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Scientific Technical Report STR17/10 - Data GIPP Experiment and Data Archive

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AHEPA and Volvi ambient seismic noise experiments - Report

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Abstract

A temporary seismic array of short-period seismometers was installed in the 8-story AHEPA hospital, located in the city of Thessaloniki, N. Greece. The scope of the survey was to assess the dynamic characteristics of the RC-building by processing ambient vibration recordings of more than 40 seismic stations installed at different positions in the building. Part of the instruments was used in a soil experiment, outside of the hospital, to study possible Soil Structure Interaction phenomena. In addition to above experiments, a site-specific survey was performed in the Volvi basin, 30km ENE of the city of Thessaloniki. The scope of this experiment was to investigate the soil properties and the geometry of the subsurface geology.

Coordinates: for the AHEPA experiment: 40.62°N, 22.96°E,
for the Volvi experiment: BRGM-array 40.65°N, 23.24°E,
GER-array 40.61°N, 23.21°E.

Keywords: Seismometers, ambient noise, building monitoring, soil properties

1. Introduction

In the framework of the REAKT European project (Strategies and tools for Real-Time Earthquake Risk Reduction, http://www.reaktproject.eu/) ambient noise measurements were performed on February 12th and 13th, 2013 inside the 8-story RC-building of the AHEPA hospital, one of the largest hospitals in northern Greece. AHEPA is selected as test site for developing a structural health monitoring system and it is instrumented with a permanent strong motion network since 2012. Building monitoring was performed using 40 short-period seismic stations which output is proportional to ground velocity. These instruments were provided by the Geophysical Instrument Pool (GIPP) of the Helmholtz Centre of Potsdam. Supplementary, 7 broad-band seismometers were used in the building monitoring array, close to short-period stations for instrumental comparison purposes. These instruments belong to the Laboratory of Soil Mechanics, Foundation and Geotechnical Earthquake Engineering of the Civil Engineering Department of the Aristotle University of Thessaloniki (AUTH). A total amount of 5Gb ambient noise data was recorded for the two days of the AHEPA monitoring. Using part of this instrumentation, a soil experiment was conducted outside of the AHEPA hospital, aiming to study possible Soil Structure Interaction phenomena. The experiment,

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hereafter the SSI experiment, was conducted on February 15th, 2013 using 17 short-period and broad-band seismic stations. In addition to AHEPA and SSI experiments, a target-oriented survey was conducted in Volvi basin on March 20th and 21st, 2013. This experiment (hereafter the Volvi experiment) was made beyond the scopes of the REAKT European project, due to availability of the GIPP instruments in Thessaloniki. The scope of the Volvi experiment was to study soil properties and geology substructure at two specific sites in the basin, by recording ambient ground noise in an array of stations.

2. Data Acquisition

2.1 Ambient noise experiment in the AHEPA hospital

2.1.1 Site Description

The AHEPA general hospital in Thessaloniki is one of the largest hospitals in northern Greece, located inside the Aristotle University campus. It is a major teaching and research center and part of the National Healthcare System of Greece. The hospital complex consists of 40 buildings of various functions and typologies. It was constructed in 1971 and is considered representative of structures that have been designed according to the old 1959 Greek seismic code (Royal Decree of 1959), where the ductility and the dynamic features of the constructions are ignored. It is an 8-story infilled structure and its special feature is that it is composed of two adjacent tall building units, Unit I and Unit II, that are connected with a structural joint (Fig. 1). UNIT 1 covers a rectangular area of 29m × 16m while UNIT 2 has a trapezoidal cross section of 21m × 27m × 16 m. The total height of the building with respect to the foundation level is 28.6m with a constant inter-story height of 3.4m except for the second floor where the height increases to 4.8m due to the presence of a middle floor level which covers only a part of the typical floor plan (Fig. 1). From the structural point of view the buildings force resisting mechanism comprises longitudinal and externally transverse reinforced concrete moment resisting frames. The columns have variable dimensions along the height of the building starting 0.45m×0.70m at the lowest level (basement) and resulting to 0.35m×0.35m at the upper floor. In the longitudinal direction the outer and inner columns are connected by beams with cross-section of 0.20m × 0.60m and 0.35m × 0.40 m, respectively. In the transverse direction on the other hand only the exterior columns are connected by beams with dimensions of 0.20m × 0.95 m. The presence of beam to beam connections at all floor levels near the staircases and elevator shafts, constitute a complex structural system which is particularly evident in the middle floor where the RC beams are inverted. Reinforced concrete walls are present in both building units, surrounding partially the staircases and the lift shafts; they are not specially detailed for seismic performance. More specifically there are two walls in the transverse and one in the longitudinal direction of UNIT 1 and only one wall in the transverse direction of UNIT 2. The RC walls are 0.20m thick while their length is decreasing significantly along the structures height. Moreover, a perimeter reinforced concrete wall with dimensions of 0.20m × 3.00m has been constructed at top of the building. The foundation system consists of simple footings of variable geometries without tie-beams combined partially with a raft foundation (Bindi et al. 2015). Figure 1 represents a typical cross-section of the hospital with the foundation soil profile and the average shear wave velocities Vs estimated from down-hole survey (Raptakis et al. 1994). The soil consists of stiff clay with average Vs of about 400–450m/s. The rock basement (schist) is found at 30–35m depth having Vs velocities greater than 750m/s. The foundation soil at the hospital building can be characterized as soil type B according to EC8 soil classification.

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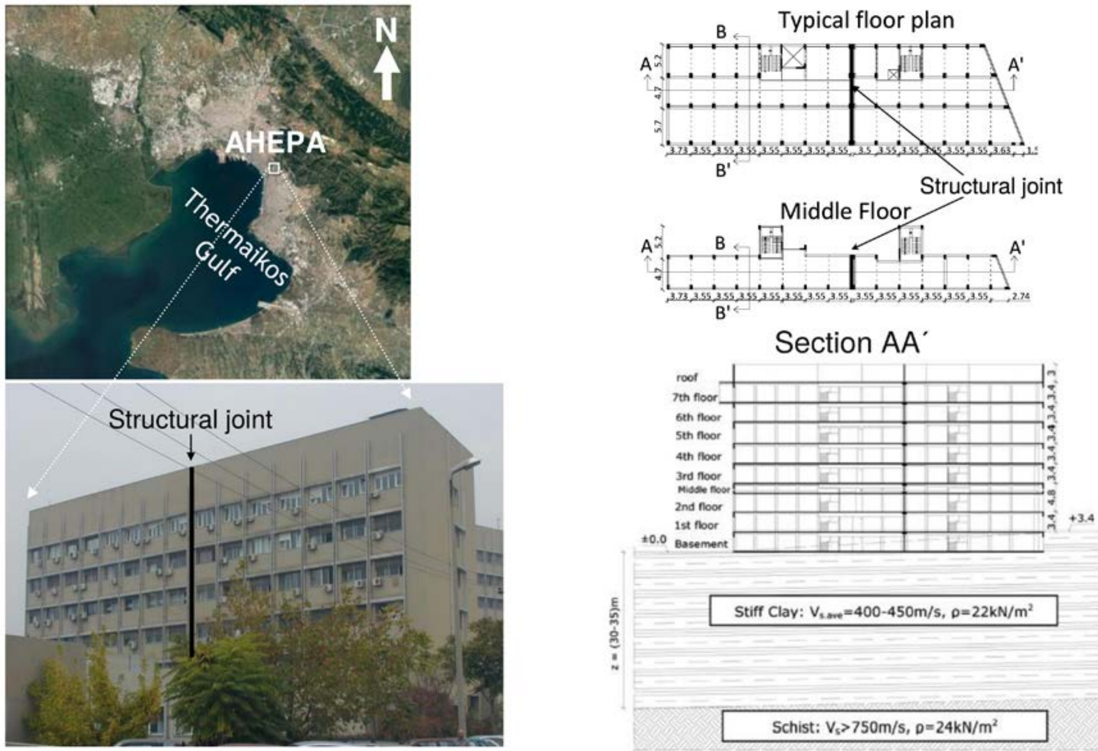

Fig. 1. The AHEPA hospital. Typical floor plan and middle floor with the structural joint and a typical soil profile in correspondence of AHEPA hospital building.

The scope of the temporary experiment was the dynamic characterization of the hospital building in terms of eigenfrequencies and mode shapes. Ambient noise measurements were used to derive the experimental modal model of the hospital building and identify its modal properties based on operational modal analysis. The modal identification results were used to update and better constrain the initial finite element model of the building, which was based on the design and construction documentation plans. In the absence of any structural geometry modification since 1971, when the building was constructed, only the variation of the material properties was taken into account. An eigenvalue sensitivity analysis of the elastic numerical modal models was performed to identify the most sensitive parameters influencing the structural modes of interest which were used in the updating process to define the optimal analytical model that reflects the experimental results. The selection of the best updated finite element (FE) models for the hospital building units was made by evaluating an appropriate response correlation function between experimental and numerical results. Three-dimensional incremental dynamic analyses of the nonlinear updated models were performed using real ground motion accelerograms that were selected based on the regional seismic hazard, to derive the "time-building specific" fragility curves that correspond to the actual state of the hospital building units. The detailed methodology and the derived fragility curves can be found in Karapetrou et al. (2016) and Pitilakis et al. (2016).

