ISSN 0967-859X
THE SOCIETY FOR EARTHQUAKE AND CIVIL ENGINEERING DYNAMICS

SECED

NEWSLETTER

Volume 26 No 3
November 2015

In this issue

Seismic Restraint and Bracing for Non-Structural Building Components

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Earthquakes are non-predictable natural disasters. It is almost an impossible task for scientists to accurately foresee the timing of a future earthquake. What can be done is to observe the results of past earthquakes, collect empirical data and analyze these for estimating seismic forces. The geographical locations where potential earthquakes may occur is well established by science. Based on these two facts buildings and facilities can be constructed to be resilient and survive major earthquakes with minimal damage.

When buildings are designed and constructed, an engineer's priority is the resilience of the structure. But this leads to the false assumption where investors assume that their buildings are "earthquake proof". Not enough attention is paid to the building contents, especially the non-structural building components, such as Mechanical, Electrical and Plumbing (MEP) installations and also architectural components. In modern buildings these components account for a considerable amount of the overall investment and they play a crucial role in making the buildings habitable. Recent surveys have firmly established that in developed countries non-structural building components account for the majority of the earthquake damage. Structural damage has been reduced to minimal levels.

If non-structural building components are properly designed and constructed, not only can we assure the life safety of the occupants but we can also achieve fully operational performance of buildings such as hospitals, police and fire stations, which are necessary in providing emergency relief after a major earthquake.

Editor's note: On 25th April this year, Martin Deveci gave a SECED evening presentation at the Institution of Civil Engineers. This paper gives a summary of that presentation.

Introduction

The purpose of this paper is to point out the importance of seismic protection of MEP systems in buildings and facilities. There is no scientific hypothesis; instead, it covers basic information about earthquakes and how they affect MEP components and demonstrates ways to restrain and brace these systems. The ultimate aim of this paper is to raise the awareness and highlight the significance of seismic protection for non-structural systems in buildings and facilities by offering a guideline for government officials, project owners and managers, consultants, contractors, control engineers and other decision makers.

Earthquake Damage of Non-Structural Systems

Seismic activities have a number of causes which include natural phenomena as well as inducement by human activities. Natural phenomena consist of volcanic action, collapse of an underground hole, or a ground layer motion which is called "plate tectonics". The first two are not as significant since these happen seldom and affect rather smaller areas. Earthquakes caused by tectonic activity are the most critical ones because of their devastating effects on wide areas.

Modern buildings can survive major earthquakes without collapsing if their structure has been designed and constructed using latest standards. However not every building is habitable after an earthquake. This is true especially in the case of large buildings when their non-structural components fail. Without the basic services such as heating, air conditioning, electricity and water supply the surviving structure becomes a shelter and no more. More importantly these systems can fail during an earthquake causing damage and threatening the life safety of the occupants. In some cases their inability to function leads to devastating consequences as witnessed during the 2011 earthquake in Japan.

The Tohoku earthquake was magnitude 9.0, and struck the Pacific cost of Japan. It was the most powerful earthquake ever recorded to have hit Japan, and the fourth most powerful earthquake in the world since modern record-keeping began in 1900. The unexpected disaster was neither the largest nor deadliest earthquake and tsunami to strike this century. More than 18,000 people were killed in the disaster, most of whom drowned. Less than an hour after the earthquake, the first of many tsunami waves hit Japan's coastline. The tsunami waves reached run-up heights of up to 39 meters at Miyako city and traveled inland as far as 10 km in Sendai. The tsunami flooded an estimated area of approximately 561 square kilometers. This included the flooding of Fukushima Daiichi Nuclear Power Plant that turned out to be the first nuclear disaster of the 21st century (Figure 1). It was caused primarily by the meltdowns of three reactors, which suffered explosions due to hydrogen gas that had built up within their outer containment after the cooling system failed due to loss of electrical power. 12 of 13 emergency power (back-up) generators were disabled and could not supply electricity. This resulted in radioactive leakage forcing authorities to evacuate and relocate people in large numbers.

Some estimates placed the insured losses from the earthquake alone at US$14.5 to $34.6 billion. The Bank of Japan offered ¥15 trillion (US$183 billion) to the banking system in an effort to normalize market conditions. The World Bank estimated economic cost at US$235 billion, making it the costliest natural disaster in world history.

This earthquake is one of the most extreme examples but

Figure 1: Flooded nuclear plant – Tohoku, Japan, 2011.

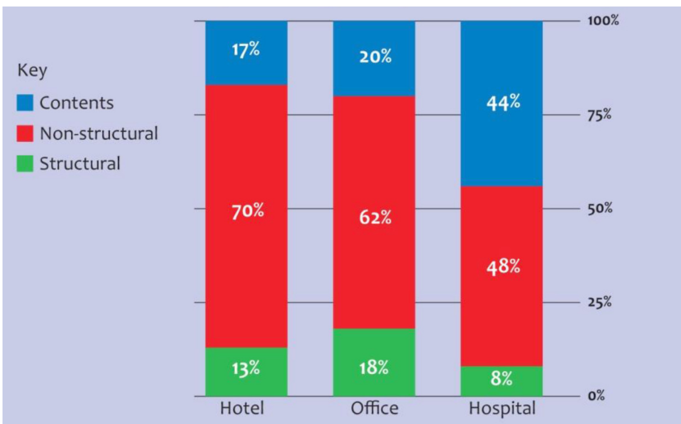

Figure 2: Percentage damage by building type, Northridge earthquake, 1994 .

Figure 3: Overturned electrical transformer due to insufficient anchoring in the İzmit earthquake, 1999.

