SECED

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

NEWSLETTER

Volume 26 No 1
February 2015

In this issue

Seismic Design of New Low-Cost Housing for El Salvador

Sebastian Kaminski
Arup, London

Katherine Coates
Arup, London

Andrew Lawrence
Arup, London

El Salvador has one of the largest divides between the rich and the poor in the world with hundreds of thousands living in poverty on only a few dollars per day. This poverty, coupled with the frequent earthquakes and other natural disasters, has left many living in sub-standard unhygienic and unsafe housing. This problem is not isolated to El Salvador, and indeed recent estimates of the housing deficit in Latin America as a whole are between 42–51 million dwellings (this is the number of new houses required to house all those in sub-standard, precariously located or overcrowded housing) (UN-Habitat, 2011).

Natural hazards including earthquakes, volcanoes, flooding and hurricanes, contribute significantly towards this housing deficit. As the worst effects of hurricanes tend to be confined to the Caribbean and the Eastern seaboard of North and Central America, one of Central America's greatest natural hazard is arguably earthquakes, as the Pacific Ring of Fire runs down the west coast. Many areas are considered to have high seismic hazard (with a Peak Ground Acceleration greater than 0.4g for a 10% probability of exceedance in 50 years). In the last 500 years, Central America has experienced many earthquakes that caused significant damage and loss of life, both in the subduction zone which forms part of the Pacific Ring of Fire and in the local faults along the volcanic chain.

New permanent low-cost housing in Latin America consists of a mixture of engineered and non-engineered housing. The design of non-engineered houses often rests entirely with the beneficiaries or local skilled workers, and will often consist of a vernacular design, or alternatively a copy of a more modern design, often masonry. The design of engineered houses is normally determined by the government, donors or Non-Governmental Organisations (NGOs). The most common permanent housing options currently being constructed in Central America are adobe, *bahareque* (a derivative of wattle-and-daub), confined masonry and reinforced hollow blockwork. Unfortunately, each of these has a number of drawbacks: adobe has very

Table 1: Selection of advantages, disadvantages and relative costs of the main permanent housing options constructed in El Salvador

Housing Type	Advantages	Disadvantages	Relative cost
Adobe	• Very cheap when the correct soil type is available locally. • Widely-known construction system. • Good thermal mass hence very cool inside. • Negligible environmental impact.	• Typically performs very poorly in an earthquake. • Requires considerable maintenance. • Harbours disease-carrying insects. • Very unpopular with locals. • Traditionally combined with a heavy tiled roof, increasing the seismic loads and the risk of injury if it falls.	Low
Bahareque	• Relatively low-cost. • Can have good seismic resistance when in good condition. • Good thermal mass hence very cool inside. • Low environmental impact.	• Harbours disease-carrying insects. • Susceptible to insect attack and water ingress. • Requires considerable maintenance. • Relatively unpopular with locals. • Traditionally combined with a heavy tiled roof, increasing the seismic loads and the risk of injury if it falls.	Medium
Confined masonry	• Good seismic resistance when well-constructed. • Challenging to construct (difficult to place rebar and concrete in small confining elements). • Good thermal mass hence very cool inside. • Popular with locals.	• Commonly constructed poorly – detailing more complex than reinforced blockwork. • Higher cost. • High environmental impact (fired clay bricks and concrete). • Seismic design rules generally mean houses often have smaller and/or fewer windows. • Typically combined with a heavy tiled roof, increasing the seismic loads and the risk of injury if it falls.	Medium-high
Reinforced blockwork	• Very good seismic resistance when well-constructed. • Very durable. • Good thermal mass hence very cool inside. • Very popular with locals. • Relatively simple to construct. • Normally combined with lightweight zinc-aluminium roof sheeting, reducing the seismic loads and risk of injury if it falls.	• Higher cost. • High environmental impact (concrete).	Medium-high

low seismic resistance, can harbour disease-carrying insects and is poorly regarded by local communities; *bahareque* often deteriorates after approximately a decade due to insect attack and water ingress (López et al., 2004); confined masonry is very workmanship dependent and relatively expensive (see Table 1). The existing best option for permanent low-cost housing in El Salvador is widely considered to be reinforced hollow blockwork, which is very durable and has good seismic resistance when well-constructed; however it is moderately expensive and not very sustainable.