In the framework of the REAKT project, a permanent strong motion network (Sosewin network) was installed on May 2012 for monitoring the building and implementing an early earthquake warning system for near real time damage assessment. It comprises 13 triaxial accelerometers (MEMS ADXL203 chip) installed on the basement, the first

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and fourth floors and the roof, as Figure 2 shows. One more accelerometer is installed on the roof of a nearby building and used as bridge node for the data transmission to the two gateways installed outside of the Laboratory of Soil Mechanics, Foundations and Geotechnical Earthquake Engineering. The Sosewin network was in operation during both days of the AHEPA experiment.

2.1.2 Experiment design and instrumentation

During the first day of the AHEPA experiment (February 12th, 2013), the two building units were instrumented with 41 seismic stations including 37 short-period triaxial seismometers L4C-3D Mark Product sensors (1Hz natural frequency) connected with Earth Data Logger 24-bit digitizers (EDL PR6-24), and 4 broadband CMG-40 Güralp triaxial seismometers (30s natural period) connected with DAS-130 Reftek 24-bit recorders. GPS antennas guaranteed the time synchronizations among the instruments. All the instruments were supported by external 12V batteries. For each building unit, two short-period instruments were deployed at each floor, the first on the external side and the second close to the structural joint. Due to restrictions in the logistics, the stations were deployed along the longitudinal corridors, located almost in the middle of the structure. Figure 3 shows the location and distances (in m) between the stations deployed in the first day of the experiment. The broadband stations were installed at the 4th, 5th, 6th and 7th floors of the building, one per floor, close to short-period seismometers for instrumental comparison purposes. One L4C-3D station was installed on the field, outside the building, and used as reference point. Ambient noise was recorded by all stations simultaneously for about 4 hours with sampling rate 500 samples per second and gain 10 as pre-amplifier for the L4C-3D, and gain 1 for the CMG-40 stations. North direction of all the stations was placed parallel to the longitudinal structural direction of the building towards the Thermaikos gulf. Figure 3 shows the location, the distances and the names of all the stations installed during the first day of the AHEPA experiment. Table 1 summarizes the location and ID numbers of the used instrumentation.

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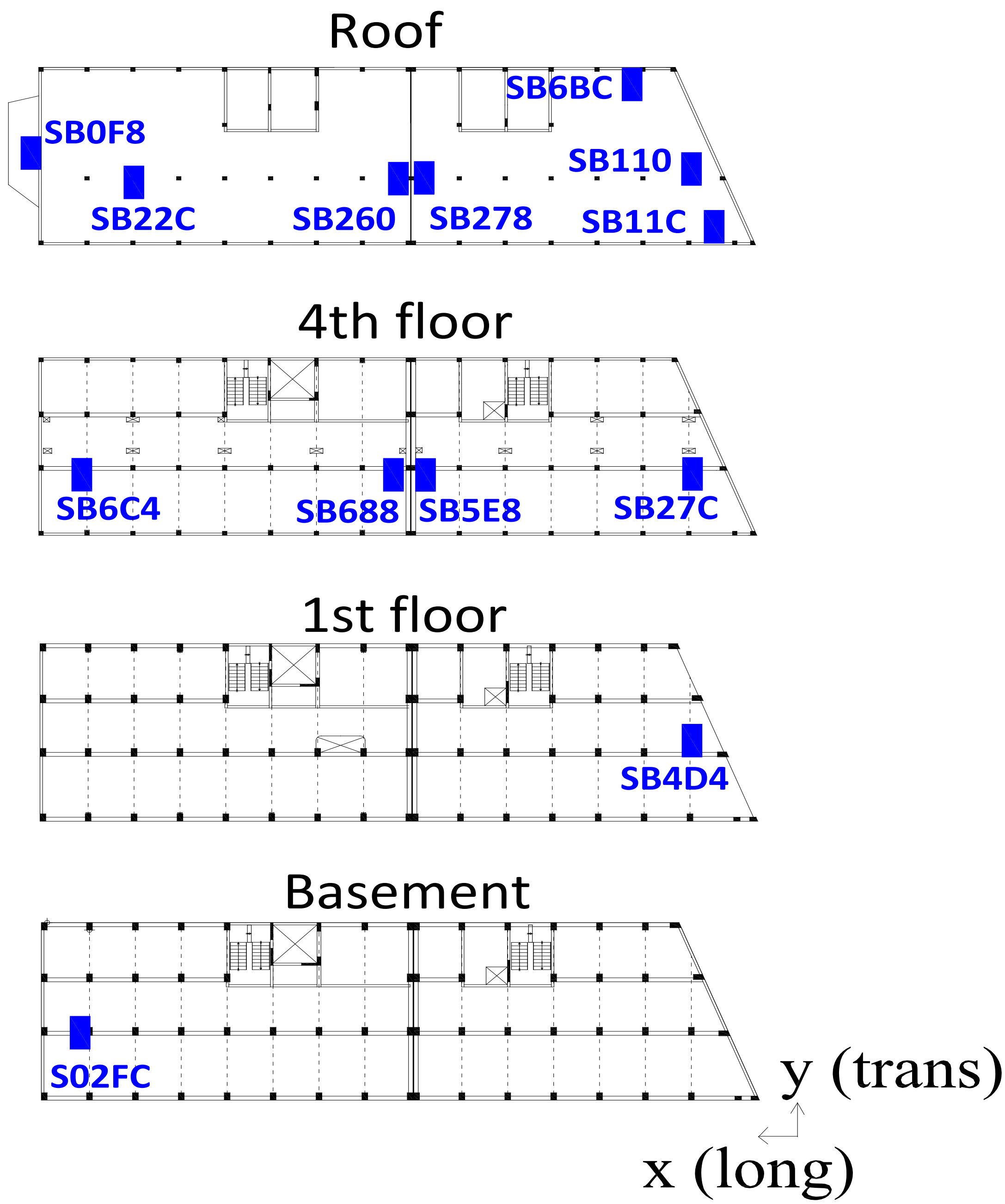

Fig. 2. The permanent accelerometer SOSEWIN network, working on a continuous basis in AHEPA hospital since May 2012.

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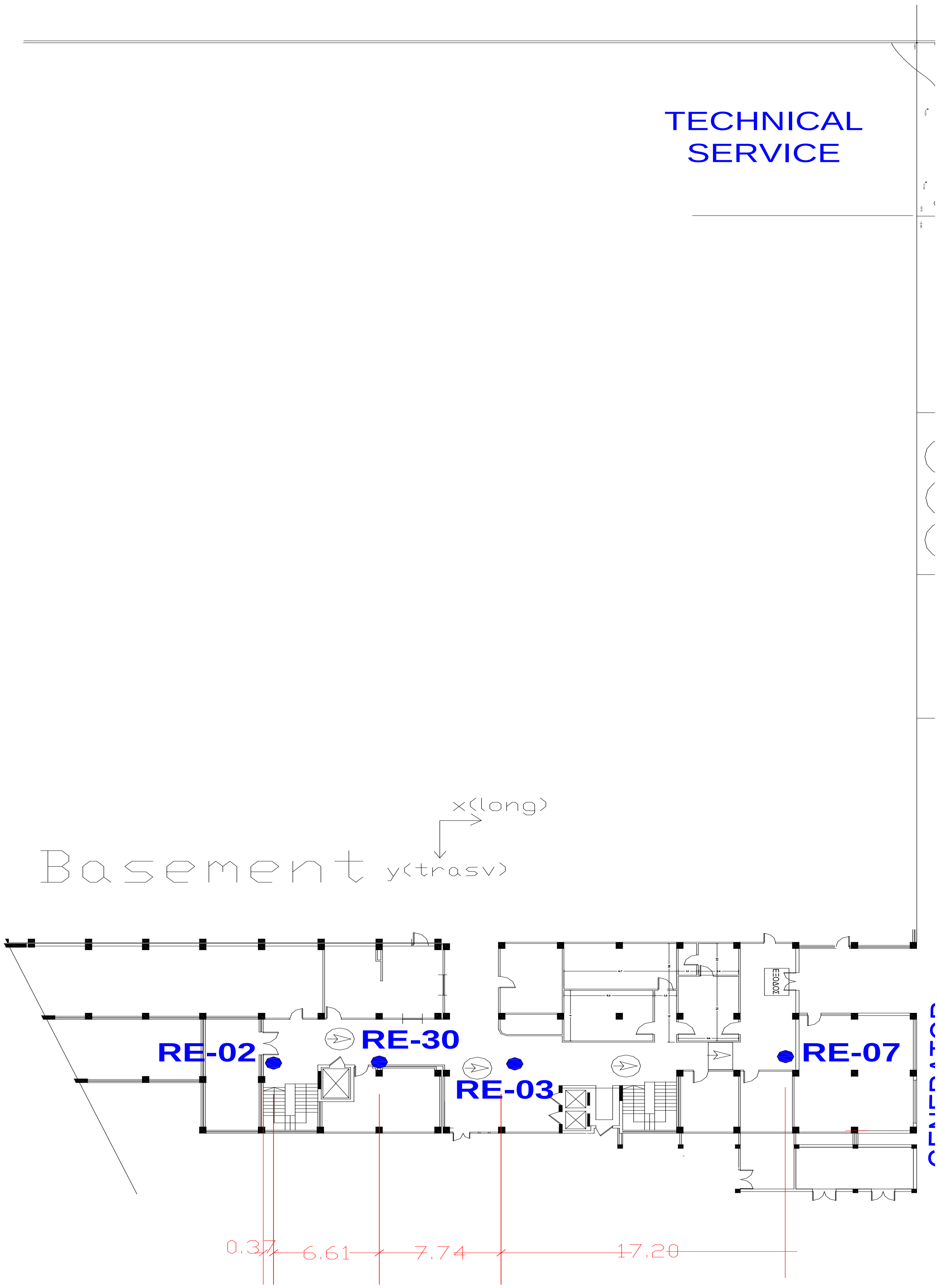

