Chapter 37
System Identification and Structural Modelling of Italian School Buildings

Gerard O'Reilly, Ricardo Monteiro, Daniele Perrone, Igor Lanese, Matthew Fox, Alberto Pavese, and Andre Filiatrault

Abstract Extensive damage to school buildings has been observed during past earthquakes in Italy, with the 2002 Molise event resulting in the complete collapse of a school building leading to numerous casualties. As part of a wider project in Italy to assess the seismic risk in school structures, six school buildings of various construction typologies were surveyed and instrumented to validate detailed numerical models of typical school structures located throughout Italy.

Keywords System identification • Structural modelling • School buildings • Reinforced concrete • Masonry

Of the six school buildings considered as part of the aforementioned project, three were reinforced concrete frame building constructed before the introduction of seismic design codes in Italy in the 1970s. The first of these is a three-story frame situated in Ancona, which is along the Adriatic coast of Italy in the province of Marche and is shown in Fig. 37.1a. Similar to this is another three-story frame building located in Carrara, which is along the Mediterranean Sea side of Italy in the province of Tuscany and is illustrated in Fig. 37.1c. Finally, the third reinforced concrete frame school building is shown in Fig. 37.1e and located in Tito, which is in the southern region of Italy in the province of Basilicata, which consists of another three-story frame. In addition to reinforced concrete frame buildings, a number of masonry buildings were also included in the study, such as the two-story masonry building situated in Avola, Sicily and shown in Fig. 37.1f which was constructed in the 1930s. Similarly, Fig. 37.1b shows another school that consists of a two-story masonry school building constructed in 1960's. A third and final typology was also added to include a precast concrete school building constructed in 1987 in Cassino, Italy, as shown in Fig. 37.1d.

Several accelerometers were installed at various locations in each school building to record ambient vibrations. These instruments were used to identify the modal properties of the existing structures. Comparisons were made between the recorded modal properties, such as natural frequencies and mode shapes, and those predicted from eigenvalue analyses using advanced three-dimensional numerical modelling techniques developed to assess the structures under extreme seismic loading. Details of the instrumentation and numerical models will be discussed in the oral presentation. Table 37.1 compares the first three measured ambient vibration natural frequencies for each of the six buildings with those blindly predicted by

G. O'Reilly (✉) • R. Monteiro • D. Perrone
School for Advanced Studies IUSS Pavia, Palazzo del Broletto, Piazza della Vittoria n. 15, 27100, Pavia, Italy
e-mail: gerard.oreilly@iusspavia.it

I. Lanese
European Centre for Training and Research in Earthquake Engineering (EUCENTRE), Via Adolfo Ferrata, 1, 27100, Pavia, Italy

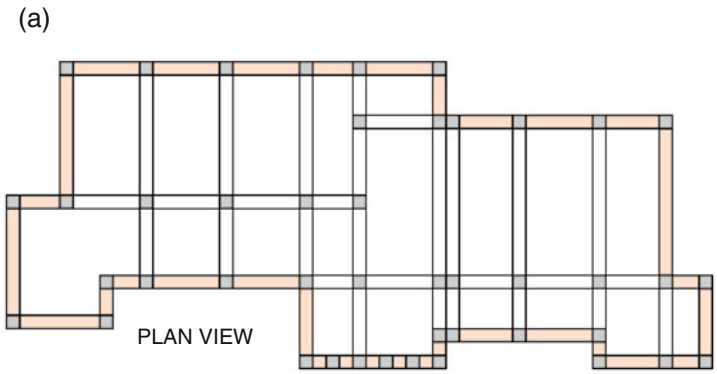
M. Fox
Beca Ltd, 410 Colombo Street, Sydenham, Christchurch 8023, New Zealand