Figure 4: Failure of vibration isolators due to non-ductile housing material.

it provides a good indication on how bad things can escalate when risk is not managed. The nuclear plant's structure survived the earthquake but luck of detailed attention to non-structural components, in this case the diesel generators, proved to be a fatal mistake.

Large buildings and facilities are served by many different types of mechanical–electrical equipment and ducting, piping, and cable tray installations, which are essential components of the building. These integrated systems suffer various types of damages and in the case of modern buildings account for the majority of the total damages.

After the 1994 Northridge earthquake in California, data was collected to assess sources of damage (Figure 2). Regardless of the building type it was clearly demonstrated that most of the damage was in the non-structural part while the structural damage was limited to 18% of the total cost in the worst case. In some buildings the non-structural damage accounted for 70% of the cost. Some common damages suffered by MEP systems are shown in Figures 3, 4, 5 and 6.

Building Codes and Seismic Force Calculations

Earthquake risk management and mitigation for non-structural components of buildings and facilities have progressed significantly through the development of new building codes, design guidelines and standards. These include the International Building Code (IBC), American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) documents and Federal Emergency Management Agency (FEMA) design guides. In addition to these most well-known and used codes, the followings can be utilized as supporting guides:

- ASHRAE, Handbook – Fundamentals, Chapter 54
- ASHRAE, A Practical Guide to Seismic Restraint
- SMACNA, Seismic Restraint Manual: Guidelines for Mechanical Systems
- NFPA, National Fire Protection Association
- FEMA 412, Installing Seismic Restraints for Mechanical Equipment
- FEMA 413, Installing Seismic Restraints for Electrical Equipment

Figure 5: Suspended HVAC equipment came down at the Santiago airport terminal in the 2010 magnitude-8.8 Chile Earthquake (Photo courtesy of Gokhan Pekcan).

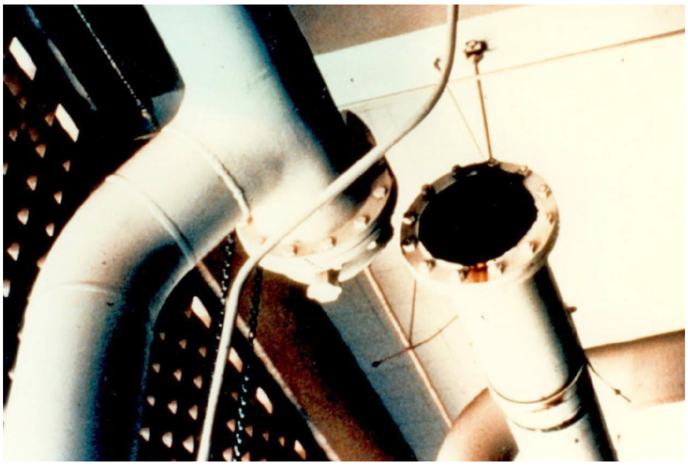

Figure 6: Pipe joint failure in the 1971 magnitude-6.6 San Fernando Earthquake (Photo courtesy of John F. Meehan).

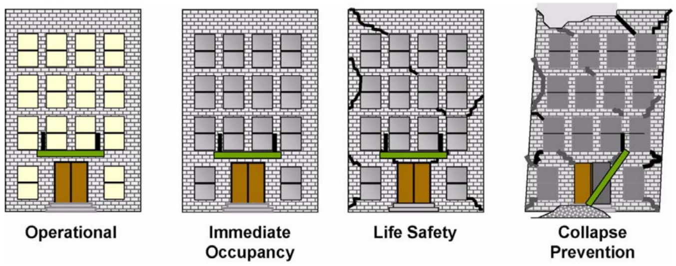

Figure 7: Graphic illustration of Performance Levels (FEMA, 2004a).

- FEMA 414, Installing Seismic Restraints for Duct and Pipe
- FEMA 460, Seismic Considerations for Steel Storage Racks

It is very difficult to predict the magnitude of seismic forces. Instead, these can be calculated by using formulas, based on empirical data collected from past earthquakes. ASCE 7-10 (referred to by IBC 2012) has a specific section for seismic requirements of non-structural components and provides the following equations:

$$F_p = \frac{0.4 a_p S_{DS} W_p}{R_p / I_p}\left(1 + 2\frac{z}{h}\right) \quad (1)$$

$$F_{pV} = \pm 0.2 S_{DS} W_p \quad (2)$$

where F_p is the design seismic horizontal force and F_{pV} is the design seismic vertical force, a_p is the component amplification factor, S_{DS} is the design spectral response acceleration at short periods, W_p is the component operating weight, R_p is the component response modification factor, I_p is the component importance factor, z is the height in the structure at point of attachment of the component, and h is the average roof height of the structure.

Performance Based Design

There are various types and sizes of buildings each with their own design considerations. Nevertheless they can be grouped into a number of categories that determine their resilience to earthquakes. These are called "performance levels" that range from high (operational) to low (collapse prevention) performance (Figure 7). For example hospitals, police and fire stations should have the highest performance level since these are the type of facilities that have to deal with the aftermath of an earthquake and provide the first response. On the other hand, performance expectations of a simple warehouse or farm building would be very low.