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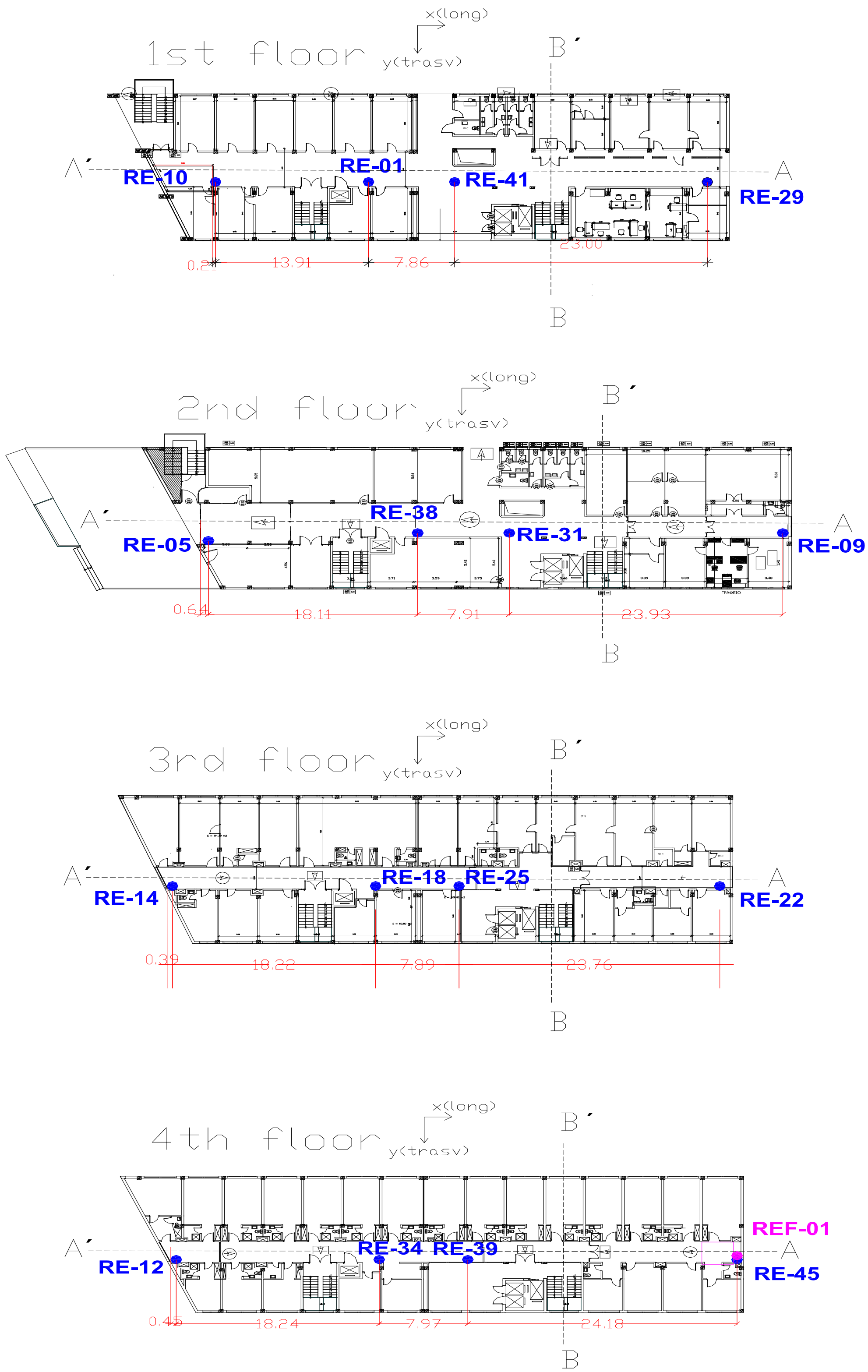

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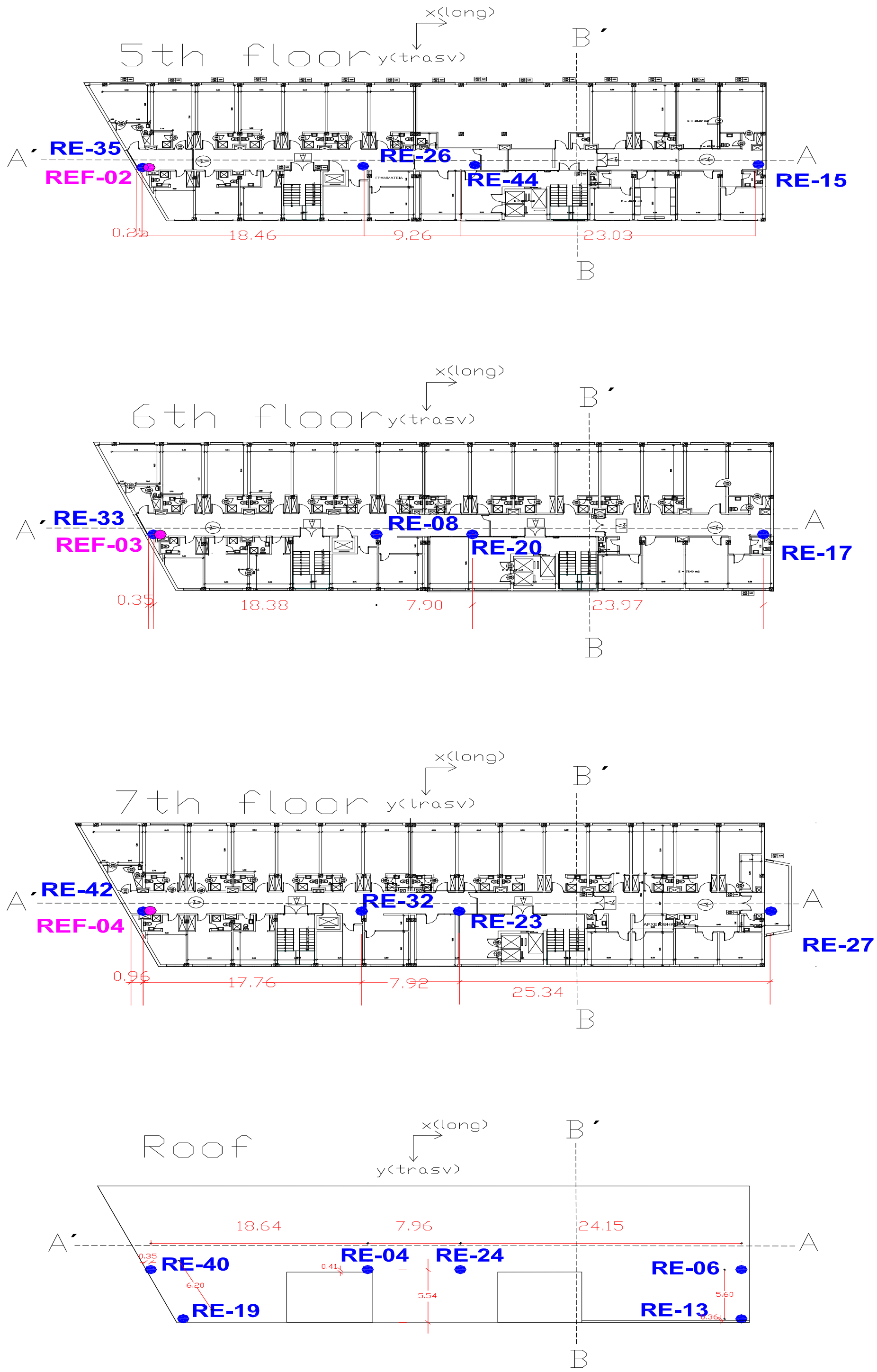

Fig. 3. View plan of all the floors with the instrumentation deployed during the first day of the AHEPA experiment (February 12th, 2013).