Arup (a UK-based design consultancy), Engage for Development (a UK-based charity) and the Imperial College El Salvador Project (a UK-based charitable organisation) have been working with REDES (a small El Salvadorean NGO) for the past four years, with the aim of developing an alternative, low-cost, sustainable, seismically-resistant and appropriate low-cost house design suitable for El Salvador. The design should also be easy to construct and maintain by the local communities themselves, and ideally use local materials such that more money goes back into the local economy.

Overview of Design

After conducting research into existing low-cost housing in the Latin American region, in particular using bamboo structurally (Kaminski, 2013), the team developed a solution which takes the vernacular bahareque design and "engineers" it by essentially: treating the timber and wall matrix against insect attack, replacing the mud render with a more durable and stronger cement mortar and engineering the connection details.

The design that is being developed is a single-storey four roomed building, approximately 6 m × 6 m, with two bedrooms, one lounge and one kitchen. The foundations of the house are a thin reinforced concrete slab sitting on reinforced concrete ground beams under the walls. The walls sit on two courses of hollow reinforced blockwork, protecting the frame above from water and insect attack. The wall and roof structural frame sits on the blockwork and consists of a simple 2" × 4" structurally graded and pressure-treated pine frame, nailed together with steel straps at key locations to resist wind and seismic loads. The walls are wrapped in a thin galvanised chicken mesh on both sides, and *vara de castilla* (also known as *caña brava* – a local type of cane approximately 25 mm in diameter and up to 6 m long (Chan, 2014)) is nailed to the frame. The *vara de castilla* is sourced from local farmers and is treated on site against insects with boron. Cement mortar is then plastered on both sides of the walls to form the 60 mm thick shear walls. The bases of the walls are painted with waterproof paint to protect against driving rain. The roof consists of lightweight cement fibreboard sheeting screwed down onto the timber purlins and rafters. The design life of the house is 30 years with minimal maintenance.

Prototype houses

Two prototype houses were successfully built in El Salvador in 2012, and have allowed the house design and construction method to be optimised (El Salvador Project 2012, 2012). They were evaluated again in 2013 and the beneficiaries were very happy with them, with no reported structural problems (see Figures 1 and 2).

Figure 1: Prototype cane and mortar house under construction (El Salvador Project, 2012). © Sebastian Kaminski

Figure 2: Prototype cane and mortar house, completed in 2012 (El Salvador Project, 2012). © Sebastian Kaminski

Seismic Design Approach

The lateral stability system of the structure relies upon perpendicular shear walls in both directions, roughly evenly spaced. With a light roof, most of the seismic load is generated by the self-weight of the walls themselves.

As El Salvador is in a region of high seismic hazard, the seismic demands govern the design of the lateral system; hurricane winds do not tend to affect El Salvador as it is on the West coast of Central America. The El Salvadorean seismic code (MOP, 1994) is based on the Mexico City code and loosely in turn on an old version of the Uniform Building Code (UBC). In addition, the other El Salvadorean material design codes are also limited in their scope or refer back to US or Mexican codes (López et al., 2004). Therefore, in order to be able to use an up-to-date, comprehensive and consistent set of design codes, the most recent US design code has been selected as the design basis (International Building Code, IBC) . The IBC is also appropriate as many of the materials available in El Salvador are imported from the US.

A comparative study of different seismic hazard assessments for El Salvador was conducted in order to determine the most appropriate design parameters. Table 2 presents the maximum seismic hazard determined for any area within El Salvador from a number of different published sources.

A design PGA of 0.5g (10% probability of exceedance in 50 years) has been selected for the design because Benito et al. (2012) was considered to best reflect the most up-to-date understanding of seismic hazard in the region, and one which involved a collaborative effort between different specialists in the region. It also reflects the design criteria according to which the house may be built anywhere within the country.

Two performance levels have been considered for the design:

Table 2: Maximum seismic hazard for any area within El Salvador

Code and date	Equivalent PGA at 475/500-year return period (g)	Comments
El Salvadorean Seismic Code (MOP, 1994)	0.4	
GSHAP Database 1999 (USGS, 2011)	0.38	
A New Evaluation of Seismic Hazard for the Central America Region paper (Benito et al, 2012)	0.5	Value appropriate for the capital, San Salvador.