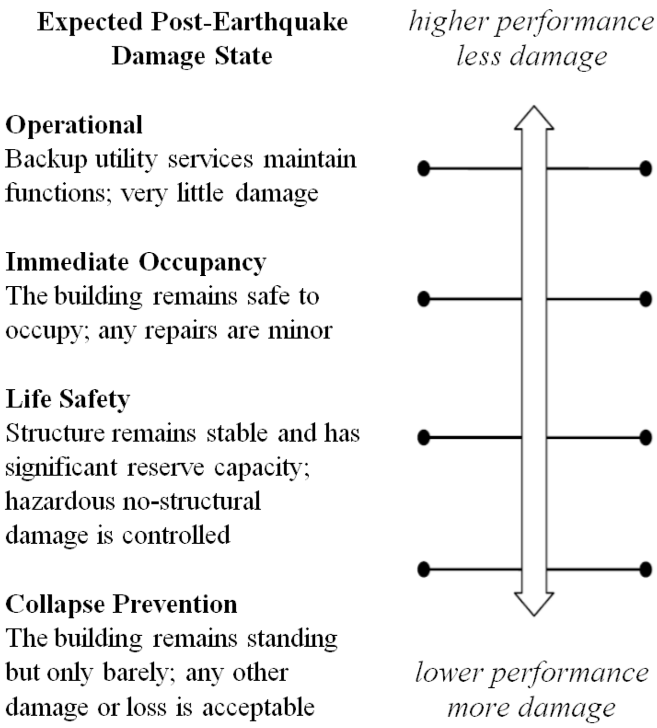

Figure 8: Building Performance Levels and Damage Expectations (FEMA, 2000).

Building performance is a combination of the performance of both structural and non-structural components. FEMA (Federal Emergency Management Agency) has described four non-structural performance levels (Figure 8). Performance based seismic design clearly describes how a building is likely to perform in a potential hazard. It permits design of new buildings or upgrade of existing buildings with a realistic understanding of the risk, occupancy interruption, and financial loss that may occur as a result of an earthquake.

Operational Non-Structural Performance Level

At this level, most non-structural systems required for normal use of the building including lighting, plumbing, HVAC, and computer systems are expected to be functional, although minor cleanup and repair of some items may be required. This Non-structural Performance Level requires considerations beyond those that are normally within the sole province of the structural engineer. In addition to assuring that non-structural components are properly mounted and braced within the structure, it is often necessary to provide emergency standby utilities. Some mechanical and electrical equipment should go through rigorous qualification testing to prove that it can function during or after an earthquake.

Immediate Occupancy Non-Structural Performance Level

At this level, minor window breakage and slight damage could occur to some components. Assuming that the building is structurally safe, occupants could safely remain in the building, although normal use may be impaired and some cleanup and inspection may be required. In general, components of mechanical and electrical systems in the building are structurally secured and should be able to function if necessary. Utility service is available. However, some components may experience misalignments or internal damage, which could impair their operation. Power, water, natural gas, and other utilities required for normal building use may not be available for reasonably acceptable times. The risk of life-threatening injury due to non-structural damage is very low.

Life Safety Non-Structural Performance Level

The non-structural performance level of "Life Safety" is the post-earthquake damage state in which potentially significant and costly damage has occurred to non-structural components but they have not become dislodged and fallen, threatening life safety either inside or outside the building. Egress routes within the building are not extensively blocked, but may be impaired by lightweight debris. HVAC, plumbing, and fire suppression systems may have been damaged, resulting in local flooding as well as loss of function. While injuries may occur during the earthquake from the failure of non-structural components, overall, the risk of life-threatening injury is very low. Restoration of the non-structural components may take extensive effort.

Collapse Prevention Non-Structural Performance Level

This performance level represents a post-earthquake damage state in which extensive damage has occurred to non-structural components, but large or heavy items that pose a high risk of falling hazard to a large number of people such as parapets, cladding panels, heavy plaster ceilings, or storage racks are prevented from falling. The hazards associated with exterior elements along portions of the exterior of the building that are available for public occupancy have been reduced. While isolated serious injury could occur from falling debris, failures that could injure large numbers of people either inside or outside the structure should be avoided.

Non-structural components that are small, lightweight, or close to the ground may fall, but should not cause serious injury. Larger non-structural components in areas that are less likely to be populated may also fall.

The intent of the "Collapse Prevention" performance level is to address significant non-structural hazards without needing to restore all of the non-structural components in a building. When targeting this level of performance, it will generally be appropriate to consider "Collapse Prevention" performance as equivalent to "Life Safety" performance for the most hazardous, highest risk subset of the non-structural components in the building.

Seismic Design of Non-Structural Components

For the purpose of seismic design, non-structural components are assigned the same Seismic Design Category (SDC) as the structure. Per IBC there are six categories, ranging from A to F. They are based on the expected ground acceleration and required performance level (occupancy category). Depending on the Seismic Design Category various exemptions apply to architectural and MEP components. For example in SDC A all non-structural components are exempt.

A component Importance Factor (I_p) has to be assigned to all non-structural components as per ASCE 7-13. The component importance factor, I_p, is equal to 1.0 or 1.5 depending on their type and performance required. For example when operational level of performance (Occupancy Category IV) is needed, I_p of 1.5 is assigned to most components. For components that contain hazardous material and life safety systems, the importance factor is always taken as 1.5, regardless of performance level.

Seismic restraint design for mechanical and electrical systems can be split into two main groups:

- Floor or wall mounted, and suspended equipment;
- Pipes, ducts, electrical cable trays and other service installations.