During the second experimental day (February 13th, 2013), the AHEPA hospital was equipped with 51 stations, 44 L4C-3D/EDL and 7 CMG-40/DAS-130. The number of stations per floor was increased relative to the first monitoring day. Two stations, one L4C-3D and one CMG-40 were installed on the field, outside the building, as reference

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points. Figure 4 shows the location and distances (in m) between the stations deployed in that experiment. Ambient noise was recorded simultaneously by all stations for about 4 hours with sampling rate 500 samples per second and gain 10 as pre-amplifier for the L4C-3D, and gain 1 for the CMG-40 stations. North direction of all the instruments was placed parallel to the longitudinal structural direction of the building towards the Thermaikos Gulf. Figure 4 shows the location, distances and names of the stations installed during the second day of the AHEPA experiment, while their ID numbers summarized in Table 2.

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Table 1. Position and station information of the February 12th, 2013, AHEPA experiment.

Station name	Location/Unit	Sensor ID	Recorder ID	Sensor type
RE-03	Basement/Unit I	E3-3055	MS-1008	L4C-3D / 1Hz
RE-07	Basement/Unit I	E3-3081	MS-1014	L4C-3D / 1Hz
RE-02	Basement/Unit II	E3-3054	MS-1007	L4C-3D / 1Hz
RE-30	Basement/Unit II	E3-3186	MS-2829	L4C-3D / 1Hz
RE-41	1st floor/Unit I	E3-3198	MS-3047	L4C-3D / 1Hz
RE-29	1st floor/Unit I	E3-3185	MS-2828	L4C-3D / 1Hz
RE-10	1st floor/Unit II	E3-3127	MS-1019	L4C-3D / 1Hz
RE-01	1st floor/Unit II	E3-3053	MS-1006	L4C-3D / 1Hz
RE-31	2nd floor/Unit I	E3-3187	MS-2830	L4C-3D / 1Hz
RE-09	2nd floor/Unit I	E3-3123	MS-1018	L4C-3D / 1Hz
RE-05	2nd floor/Unit II	E3-3057	MS-1012	L4C-3D / 1Hz
RE-38	2nd floor/Unit II	E3-3195	MS-3043	L4C-3D / 1Hz
RE-25	3rd floor/Unit I	E3-3176	MS-1899	L4C-3D / 1Hz
RE-22	3rd floor/Unit I	E3-3172	MS-1888	L4C-3D / 1Hz
RE-14	3rd floor/Unit II	E3-3163	MS-1191	L4C-3D / 1Hz
RE-18	3rd floor/Unit II	E3-3168	MS-1346	L4C-3D / 1Hz
RE-39	4th floor/Unit I	E3-3196	MS-3045	L4C-3D / 1Hz
RE-45	4th floor/Unit I	E3-3202	MS-3052	L4C-3D / 1Hz
REF-01	4th floor/Unit I	T4D50	985F	CMG-40 / 30s
RE-12	4th floor/Unit II	E3-3161	MS-1170	L4C-3D / 1Hz
RE-34	4th floor/Unit II	E3-3191	MS-2859	L4C-3D / 1Hz
RE-44	5th floor/Unit I	E3-3201	MS-3050	L4C-3D / 1Hz
RE-15	5th floor/Unit I	E3-3164	MS-1330	L4C-3D / 1Hz
RE-35	5th floor/Unit II	E3-3192	MS-2861	L4C-3D / 1Hz
RE-26	5th floor/Unit II	E3-3181	MS-1901	L4C-3D / 1Hz
REF-02	5th floor/Unit II	T4K20	9858	CMG-40 / 30s
RE-20	6th floor/Unit I	E3-3170	MS-1356a	L4C-3D / 1Hz
RE-17	6th floor/Unit I	E3-3167	MS-1340	L4C-3D / 1Hz
RE-33	6th floor/Unit II	E3-3190	MS-2858	L4C-3D / 1Hz
RE-08	6th floor/Unit II	E3-3103	MS-1015	L4C-3D / 1Hz
REF-03	6th floor/Unit II	T4D78	9085	CMG-40 / 30s
RE-23	7th floor/Unit I	E3-3173	MS-1892	L4C-3D / 1Hz
RE-27	7th floor/Unit I	E3-3182	MS-1904	L4C-3D / 1Hz
RE-42	7th floor/Unit II	E3-3199	MS-3048	L4C-3D / 1Hz
RE-32	7th floor/Unit II	E3-3188	MS-2832	L4C-3D / 1Hz
REF-04	7th floor/Unit II	T4D49	908E	CMG-40 / 30s
RE-24	Roof/Unit I	E3-3174	MS-1895	L4C-3D / 1Hz
RE-06	Roof/Unit I	E3-3064	MS-1013	L4C-3D / 1Hz
RE-13	Roof/Unit I	E3-3162	MS-1173	L4C-3D / 1Hz
RE-40	Roof/Unit II	E3-3197	MS-3046	L4C-3D / 1Hz
RE-04	Roof/Unit II	E3-3056	MS-1009	L4C-3D / 1Hz
RE-19	Roof/Unit II	E3-3169	MS-1351	L4C-3D / 1Hz
RE-16	Reference point	E3-3166	MS-1332a	L4C-3D / 1Hz

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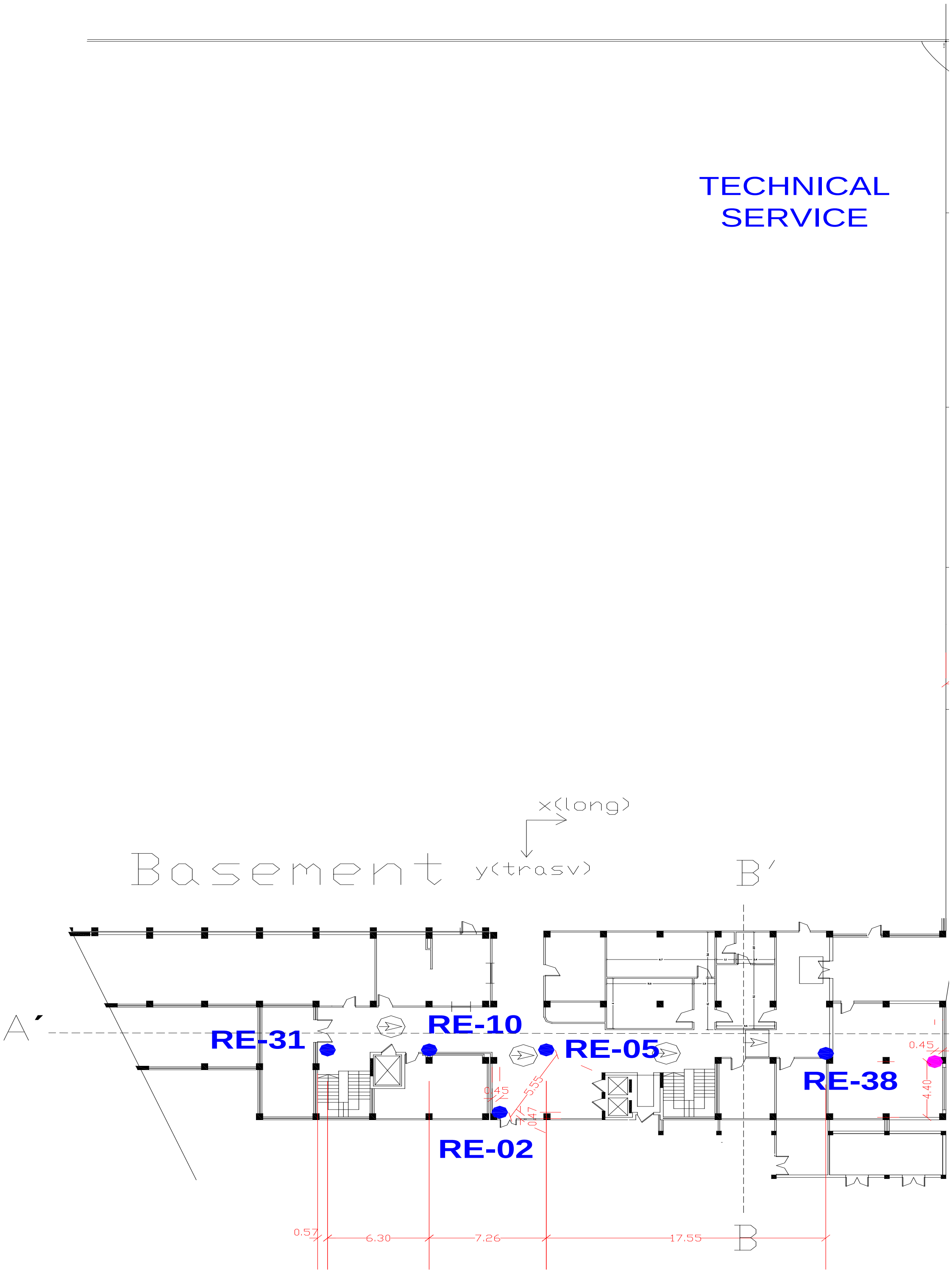

