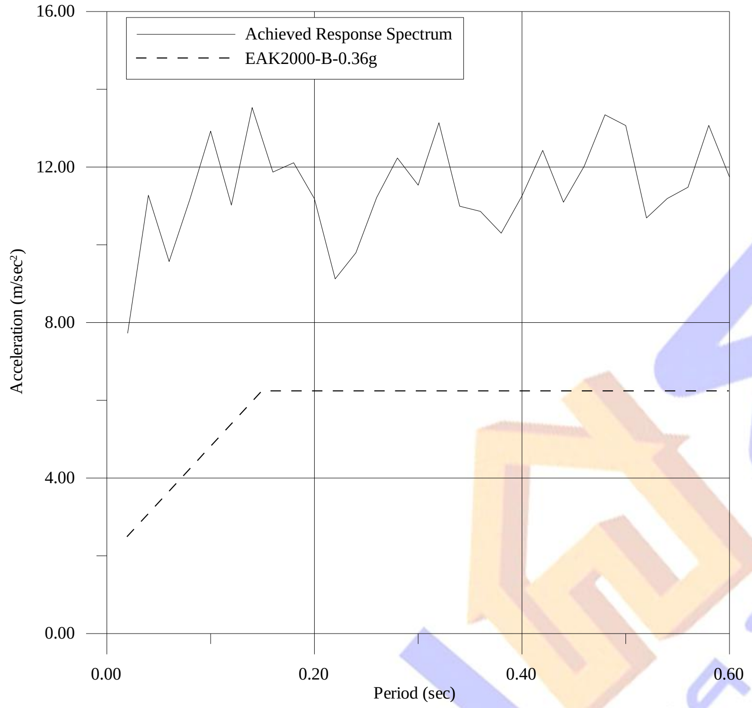


Figure. 11: Test 18: Comparison of test acceleration Spectrum with Elastic Spectrum EAK2000 for ground B and maximum ground acceleration of 0.36g, Direction Z.

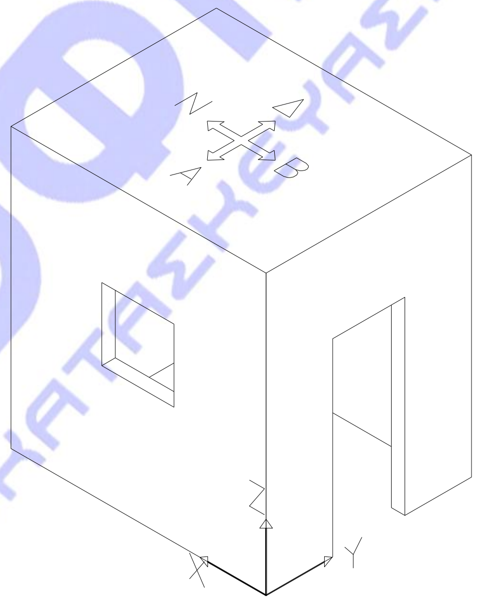


Figure. 12: Orientation of model on the seismic simulator – Positive axle rotation.

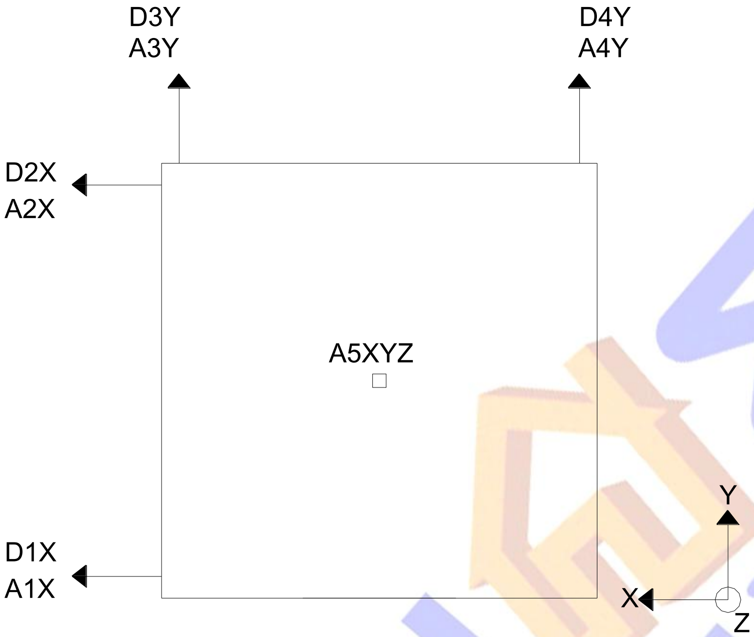


Figure. 13: Accelerometers and cable extensions position transducers at measurement points A1X/D1X, A2X/D2X, A3Y/D3Y and A4Y/D4Y, tri-axial accelerometer at point A5XYZ.