Floor mounted equipment can either be rigidly mounted

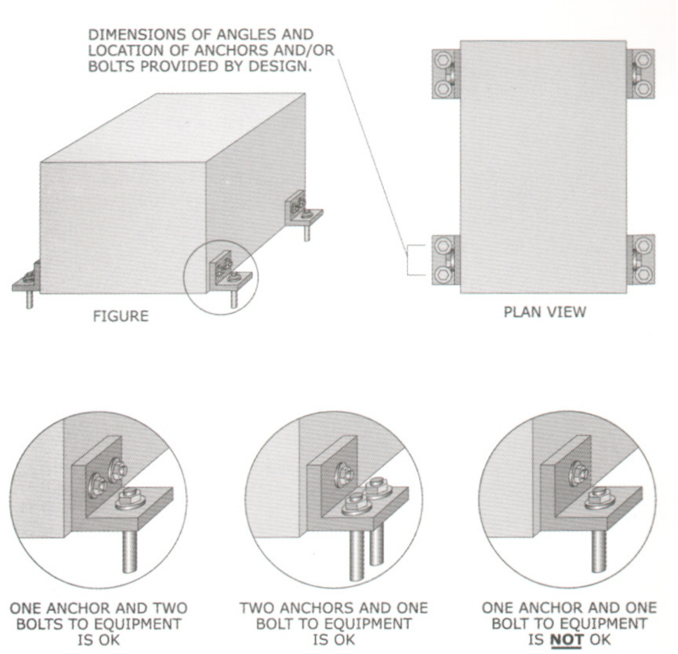

Figure 9: Typical attachment detail of equipment to a supporting structure (FEMA, 2002).

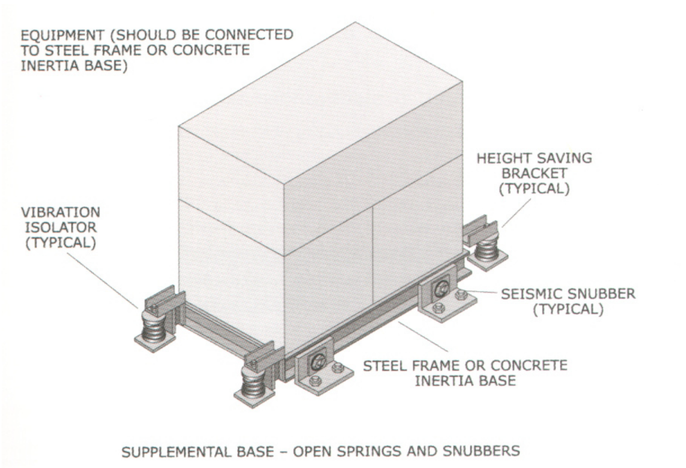

Figure 10: Typical installation with open springs and snubbers (FEMA, 2002).

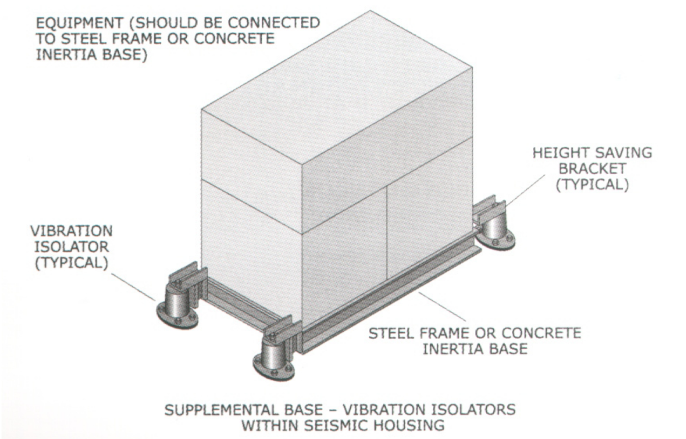

Figure 11: Typical installation with restrained vibration isolators (FEMA, 2002).

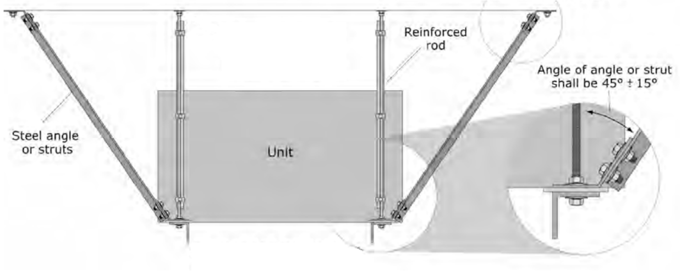

Figure 12: Typical installation of suspended equipment with threaded rods, rod stiffeners and rigid bracing (FEMA, 2002).

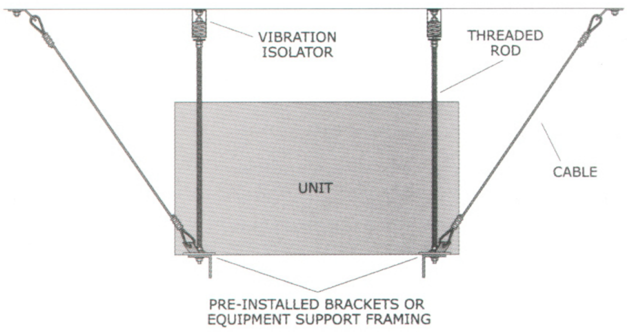

Figure 13: Typical installation of suspended equipment with threaded rods, vibration isolation hangers and wire rope bracing (FEMA, 2002).