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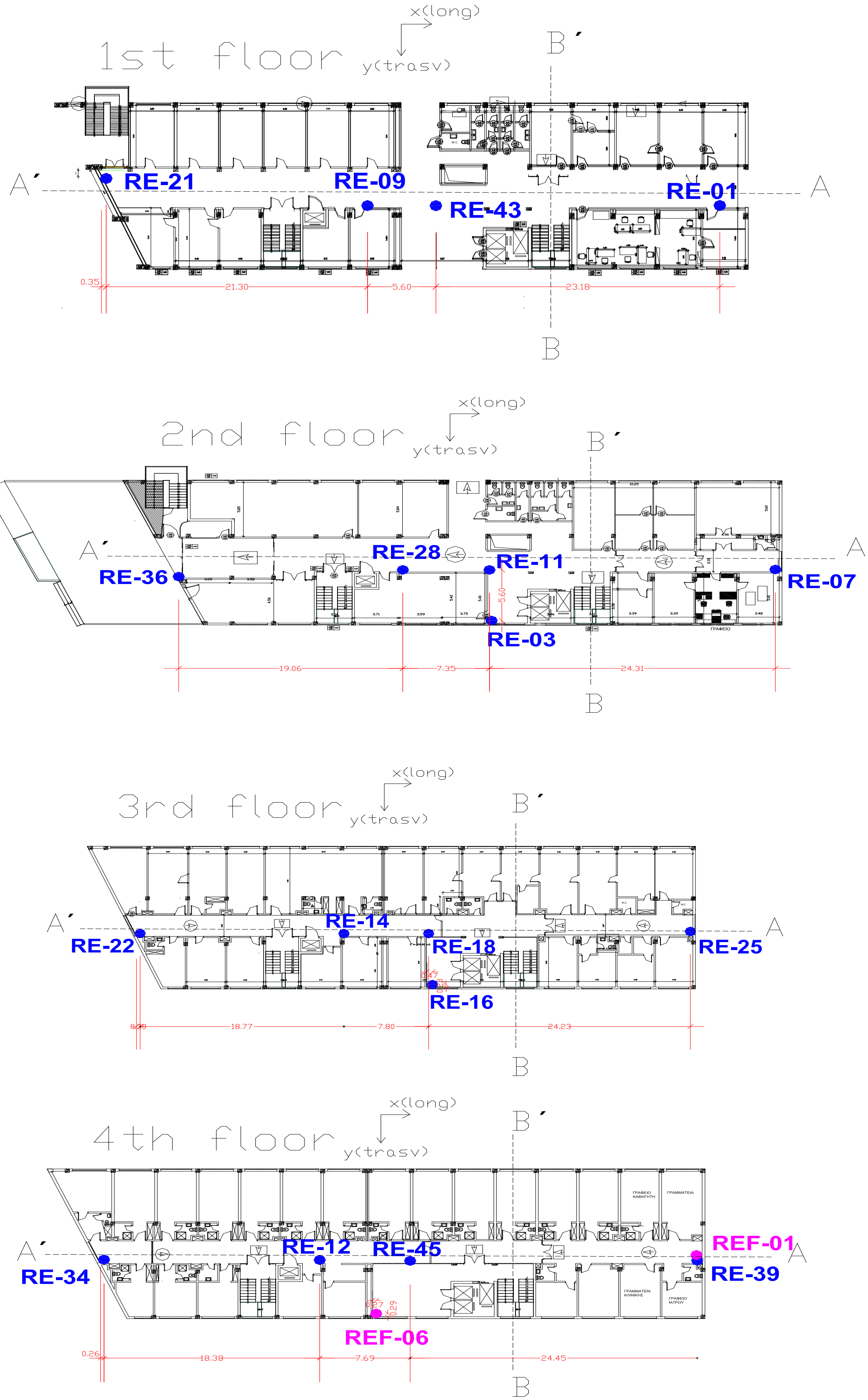

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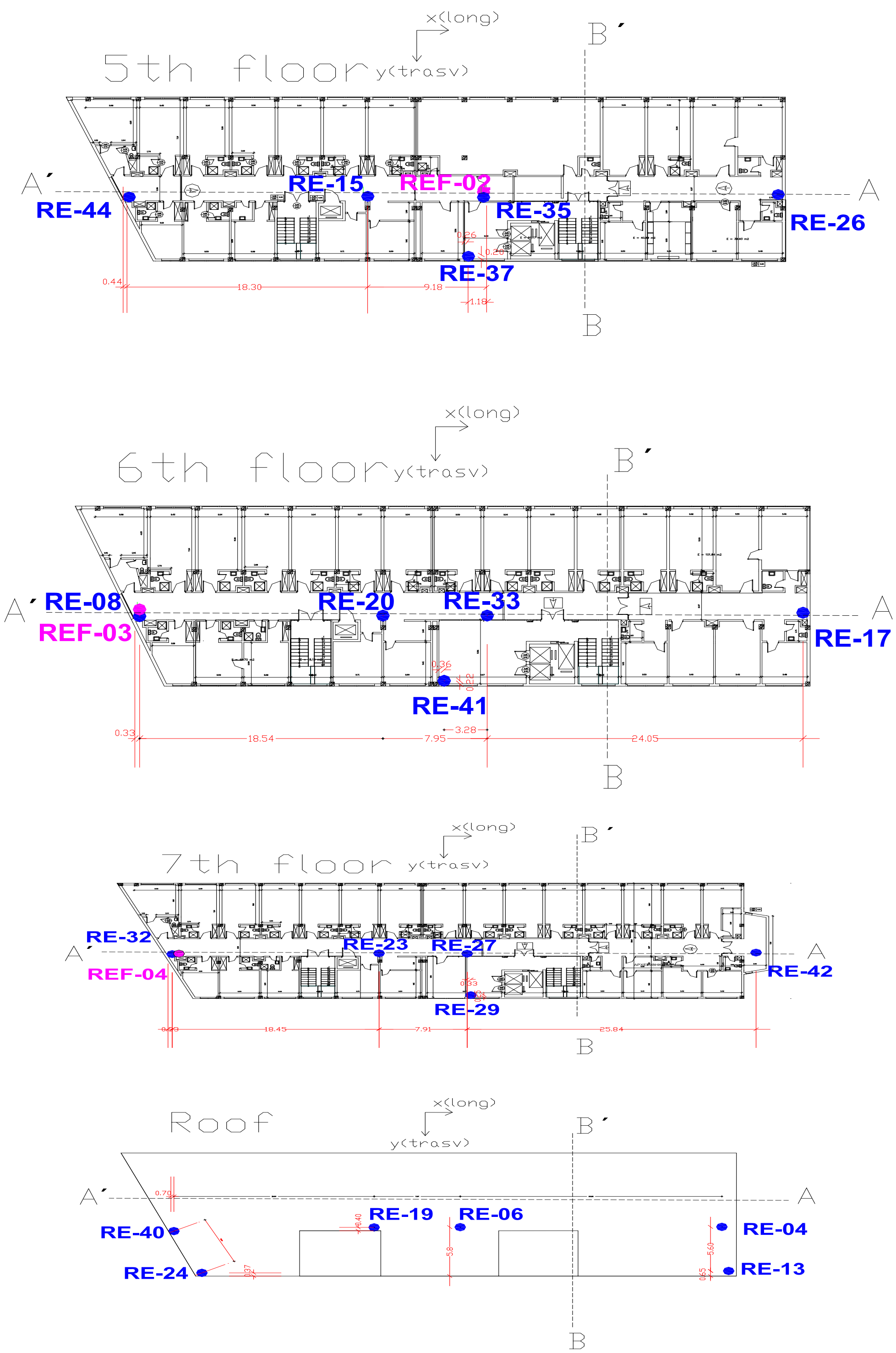

Fig. 4. View plan of all the floors with the instrumentation deployed during the second day of the AHEPA experiment (February 13th, 2013).

Table 2. Position and station information of the February 13th, 2013 AHEPA experiment.