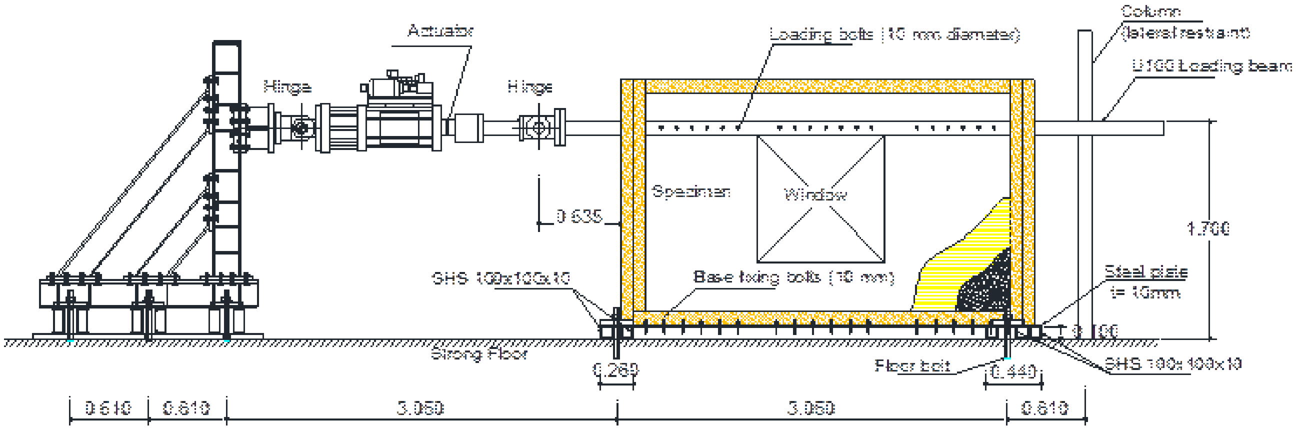

Figure 3: Elevation of in-plane test specimen (Málaga-Chuquitaype et al, 2014).

1. Small frequent event (e.g. 43-year return period): limited cracking to walls, no primary structural damage.
2. Large infrequent event (e.g. 475-year return period): cracking and crushing to walls, rotation of connections, structure remains life-safe. Frame remains largely intact and in many cases structure can be fully repaired.

Design Methodology

The wall structure both in-plane and out-of-plane does not fit into any codified lateral system and its behaviour and strength is difficult to quantify by calculation. Accordingly, whenever possible simple and conservative calculations have been used to design elements and connections, with full-scale testing to validate the results.

In-plane

In-plane testing of a bamboo/cane matrix wall and cement mortar have been conducted in both Costa Rica (González & Gutiérrez, 2003) and Colombia (Farbiarz, 2001) as part of research to develop low-cost bamboo housing. These studies provided useful preliminary evidence that such walls could resist considerable in-plane seismic loads. However, because the design for El Salvador was slightly different from the tested walls and the variables and number of tests previously conducted limited, further testing was conducted in 2013 at Imperial College London as part of an ICE Research and Development Grant (Elghazouli et al., 2013; Málaga-Chuquitaype et al., 2014).

Because the global in-plane flexural capacity of the panel could be relatively easily determined by hand (governed by tension on the rear end), the aim of the test was to determine the shear capacity and behaviour, and therefore vertical pre-stressed ties were introduced on the return walls in order to force the panel to fail in shear.

The 2013 study tested at full scale six different wall panels each with different geometric and material characteristics.