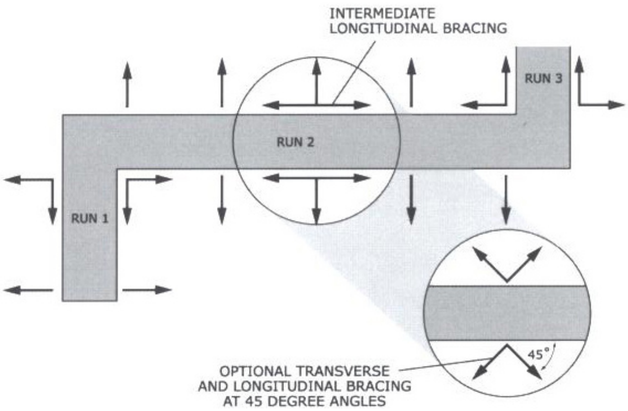

Figure 14: Seismic cable (wire rope) bracing for suspended pipe/duct/electrical cable tray lines (FEMA, 2004b).

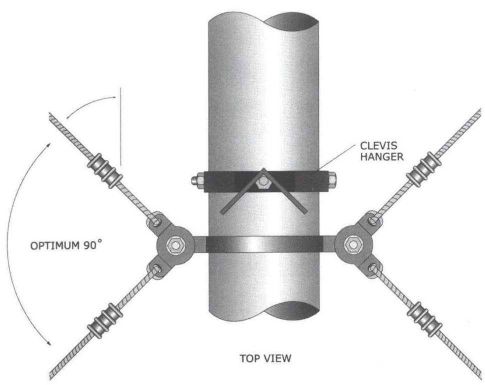

Figure 15: Seismic wire rope bracing detail (top/plan view) (FEMA, 2004b).

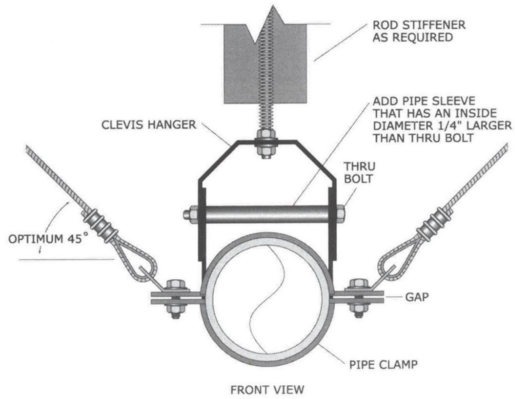

Figure 16: Seismic wire rope bracing detail (front/section view) (FEMA, 2004b).

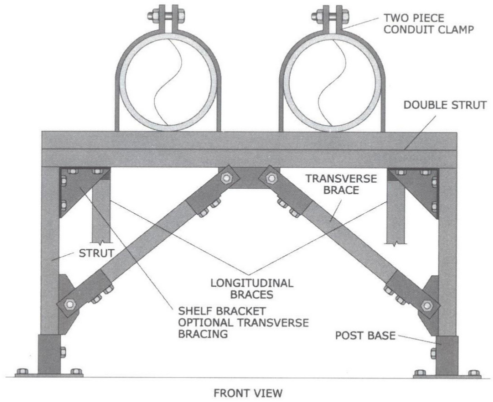

Figure 17: Seismic restraint for floor mounted pipes (FEMA, 2004b).

to the floor or to concrete pads (Figure 9) or they can be mounted on vibration isolators with snubbers (Figure 10) or directly on seismic isolators (Figure 11). If there is a need for vibration isolation, rigid mounting should not be implemented. For example a chiller or a pump needs to be isolated to avoid vibration and structure borne noise. If the equipment needs to be restrained, it is cost effective to use seismic isolators instead of using two different types of hardware, open springs and snubbers.

Suspended equipment can also either be rigidly restrained if there is no need for vibration isolation (Figure 12) or can be hung with vibration hangers and braced with steel wire ropes (Figure 13). Air handling units, fans and fan-coil units are frequently suspended and since they have motors causing vibration, they need to be isolated to avoid unwanted noises.

Wall mounted equipment rarely needs vibration isolation. Thus it is enough to rigidly mount them to the wall with anchors that are capable of resisting the calculated seismic force. In the case that wall mounted equipment needs to be vibration isolated, it can be installed on a steel support frame together with seismic isolators just like floor mounted equipment.

Regardless of how the equipment is mounted, seismic calculation should be performed to determine the seismic force and how this force affects attachment points to the structure. Only after that, attachment elements such as anchors, bolts and mounts should be selected.

Suspended pipes, ducts and electrical cable trays are critical, since those are subject to sway and cause damage to themselves and other adjacent systems close by. Therefore in most cases they should be seismically braced. The bracing (referred to as seismic bracing, sway bracing or wire rope bracing) should be designed based on calculated seismic forces. The non-structural seismic engineer has to determine the location and the number of bracing points on a layout drawing, as well as the actual brace size. There are guidelines such as SMACNA that provide practical recommendations for minimum bracing of individual piping and ducting. However in the majority of cases installation conditions are more complicated than envisaged in guidelines. To save space service lines are combined and installed on

Figure 18: Rigid mounting of equipment (Photo courtesy of Eduardo Fierro, BFP Engineers).

Figure 19: Resilient mounting of equipment (Photo courtesy of Ulus Yapi).

Figure 20: Resilient mounting of equipment (Photo courtesy of Acrefine Engineering).