Station name	Location/Unit	Sensor ID	Recorder ID	Sensor type

DOI: 10.2312/GFZ.b103-17103

RE-05	Basement/Unit I	E3-3057	MS-1012	L4C-3D / 1Hz
RE-38	Basement/Unit I	E3-3195	MS-3043	L4C-3D / 1Hz
REF-05	Basement/Unit I	T4K21	9084	CMG-40 / 30s
RE-02	Basement/Unit I-II	E3-3054	MS-1007	L4C-3D / 1Hz
RE-31	Basement/Unit II	E3-3187	MS-2830	L4C-3D / 1Hz
RE-10	Basement/Unit II	E3-3127	MS-1019	L4C-3D / 1Hz
RE-43	1st floor/Unit I	E3-3200	MS-3049	L4C-3D / 1Hz
RE-01	1st floor/Unit I	E3-3053	MS-1006	L4C-3D / 1Hz
RE-21	1st floor/Unit II	E3-3171	MS-1827	L4C-3D / 1Hz
RE-09	1st floor/Unit II	E3-3123	MS-1018	L4C-3D / 1Hz
RE-03	2nd floor/Unit I-II	E3-3055	MS-1008	L4C-3D / 1Hz
RE-11	2nd floor/Unit I	E3-3160	MS-1168	L4C-3D / 1Hz
RE-07	2nd floor/Unit I	E3-3081	MS-1014	L4C-3D / 1Hz
RE-36	2nd floor/Unit II	E3-3193	MS-3036	L4C-3D / 1Hz
RE-28	2nd floor/Unit II	E3-3183	MS-1905	L4C-3D / 1Hz
RE-18	3rd floor/Unit I	E3-3168	MS-1346	L4C-3D / 1Hz
RE-25	3rd floor/Unit I	E3-3176	MS-1899	L4C-3D / 1Hz
RE-16	3rd floor/Unit I-II	E3-3166	MS-1332a	L4C-3D / 1Hz
RE-14	3rd floor/Unit II	E3-3163	MS-1191	L4C-3D / 1Hz
RE-22	3rd floor/Unit II	E3-3172	MS-1888	L4C-3D / 1Hz
RE-45	4th floor/Unit I	E3-3202	MS-3052	L4C-3D / 1Hz
RE-39	4th floor/Unit I	E3-3196	MS-3045	L4C-3D / 1Hz
REF-01	4th floor/Unit I	T4D50	985F	CMG-40 / 30s
REF-06	4th floor/Unit I-II	T4K19	9086	CMG-40 / 30s
RE-12	4th floor/Unit II	E3-3161	MS-1170	L4C-3D / 1Hz
RE-34	4th floor/Unit II	E3-3191	MS-2859	L4C-3D / 1Hz
RE-35	5th floor/Unit I	E3-3192	MS-2861	L4C-3D / 1Hz
RE-26	5th floor/Unit I	E3-3181	MS-1901	L4C-3D / 1Hz
REF-02	5th floor/Unit I	T4K20	9858	CMG-40 / 30s
RE-37	5th floor/Unit II	E3-3194	MS-3040	L4C-3D / 1Hz
RE-15	5th floor/Unit II	E3-3164	MS-1330	L4C-3D / 1Hz
RE-44	5th floor/Unit II	E3-3201	MS-3050	L4C-3D / 1Hz
RE-33	6th floor/Unit I	E3-3190	MS-2858	L4C-3D / 1Hz
RE-17	6th floor/Unit I	E3-3167	MS-1340	L4C-3D / 1Hz
RE-41	6th floor/Unit I-II	E3-3198	MS-3047	L4C-3D / 1Hz
RE-08	6th floor/Unit II	E3-3103	MS-1016	L4C-3D / 1Hz
RE-20	6th floor/Unit II	E3-3170	MS-1356a	L4C-3D / 1Hz
REF-03	6th floor/Unit II	T4D78	9085	CMG-40 / 30s
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RE-32	7th floor/Unit II	E3-3188	MS-2832	L4C-3D / 1Hz
RE-23	7th floor/Unit II	E3-3173	MS-1892	L4C-3D / 1Hz
REF-04	7th floor/Unit II	T4D49	908E	CMG-40 / 30s
RE-06	Roof/Unit I	E3-3064	MS-1013	L4C-3D / 1Hz

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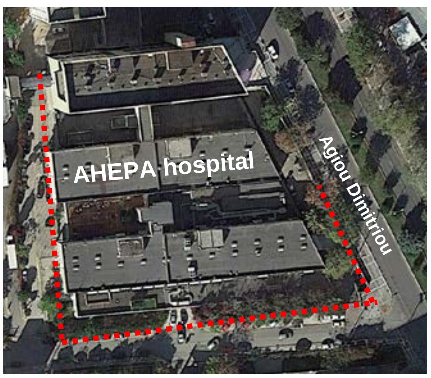
RE-04	Roof/Unit I	E3-3056	MS-1009	L4C-3D / 1Hz
RE-13	Roof/Unit I	E3-3162	MS-1173	L4C-3D / 1Hz
RE-40	Roof/Unit II	E3-3197	MS-3046	L4C-3D / 1Hz
RE-19	Roof/Unit II	E3-3169	MS-1351	L4C-3D / 1Hz
RE-24	Roof/Unit II	E3-3174	MS-1895	L4C-3D / 1Hz
RE-30	Reference point	E3-3186	MS-2829	L4C-3D / 1Hz
REF-07	Reference point	T4D47	9853	CMG-40 / 30s

2.2 Soil Structure Interaction experiment outside of the AHEPA hospital

2.2.1 Experiment design and instrumentation

Two days after the AHEPA building monitoring, a field experiment was conducted outside of the hospital. Ambient noise was recorded simultaneously to 11 short-period L4C-3D and 6 broad-band CMG-40 seismometers. The 17 stations were installed on soil or asphalt along the three sides of the building (Fig 5). The sampling rate and the gain of the stations remain the same as for the AHEPA experiment. North direction of the stations was placed parallel to the longitudinal structural direction of the hospital. The location, distances and codes of the stations installed in the SSI experiment are shown in Figure 5, while their ID numbers summarized in Table 3.



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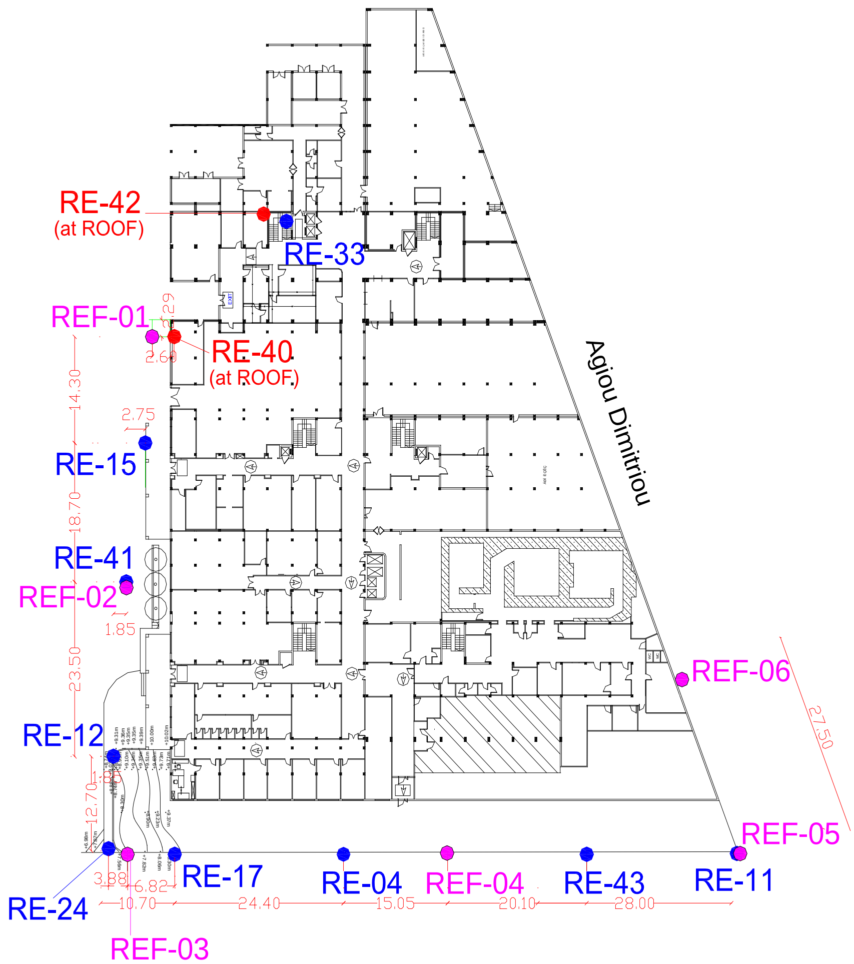

Fig. 5. Plan view of the SSI experiment conducted outside of the AHEPA hospital (February 15th, 2013).

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Table 3. Information of the stations deployed during the SSI experiment (February 15th, 2013).

Station name	Sensor ID	Recorder ID	Sensor type
RE-33	E3-3190	MS-2858	L4C-3D / 1Hz
RE-42	E3-3199	MS-3048	L4C-3D / 1Hz
RE-40	E3-3197	MS-3046	L4C-3D / 1Hz
REF-01	T4D49	9084	CMG-40 / 30s
RE-15	E3-3164	MS-1330	L4C-3D / 1Hz
RE-41	E3-3198	MS-3047	L4C-3D / 1Hz
REF-02	T4K20	9086	CMG-40 / 30s
RE-12	E3-3161	MS-1170	L4C-3D / 1Hz
RE-24	E3-3174	MS-1895	L4C-3D / 1Hz
REF-03	T4D78	985F	CMG-40 / 30s
RE-17	E3-3167	MS-1340	L4C-3D / 1Hz
RE-04	E3-3056	MS-1009	L4C-3D / 1Hz
REF-04	T4K21	9853	CMG-40 / 30s
RE-43	E3-3200	MS-3049	L4C-3D / 1Hz
RE-11	E3-3160	MS-1168	L4C-3D / 1Hz
REF-05	T4D50	9858	CMG-40 / 30s
REF-06	T4K19	9085	CMG-40 / 30s

2.3 Ambient noise measurements in Volvi basin

2.3.1 Site Description

In addition to AHEPA and SSI experiments, an array of seismometers was deployed on March 20th and 21st, 2013 at two selected sites within the Volvi sedimentary basin. Volvi basin is a typical tectonic basin trending E-NW, located 30km ENE of the city of Thessaloniki, in Northern Greece. It is the epicentral area of the June 20th 1978, M6.4 earthquake and the location of the permanent EUROSEISTEST accelerometer network (http://euroseisdb.civil.auth.gr/) which working on a continuous basis since 1993. The subsoil structure of the basin has been studied a lot by using many different geophysical methods (Jongmans et al. 1998; Raptakis et al. 2000; Raptakis et al. 2005; Manakou et al. 2010). Two sites within the basin were selected to investigate using the instrumentation from GIPP. The first site is located at the western part of the basin where the sediments are quite thick, around 500m, (BRGM-array, in Fig. 6), and the second site is located at the southwestern part of the basin (GER-array, in Fig.6), where the seismic fault related to 1978 earthquake has surface appearance. The definition of the Vs structure below the investigated sites will be used to verify the available geological information and it will be incorporated to the extension of the available 3D model (Manakou et al. 2010) towards the southwestern part of the basin.