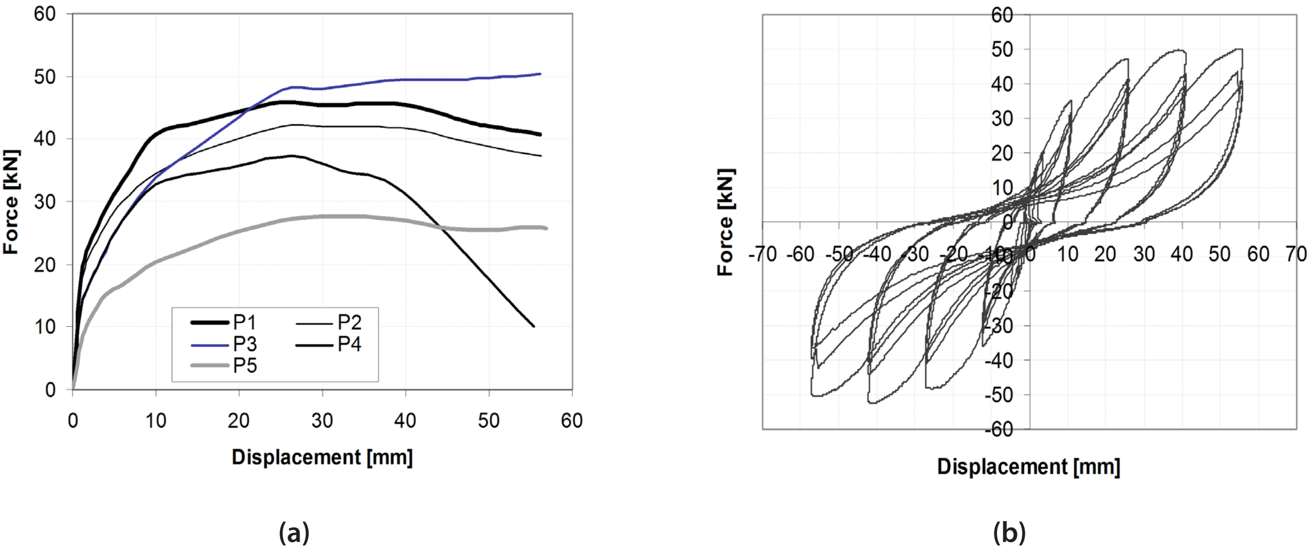

Figure 4: (a) Envelopes of the force-displacement hysteresis for different panel types, and (b) force-displacement hysteresis for one of the panels (Málaga-Chuquitaype et al, 2014).

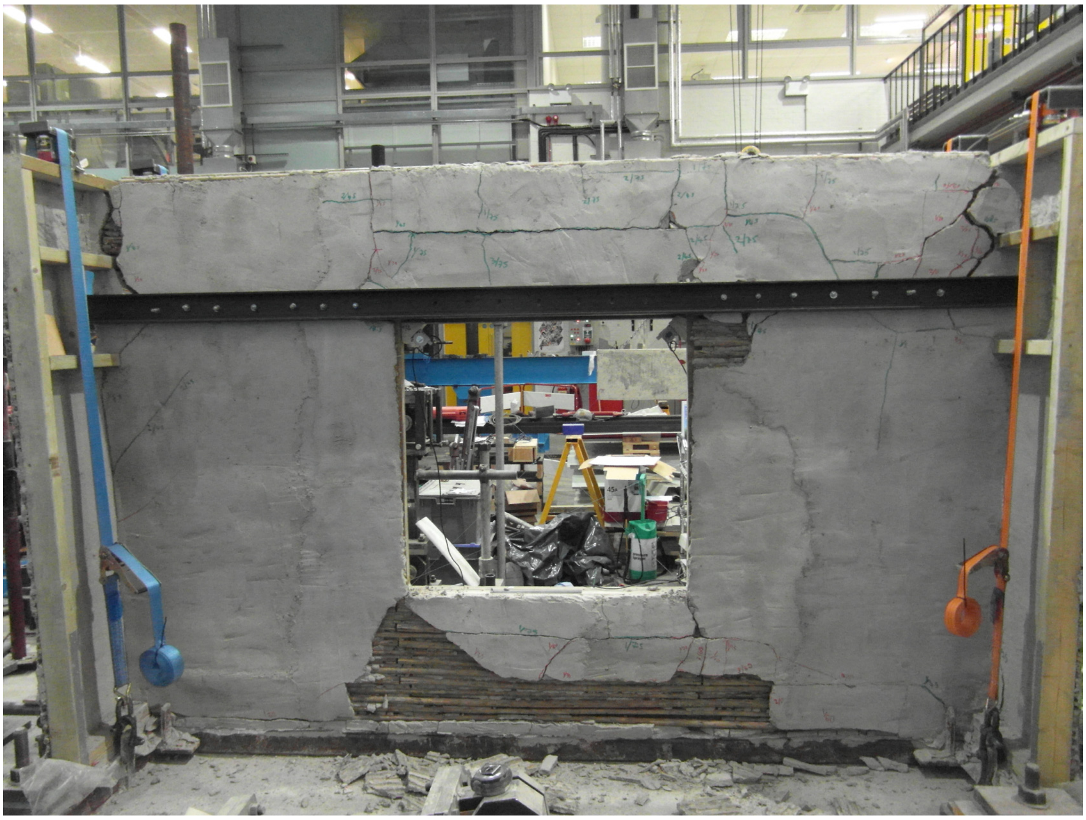

Figure 5: In-plane testing of wall panel at Imperial College London, 2013. Image shows typical damage state at failure, using single-sided chicken mesh only (Kaminski, 2012).