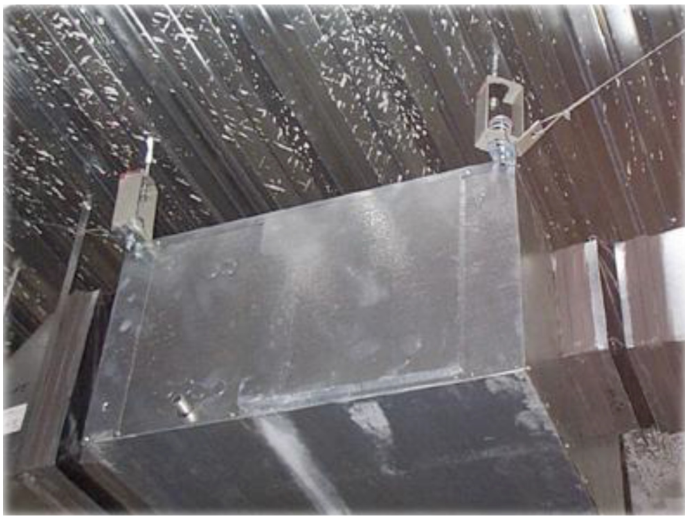

Figure 21: Suspended equipment with 4-way brace.

custom-made supports. In other words, seismic bracing should be acomplished on a case-by-case approach based on seismic calculations and structural attachment details.

Figure 14 shows a general concept of seismic bracing for a pipe/duct/electrical cable tray layout system. As demonstrated on this schematic, all runs of the system should be seismically braced in both lateral (transverse) and longitudinal (axial) directions. Alternatively, 45° angle bracing can be used, instead of having lateral and longitudinal braces separately. This type of bracing is utilized to reduce installation cost and save time. Such a bracing detail of a single pipe run is shown in Figures 15 and 16.

Floor-mounted pipes are as critical as suspended ones especially in industrial facilities where large diameter pipes are subject to severe earthquake damages. These pipes need to be installed with steel supports designed by professional seismic engineers. A seismically braced steel support installation for floor mounted pipes is shown in Figure 17.

Seismic Installation Examples of MEP Systems

In this section, seismic installation examples are presented for various types of equipment, piping and ducting. Figure 18 shows direct attachment of equipment with a custom-manufactured bracket to a supporting structure. The bracket is reinforced and secured to the base with four bolts, while bigger bolts are used to fasten to the steel beam underneath.

Pumps are a very common type of equipment and found on all buildings that have MEP installations. They generate vibration and are therefore installed on inertia bases supported on vibration isolators. In seismic applications snubbers are used for restraining together with free standing

Figure 22: Rigid bracing of piping (Photo courtesy of Maryann Phipps, Estructure).

Figure 23: Pipe line installation with 4-way wire rope bracing (Photo courtesy of Ulus Yapi).

open springs. In most cases, housed (restrained) vibration isolators are preferred (Figure 19)

Figure 20 shows seismic installation of a large cooling tower. The equipment is placed on a structural steel base that has been stiffened at isolator locations. Reinforced housed isolators are used to withstand the high seismic forces, each secured by six anchors to the housekeeping pad. The housekeeping pad is also properly anchored to the supporting concrete structure below.

An example of suspended equipment is shown in Figure 21. An inline fan is installed with vibration isolation hangers and braced with four steel wire ropes.

Suspended services such as piping, ducting and cable trays are usually braced using rigid or steel wire ropes. Rigid bracing is only used when vibration isolation is not a concern (Figure 22). Steel wire ropes, on the other hand, can be used with or without vibration isolation, making them more common than rigid braces. Figure 23 illustrates typical piping installation with 4-way steel wire rope bracing. Pipes are supported on structural steel members that are suspend using vibration isolators. Steel wire ropes are attached to the supporting frame and structure. They are intentionally installed with a limited amount of slack so that vibration transmission is eliminated.

Conclusion

Seismic design of mechanical, electrical and plumbing systems in modern buildings and facilities is crucial in order to assure the life safety of occupants and minimize damages. In the case of essential facilities the continued functioning of these systems is paramount both for safety reasons and also to ensure continued operation. The development of new building codes, standards and guidelines provides engineers with adequate means to design buildings with various target performance levels. Unfortunately the design on its own is not sufficient; it is important to enforce the correct implementation of the seismic calculations and prints during the construction phase. Hence site supervision and quality control play a key role in achieving resilient buildings.

In simplified terms engineers are faced with the task of securing MEP systems to the structure so that they do not become dislodged and fall. From this prospective the selection of attachment elements such as anchors, bolts, restraint mounts, snubbers etc. is the most critical part. Therefore only quality products that are independently tested and certified should be used.

Finally it is important to point out that not all building standards include requirements for non-structural components. The weaknesses in some local codes should be taken into consideration carefully and they should not prevent designers from implementing proper seismic design for non-structural components. Investors, architects and other parties involved should consult a seismic design specialist to manage the risk.

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Federal Emergency Management Agency (FEMA) (2002). Installing Seismic Restraints for Mechanical Equipment, FEMA 412.

Federal Emergency Management Agency (FEMA) (2004a). Risk Management Series – Primer for Design Professionals: Communicating with Owners and Managers of New Buildings on Earthquake Risk, FEMA 389.

Federal Emergency Management Agency (FEMA) (2004b). Installing Seismic Restraints for Duct and Pipe, FEMA 414.

Forthcoming Events

Date	Venue	Title	People
27/1/2016 at 18:00	Institution of Civil Engineers, 1 Great George St, London	*Uncertainty Modelling and Visualisation for Tsunami Hazard and Risk Mapping*	*Speakers*: **Katsu Goda** (Bristol) *Organisers*: **Tiziana Rossetto** (UCL)

For up-to-date details of SECED events, visit the website: **www.seced.org.uk**

Notable Earthquakes March 2014 – June 2014

Reported by British Geological Survey

Issued by: Davie Galloway, British Geological Survey, February 2015.
Non British Earthquake Data supplied by The United States Geological Survey.