2.3.2 Experiment design and instrumentation

At GER-array 20 seismic stations were deployed in three clusters of 6-7 stations each; cluster A, B and C (Fig. 7). In total, 13 short-period L4C-3D seismometers connected to EDL recorders and 7 broadband CMG-40 connected to DAS-130 digitizers were deployed. Broadband sensors were distributed among clusters A, B and C for recording possibly large period wavelengths. The topography of the area covered by the three clusters is steep and the elevation is ranging from 220m (stations of cluster A) to 145m

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(stations of cluster C) above sea level. All the stations were installed on the Promygdonian sedimentary system which outcrops at this part of the basin and deepens to 100-120m depth below BRGM-array. The interstation distances between the stations of the array are ranging between 20m to 2.2km, meaning different recording wavelengths. Table 4 summarizes the location and station information of the three clusters in GER-array. Ambient noise was recorded simultaneously to all stations for few hours, with 200 Hz sampling rate and gain 1 for both types of sensors. All of them were oriented towards the geographic North with a compass.

In BRGM-array, 5 short-period L4C-3D and 6 broadband CMG-40 seismometers were installed in an almost circular area with diameter of about 800m (Fig. 8). All the stations were installed on the Mygdonian sedimentary system of the basin. Their interstation distances ranging between 20 and 800m. Ambient noise was recorded simultaneously to all stations for few hours, with 200 Hz sampling rate and gain 1 for both types of seismometers. All of them were oriented towards the geographic North with a compass. Table 5 summarizes the station information of the BRGM-array.

Fig. 6. Google Earth map showing the location of the two investigated sites in Volvi basin, the BRGM and GER-arrays.

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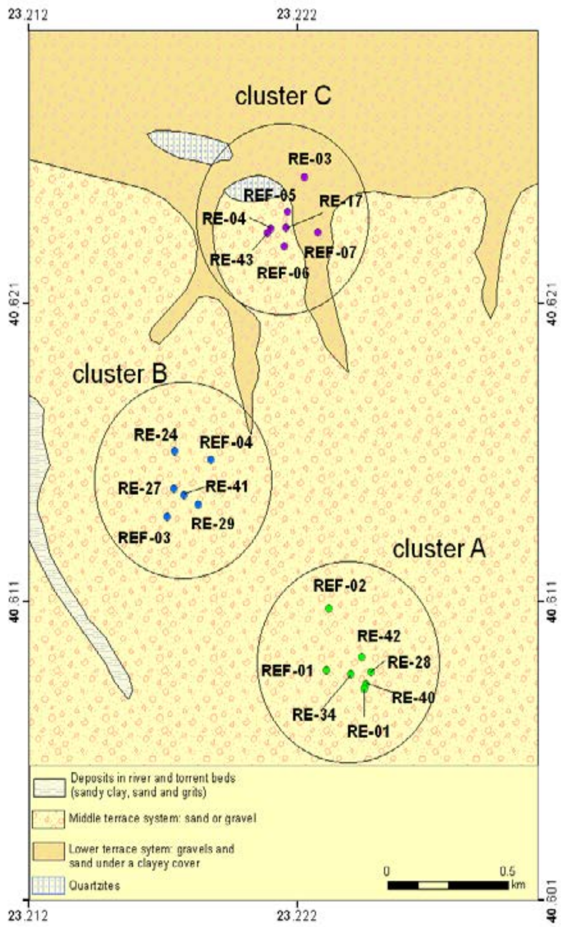

Fig. 7. Map with the station configuration of the clusters A, B and C of the GER-array.

Table 4. Station information for the three clusters A, B and C deployed in GER-array.

Station name	Station coordinates	Sensor ID	Recorder ID	Sensor type
		Cluster A		
RE-40	40.60845ºN, 23.22438ºE	E3-3197	MS-3046	L4C-3D / 1Hz
RE-01	40.60829ºN, 23.22432ºE	E3-3053	MS-1006	L4C-3D / 1Hz
RE-28	40.60886ºN, 23.22456ºE	E3-3183	MS-1905	L4C-3D / 1Hz
RE-34	40.60880ºN, 23.22381ºE	E3-3191	MS-2859	L4C-3D / 1Hz
RE-42	40.60934ºN, 23.22422ºE	E3-3199	MS-3084	L4C-3D / 1Hz
T4K21	40.62359ºN, 23.22258ºE	T4K21	9084	CMG-40 / 30s
T4D78	40.61098ºN, 23.22299ºE	T4D78	9085	CMG-40 / 30s
		Cluster B		
RE-41	40.61479ºN, 23.21760ºE	E3-3198	MS-3047	L4C-3D / 1Hz
RE-27	40.61501ºN, 23.21722ºE	E3-3182	MS-1904	L4C-3D / 1Hz
RE-29	40.61447ºN, 23.21814ºE	E3-3185	MS-2828	L4C-3D / 1Hz
T4K19	40.61407ºN, 23.21696ºE	T4K19	9086	CMG-40 / 30s
T4D50	40.61598ºN, 23.21861ºE	T4D50	908E	CMG-40 / 30s
RE-24	40.61625ºN, 23.21726ºE	E3-3174	MS-1895	L4C-3D / 1Hz
		Cluster C		
T4D49	40.62428ºN, 23.22146ºE	T4D49	9858	CMG-40 / 30s
RE-17	40.62375ºN, 23.22140ºE	E3-3167	MS-1340	L4C-3D / 1Hz
RE-04	40.62373ºN, 23.22082ºE	E3-3056	MS-1009	L4C-3D / 1Hz
RE-43	40.62355ºN, 23.22072ºE	E3-3200	MS-3049	L4C-3D / 1Hz
T4D47	40.62313ºN, 23.22132ºE	T4D47	908E	CMG-40 / 30s
T4K20	40.62359ºN, 23.22258ºE	T4K20	985F	CMG-40 / 30s
RE-03	40.62543ºN, 23.22208ºE	E3-3055	MS-1008	L4C-3D / 1Hz

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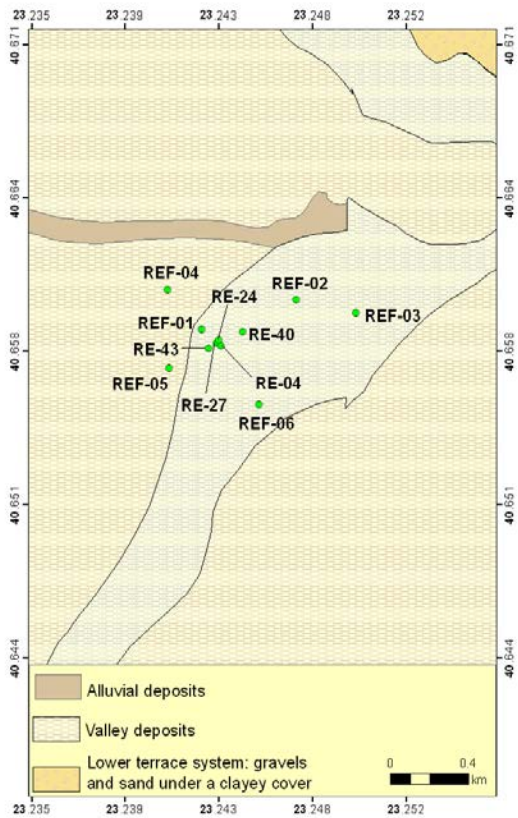

Fig. 8. Map with the station configuration of the BRGM-array.

Table 5. Station information for the instruments deployed in BRGM-array.