A. Pavese
Department of Civil Engineering and Architecture, University of Pavia 27100, Pavia, Italy

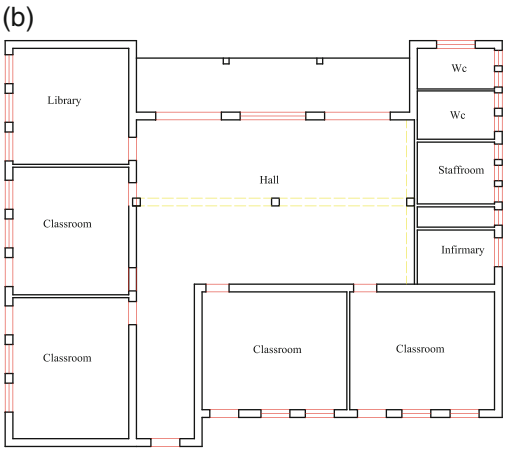
A. Filiatrault
School for Advanced Studies IUSS Pavia, Palazzo del Broletto, Piazza della Vittoria n. 15, 27100, Pavia, Italy

Department of Civil, Structural and Environmental Engineering, State University of New York at Buffalo, Buffalo, NY 14260, USA

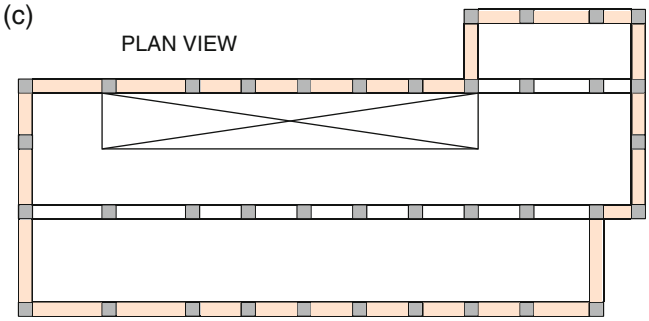
J. Caicedo, S. Pakzad (eds.), *Dynamics of Civil Structures, Volume 2*, Conference Proceedings
of the Society for Experimental Mechanics Series, DOI 10.1007/978-3-319-54777-0_37



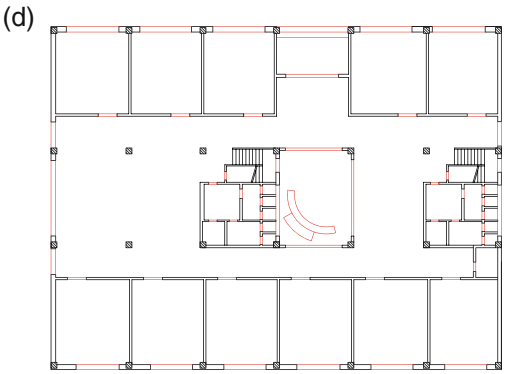
Scuola Elementare Carlo Antognini in Ancona, Italy



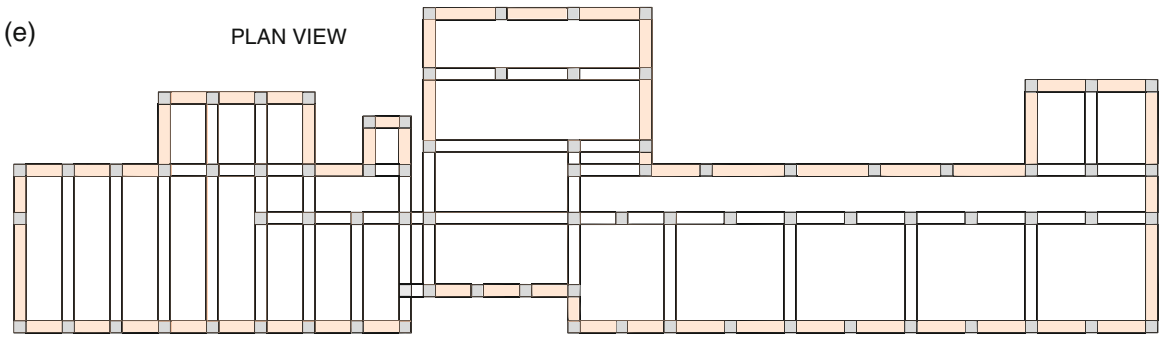
Scuola Elementare "Emiliano Rinaldini" Ghedi, Italy