			Time			Dep	Magnitude			
Year	Day	Mon	UTC	Lat	Lon	km	ML	Mb	Mw	Location
2014	01	MAR	13:58	56.85N	7.51E	10	3.2			EASTERN NORTH SEA
2014	02	MAR	20:11	27.43N	127.37E	119			6.5	RYUKYU ISLANDS, JAPAN
2014	03	MAR	17:50	53.21N	1.04W	1	1.6			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	10	MAR	02:21	53.21N	1.02W	1	1.8			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	10	MAR	05:18	40.83N	125.13W	17			6.8	NORTHERN CALIFORNIA
2014	11	MAR	11:37	53.21N	1.02W	1	1.8			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	16	MAR	21:16	19.98S	70.70W	20			6.7	TARAPACA, CHILE
2014	18	MAR	20:45	52.32N	6.30W	9	2.2			COUNTY WEXFORD, IRELAND
Felt County Wexford (3 EMS).										
2014	19	MAR	19:34	53.20N	1.02W	1	1.8			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	21	MAR	13:45	53.22N	1.02W	1	1.6			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	23	MAR	11:46	53.21N	1.02W	1	1.6			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	25	MAR	04:23	53.21N	1.02W	1	1.7			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	30	MAR	13:29	53.21N	1.02W	1	1.6			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	01	APR	23:46	19.61S	70.77W	25			8.2	TARAPACA, CHILE
Six people killed, scores more injured and at least 2,500 buildings and 150 boats damaged in the Iquique area, Tarapaca. Many landslides and power outages also occurred in the epicentral area. A tsunami was also generated with a maximum wave height of 87cm recorded at Tocopilla, Chile.										
2014	01	APR	23:57	19.89S	70.95W	28			6.9	TARAPACA, CHILE
2014	03	APR	01:58	20.31S	70.58W	24			6.5	TARAPACA, CHILE
2014	03	APR	02:43	20.57S	70.49W	22			7.7	TARAPACA, CHILE
2014	03	APR	06:30	51.72N	2.25W	16	2.3			STROUD, GLOUCESTERSHIRE
Felt Stroud (2 EMS).										
2014	04	APR	22:40	28.17N	103.62E	25		5.4		YUNNAN, CHINA
At least 21 people injured, 75 houses destroyed and 2,700 others damaged in the Yongshan area of Yunnan Province, China.										
2014	11	APR	07:07	6.59S	155.05E	61			7.1	PAPUA NEW GUINEA
One person killed and at least 50 buildings destroyed in the town of Buin on Bougainville Island, PNG.										
2014	11	APR	08:16	6.79S	154.95E	20			6.5	PAPUA NEW GUINEA
2014	11	APR	20:29	11.64N	85.88W	135			6.6	NICARAGUA

			Time			Dep	Magnitude			
Year	Day	Mon	UTC	Lat	Lon	km	ML	Mb	Mw	Location
2014	12	APR	20:14	11.27S	162.15E	23			7.6	SOLOMON ISLANDS
2014	13	APR	12:36	11.46S	162.05E	39			7.4	SOLOMON ISLANDS
2014	13	APR	13:24	11.13S	162.05E	10			6.6	SOLOMON ISLANDS
2014	15	APR	03:57	53.50S	8.72E	11			6.8	BOUVET ISLAND REGION
2014	17	APR	06:07	52.73N	0.73W	2	3.2			OAKHAM, RUTLAND
Felt throughout Rutland, Leicestershire and surrounding areas (4 EMS).										
2014	18	APR	06:50	52.72N	0.73W	3	3.5			OAKHAM, RUTLAND
Felt throughout Rutland, Leicestershire and surrounding areas (4 EMS).										
2014	18	APR	14:27	17.40N	100.97W	24			7.2	GUERRERO, MEXICO
2014	19	APR	01:04	6.66S	155.09E	29			6.6	PAPUA NEW GUINEA
2014	19	APR	13:28	6.76S	155.02E	43			7.5	PAPUA NEW GUINEA
2014	24	APR	03:10	49.64N	127.73W	10			6.5	VANCOUVER ISLAND, CANADA
2014	28	APR	22:05	52.72N	0.73W	3	1.7			OAKHAM, RUTLAND
Felt Oakham, Cottesmore, Ashwell, Langham and Braunston, Rutland (3 EMS).										
2014	01	MAY	06:36	21.45S	170.36E	106			6.6	VANUATU
2014	02	MAY	18:12	53.19N	1.83E	10	3.4			SOUTHERN NORTH SEA
2014	04	MAY	09:15	24.61S	179.09E	527			6.6	FIJI ISLANDS REGION
2014	05	MAY	11:08	19.66N	99.67E	6			6.1	THAILAND
One person killed and 32 others injured in Chiang Rai, Thailand.										
2014	12	MAY	18:38	49.94S	114.80W	11			6.5	SOUTH PACIFIC OCEAN
2014	13	MAY	06:35	7.21N	82.31W	10			6.5	PANAMA
2014	24	MAY	09:25	40.29N	25.39E	6			6.9	AEGEAN SEA
At least 100 people injured on the island of Gokceada, Turkey.										
2014	14	JUN	11:10	10.12S	91.09E	4			6.5	SOUTH INDIAN OCEAN
2014	18	JUN	08:44	53.40N	1.38W	4	2.8			ROTHERHAM, S YORKSHIRE
Felt Rotherham, Sheffield and Doncaster (3 EMS).										
2014	20	JUN	16:01	55.79N	6.35W	6	1.7			ISLAY, ARGYLL & BUTE
Felt Bowmore, Bruichladdich, Ballygrant, Bridgend, Glenegedale and Portnahaven, Islay (3 EMS).										
2014	20	JUN	16:01	55.79N	6.38W	7	2.5			ISLAY, ARGYLL & BUTE
Felt Bowmore, Bruichladdich, Ballygrant, Bridgend, Glenegedale and Portnahaven, Islay (3 EMS)										
2014	23	JUN	19:19	29.98S	177.73W	20			6.9	KERMADEC ISLANDS
2014	23	JUN	19:21	29.94S	177.52W	10			6.5	KERMADEC ISLANDS
2014	23	JUN	20:06	29.94S	177.61W	26			6.7	KERMADEC ISLANDS
2014	23	JUN	20:53	51.85N	178.74E	110			7.9	ALEUTIAN ISLANDS
2014	29	JUN	07:52	55.47S	28.37W	8			6.9	SOUTH SANDWICH ISLANDS
2014	29	JUN	17:15	14.98S	175.51W	18			6.7	TONGA REGION