Station name	Station coordinates	Sensor ID	Recorder ID	Sensor type
RE-27	40.65791ºN, 23.24325ºE	E3-3182	MS-1904	L4C-3D / 1Hz
RE-24	40.65806ºN, 23.24336ºE	E3-3174	MS-1895	L4C-3D / 1Hz
RE-04	40.65782ºN, 23.24348ºE	E3-3056	MS-1009	L4C-3D / 1Hz
RE-43	40.65769ºN, 23.24290ºE	E3-3200	MS-3049	L4C-3D / 1Hz
REF-01	40.65854ºN, 23.24260ºE	T4K20	9086	CMG-40 / 30s
RE-40	40.65840ºN, 23.24447ºE	E3-3197	MS-3046	L4C-3D / 1Hz
REF-02	40.65981ºN, 23.24694ºE	T4D49	9853	CMG-40 / 30s
REF-03	40.65924ºN, 23.24968ºE	T4K19	985F	CMG-40 / 30s
REF-04	40.66023ºN, 23.24100ºE	T4D50	9085	CMG-40 / 30s
REF-05	40.65686ºN, 23.24109ºE	T4D78	9858	CMG-40 / 30s
REF-06	40.65528ºN, 23.24524ºE	T4K21	908E	CMG-40 / 30s

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3. Instrument Properties

The broad-band CMG-40 seismometers with ID numbers T4D47, T4D49 T4D50 and T4D78 were 1-second/100Hz instruments and changed after request to Guralp, to 30s/50Hz 40Ts. The broad-band seismometers with ID numbers T4K19, T4K20 and T4K21 sensors are standard 40Ts (i.e. 30s natural period). The difference of the sensitivity values of the above two groups of the CMG-40 units are reported in Table 6. For the L4C-3D/EDL stations, the settings such as gain and A-D conversion factor are the same, while sensitivity, normalization factor and poles and zeros values are average values. For exact values, please contact GIPP staff. Both types of stations recorded 3 components (vertical, N-S and E-W). The channel order for all of them is as follows 1: Vertical component, 2: N-S component, 3: E-W component.

Table 6. Sensor and recorder properties for the short-period and broadband seismometers used in AHEPA, SSI and Volvi experiments.

Sensor	Logger gain	A-D conversion	Sensitivity V/(m/s)	Normalization factor @1Hz	Poles (rad/s)	Zeros (rad/s)
L4C-3D (Mark Products)						
L4C-3D	10	0.244	170	1.414	-4.443 ± 4.443i	0.0, 0.0
CMG-40 (Guralp)						
T4K19	1	0.244	V: 2X393 NS: 2X401 EW: 2X405	-0.314	$-23.56 \times 10^{-3} \pm j\ 23.56 \times 10^{-3}$, -180, -160, -80	0.0, 0.0
T4K20	1	0.244	V: 2X399 NS: 2X401 EW: 2X410	-0.314	$-23.56 \times 10^{-3} \pm j\ 23.56 \times 10^{-3}$, -180, -160, -80	0.0, 0.0
T4K21	1	0.244	V: 2X398 NS: 2X404 EW: 2X412	-0.314	$-23.56 \times 10^{-3} \pm j\ 23.56 \times 10^{-3}$, -180, -160, -80	0.0, 0.0
T4D47	1	0.244	V: 2X995 NS: 2X993 EW:2X1004	-0.314	$-23.56 \times 10^{-3} \pm j\ 23.56 \times 10^{-3}$, -50, 159	0.0, 0.0
T4D49	1	0.244	V: 2X984 NS: 2X989 EW: 2X971	-0.314	$-23.56 \times 10^{-3} \pm j\ 23.56 \times 10^{-3}$, -50, 159	0.0, 0.0
T4D50	1	0.244	V: 2X990 NS: 2X984 EW: 2X989	-0.314	$-23.56 \times 10^{-3} \pm j\ 23.56 \times 10^{-3}$, -50, 159	0.0, 0.0
T4D78	1	0.244	V: 2X981 NS: 2X984 EW: 2X1002	-0.314	$-23.56 \times 10^{-3} \pm j\ 23.56 \times 10^{-3}$, -50, 159	0.0, 0.0

* NOTE for the CMG-40 sensors: A factor of 2x must be used when the sensor outputs are used differentially (also known as push-pull or balanced output).
* NOTE for the EDL recorders: The sensitivity value for gain 10 is $1*10^7$ Counts/Volt.
* NOTE for the DAS-130 recorders: The true bit weight for gain 1 is 104.2mV/count.

4. Data Availability/Access

Data is archived at the *GIPP Experiment and Data Archive* where it will be freely available for further use under a "Creative Commons Attribution-ShareAlike 4.0 International License" (CC BY-SA 4.0).

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When using the data, please cite the REAKT datasets, and acknowledge the use of GIPP instruments. You can additionally cite this Scientific Technical Report STR, especially if referring to particular details explained therein.

Recommended citation for data described in this publication:

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5. Data Description

The digital data from the L4C-3D/EDL stations used in AHEPA and SSI experiments have sampling rate of 500 samples per second and pre-amplifier gain 10. The same sampling rate (500 sps) was used for the CMG-40/DAS stations, with no pre-amplifier (gain 1). For the Volvi experiment, the sampling rate of both types of instruments (L4C-3D/EDL, CMG-40/DAS) was set to 200 samples per second with no pre-amplifier (gain 1). Available data of the three experiments is raw data, MSEED for the L4C-3D and RefTek format for the CMG-40 stations. The raw data of the CMG-40 stations is in units of Volts and counts for the L4C-3D stations. No filtering was applied due to the acquisition procedure and no processing was made to raw data.

4.1 Data Completeness

During the three experiments some station failures were faced. In cases their maintenance was not possible the problematic stations were replaced with other available stations.

4.2 File Format

Data from the L4C-3D/EDL stations is in MSEED, while for the CMG-40/DAS stations in RefTek format. The REF type format can be easily converted to MSEED, SEG-Y, SAC or ASCII by using PASSCAL package utilities available from the PASSCAL instrument center (http://www.passcal.nmt.edu/content/software-resources).

4.3 Data Content and Structure

❖ The data from the AHEPA building monitoring for both sensor types is archived in the folder *AHEPA-experiment*. The folder contains subfolders with the name of the stations used during the two-day AHEPA experiment. The name of these subfolders for the L4C-3D/EDL stations is as follows: *RE-XX_E3-YYYY_MS-ZZZZ*, where RE-XX is the station name, E3-YYYY is the sensor ID, and MS-ZZZZ is the recorder ID. The subfolders name for the CMG-40/DAS stations is as follows: *REF-XX_T4XXX_YYYY*, where REF-XX is the station name, T4XXX is the sensor ID and YYYY is the digitizer ID.

- Each of the *RE-XX_E3-YYYY_MS-ZZZZ* folders contains the raw MSEED data file of the three components of the corresponding RE-XX station into two subfolders named according to the date of the experiment, in Julian calendar format (i.e. *043*: for the February 12th, 2013 and *044*: for the February 13th, 2013 experiment). The format of the raw data files included in these subfolders is as follows: eYYYYDDMMTTTTTTTT, where eYYYY: is the sensor ID, DD: day of the experiment, MM: month of the experiment, TTTTTTTT: acquisition start-time number in hour, minutes, seconds and milliseconds. In case of a station malfunction, the sensor ID (eYYYY) is replaced with EDATA. Generally, each data file contains 24h length data (in UTC). In case of time gaps during the acquisition process, there maybe multiple files with later starting times. The files with the extension *.pri0 corresponds to vertical component, the files with the extension *.pri1 to N-S component and the files with the extension *.pri2 to E-W component. Information for the recorder, the GPS status, and the coordinates of the corresponding station are also reported in each of the *RE-XX_E3-YYYY_MS-ZZZZ* folders.
- Each of the *REF-XX_T4XXX_YYYY* folders contains two subdirectories. The *DATA* subdirectory contains the raw RefTek data of the three components of the corresponding REF-XX station and the *0* subdirectory reports information about the recorder, the GPS status and the station coordinates. The raw RefTek data files of a specific station, namely as follows: HHMMSSMsMs_ZZZZZZZZ where HH: is the acquisition start-time number in hour, MM: in minutes, SS: in seconds and MsMS: in milliseconds, and ZZZZZZZZ: is a code related to digitizer connected with the specific REF-XX seismometer. For the four stations used in both monitoring days of the AHEPA experiment (see Tables 1 & 2), the *DATA* subdirectory contains two RefTek data files; one corresponding to February 12th, 2013 and the other to February 13th, 2013 experimental day. Each data file contains the whole record length of the recording (in UTC). In case of a station malfunction, no data file appears at the *DATA* and *0* subdirectories of the problematic station.

❖ The data from the SSI experiment is archived in the folder *SSI-experiment*. It contains the records of both type of instruments used in that experiment. The name of the subfolders and the data files of the short-period and broadband seismometers follow the same coding as in *AHEPA-experiment*. The data files are included within a subfolder with name the date of the experiment, in Julian calendar format (i.e. *046*: for the February 16th, 2013).

❖ The data from the Volvi experiment is archived in the folder *Volvi-experiment*. It contains two subfolders with names the two arrays deployed in Volvi on March 20th and 21st, 2013, the GER-array and BRGM-array. The data from the three clusters A, B and C deployed in GER-array are included in the subfolder *079* (the date of the GER-array experiment according to Julian calendar). The data from the BRGM-array archived in the subfolder *080* (the date of the BRGM-array experiment according to Julian calendar). The data files from both types of stations deployed in both arrays archived into subfolders with coding similar to that used in *AHEPA-experiment*.

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