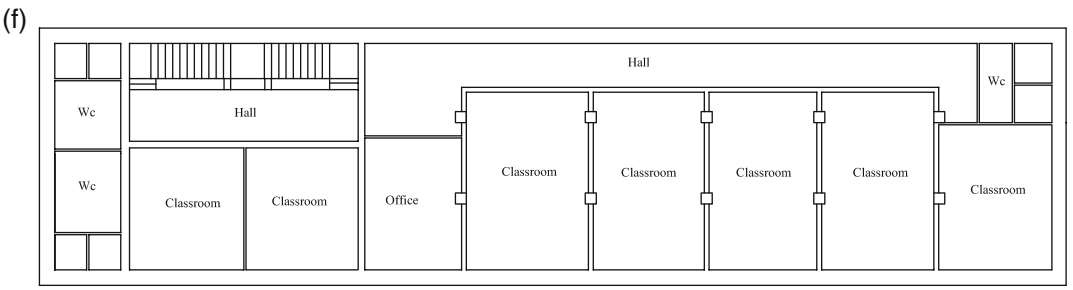
Istruzione Superiore Liceo Classico " E. Repetti" in Carrara, Italy



Scuola Elementare Enzo Mattei in Cassino, Italy



Scuola Media G. Pascoli in Tito, Italy



Istituto di Istruzione Superiore "Ettore Majorana" Avola, Italy

Fig. 37.1 Plan view of the various schools instrumented throughout Italy

Table 37.1 Measured ambient vibration and numerically predicted natural frequencies

			Natural frequencies (Hz)		
School building and location	Mode No.	Mode shape	Ambient vibrations measured	Numerically predicted	Measured/Predicted
Scuola elementare Carlo Antognini, Ancona, Italy	1	Translation	5.25	1.61	3.26
	2	Torsion	6.38	2.25	2.83
	3	Translation	9.63	2.74	3.51
Istituto istruzione superiore liceo classico, "E. Repetti" Carrara, Italy	1	Translation	4.50	1.49	3.02
	2	Torsion	5.13	2.36	2.17
	3	Torsion	6.38	2.51	2.54
Scuola elementare Enzo Mattei, Cassino, Italy	1	Torsion	7.50	0.99	7.58
	2	Torsion	17.8	3.97	4.48
	3	–	Not measured	0.99	–
Scuola media G. Pascoli, Tito, Italy	1	Torsion	11.6	2.43	4.77
	2	Torsion	22.0	3.17	6.94
	3	–	Not measured	3.39	–
Istituto di istruzione superiore "Ettore Majorana" Avola, Italy	1	Torsion	6.63	3.13	2.12
	2	Torsion	17.5	4.35	4.02
	3	–	Not measured	4.55	–
Scuola elementare "Emiliano Rinaldini" Ghedi, Italy	1	Torsion	1.38	4.35	0.32
	2	Torsion	2.88	4.72	0.61
	3	Torsion	13.75	5.00	2.75

Table 37.2 Natural frequencies of scuola elementare Carlo Antognini in Ancona, Italy obtained from 2016 Norcia earthquake triggered records and from ambient vibrations measurements

Mode No.	Earthquake triggered natural frequencies	Ambient vibrations natural frequencies	Earthquake triggered/Ambient vibrations
1	3.88	5.25	0.74
2	4.50	6.38	0.71
3	6.63	9.63	0.69

the numerical models. Considerable differences exist between the measured natural frequencies and those predicted by the numerical models. In most cases, the numerical models underpredict the natural frequencies. Reasons for these differences will be discussed during the oral presentation.

The accelerometers installed on the roof of the Scuola Elementare Carlo Antognini in Ancona, Italy were triggered during the recent (August 24, 2016) Norcia earthquake in central Italy [1]. The site of the building is located at approximately 160 km from the epicentre of the earthquake. The response amplitudes of the building under this earthquake event were much larger than that under ambient vibrations. Table 37.2 compares the first three natural frequencies of the building extracted from the earthquake triggered records from those obtained from of ambient vibrations measurements. The natural frequencies extracted from the earthquake triggered records are significantly lower than those obtained from ambient vibrations measurements. Reasons for these reductions in natural frequencies will also be discussed during the oral presentation.

Reference

1. Celano, F., Cimmino, M., Coppola, O., Magliulo, G., Salzano, P.: Report dei danni registrati a seguito del terremoto del Centro Italia del 24 agosto 2016 (Release 1), p. 26 (2016). Available at: http://www.reluis.it