SECED Newsletter

The SECED Newsletter is published quarterly. All contributions of relevance to the members of the Society are welcome. Manuscripts should be sent by email. Diagrams, pictures and text should be attached in separate electronic files. Hand-drawn diagrams should be scanned in high resolution so as to be suitable for digital reproduction. Photographs should likewise be submitted in high resolution. Colour images are welcome.

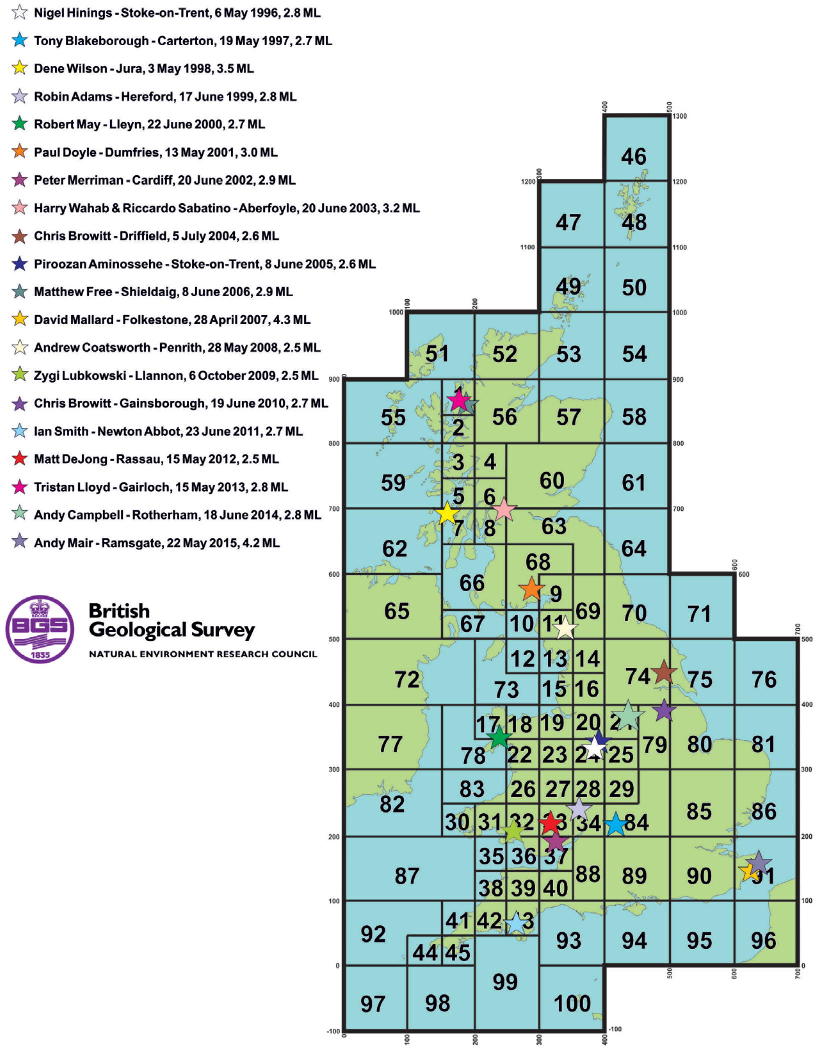
Please contact the Editor of the Newsletter, Damian Grant, for further details: damian.grant@arup.com.

SECED Earthquake Competition Result 2015

When the M_L 4.2 earthquake struck in Ramsgate, Kent, in May this year, Andy Mair, former SECED committee chairperson, became 2015's Earthquake Competition winner. Andy was presented with a bottle of bubbly at October's meeting.

Each year, Alice Walker organises the competition to "predict" the location of the next magnitude 2.5 or greater earthquake to occur in Britain. Participants use both knowledge of historical British seismicity and blind luck (heavily weighted towards the latter) to select locations from the grid shown in the figure below.

This was Andy's first win, although there is a long-standing tradition of SECED committee members winning the prize. Last year, Andy Campbell, current SECED chairperson, successfully located the M_L 2.8 Rotherham earthquake.



Earthquake Competition Winners, 1996–2015

SECED

SECED, The Society for Earthquake and Civil Engineering Dynamics, is the UK national section of the International and European Associations for Earthquake Engineering and is an Associated Society of the Institution of Civil Engineers. It is also sponsored by the Institution of Mechanical Engineers, the Institution of Structural Engineers, and the Geological Society. The Society is also closely associated with the UK Earthquake Engineering Field Investigation Team. The objective of the Society is to promote co-operation in the advancement of knowledge in the fields of earthquake engineering and civil engineering dynamics including blast, impact and other vibration problems.

For further information please contact the SECED Secretary at the ICE at: secretary@seced.org.uk.