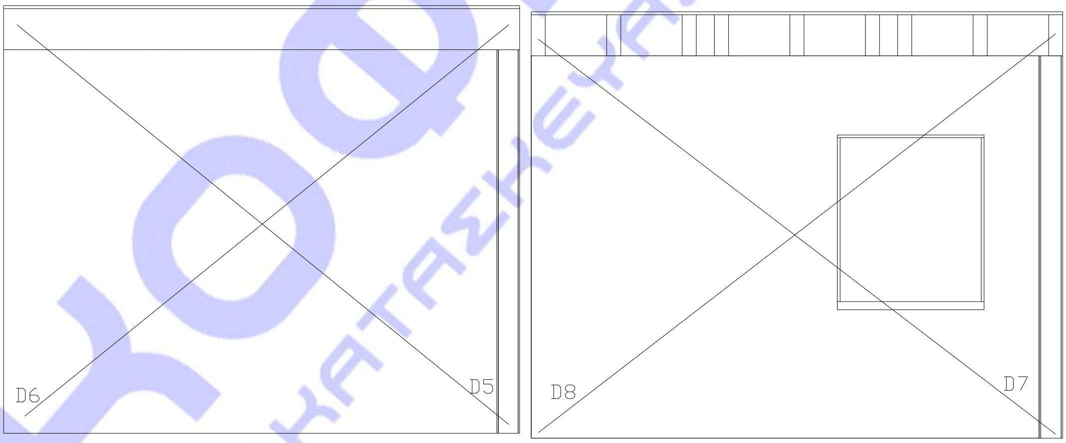
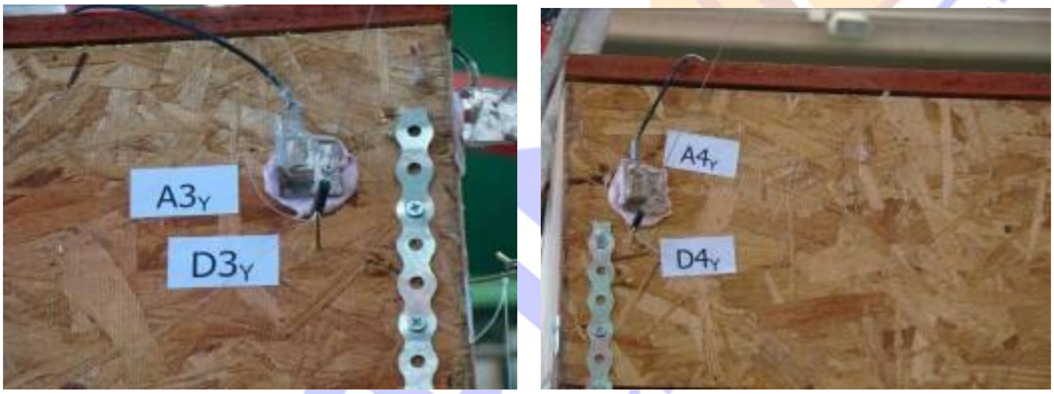


Figure. 14: Transducers to measure displacement at measurement points D5-D8.

(a) (b)

Figure. 15: Accelerometers and cable extensions position transducers at measurement point (a): A1X/D1X and (b): A2X/D2X.



(a) (b)

Figure. 16: Accelerometers and cable extensions position transducers at measurement point (a): A1X/D1X and (b): A2X/D2X.

Figure. 17: Tri-axial accelerometer at position A5XYZ.

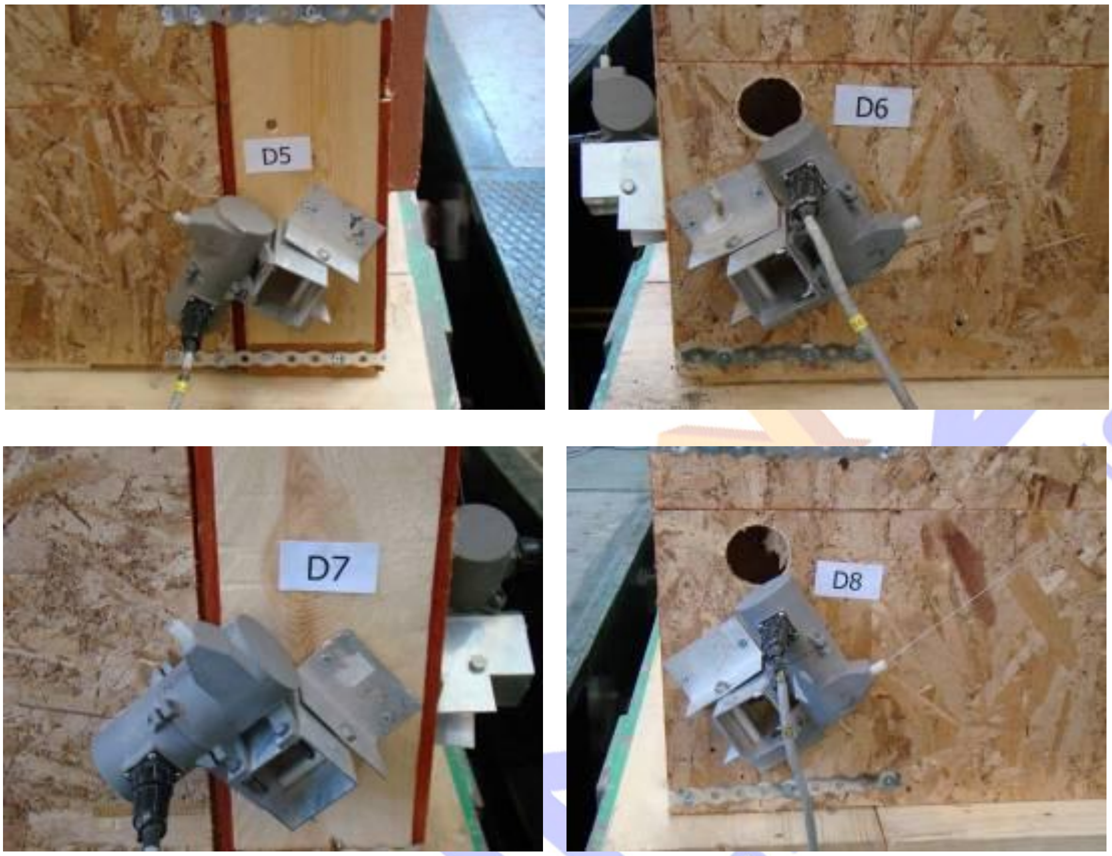


Figure. 18: Transducers to measure displacement at measurement points D5 to D8.