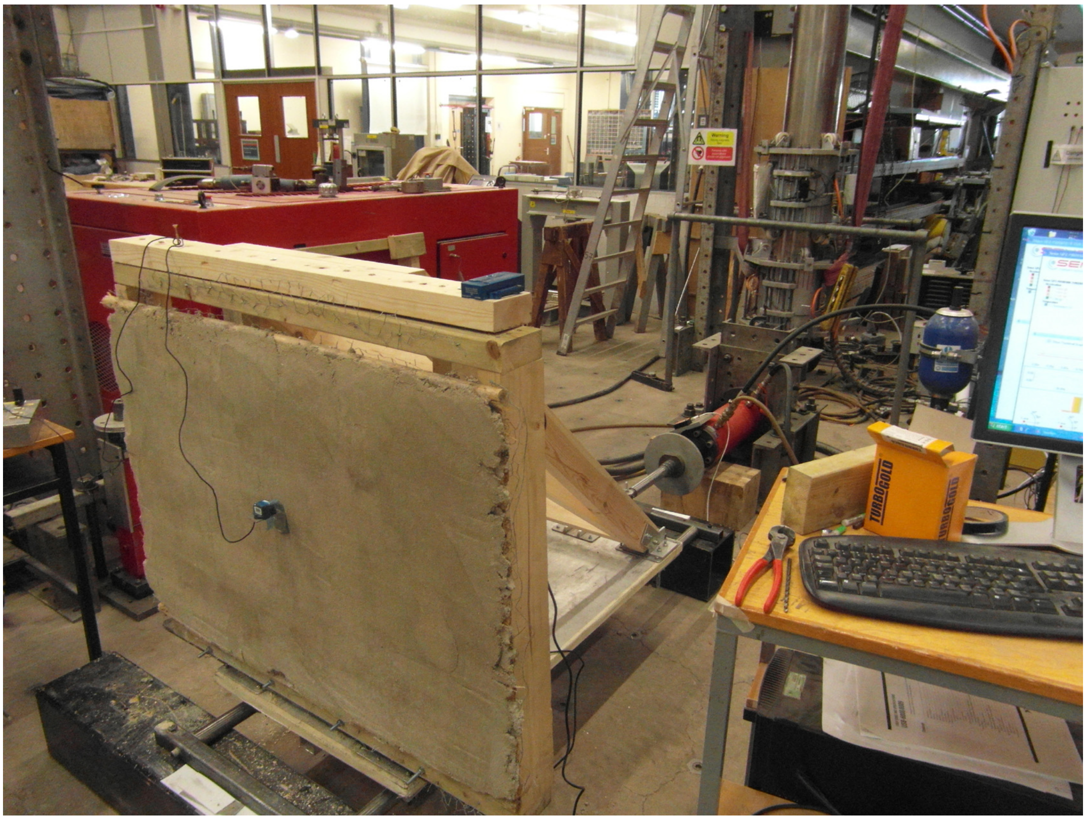

Figure 6: Set up for out-of-plane testing of wall panels on a uni-directional shake-table at Cambridge University (Kaminski, 2014).

Figure 7: Completed full-scale room of a house at the *Universidad Mariano Gálvez* in Guatemala City, ready for bi-directional shake-table testing (Kaminski, 2014).

The wall panels tested were 3 m long, 1.85 m high, and with 1 m return walls at each end, with most tests incorporating a 1 m × 1 m window (Figure 3). The panel dimensions matched the typical wall size to be used in the final design. The panel was bolted down to the lab floor along its length and on the wall returns, replicating the fixings in the final design. The load was applied via a loading beam situated with multiple bolts along its length (in order to distribute the load and avoid local crushing) and situated at ¼ down the height of the panel, in order to better replicate the actual centre of application of net horizontal load (and reduce the risk of a flexural failure occurring).

The panels were each tested under cyclic displacement control based on the EN 12512 protocol (CEN, 2005). The results of the tests concluded that, for drifts under 1%, the level of damage was considered acceptable and the panels showed relatively stable hysteresis, with reasonably good levels of energy dissipation (Figures 4a and 4b). Initial cracking occurred at 15–20 kN (drifts of ~0.1%), with the ultimate load achieving 37–50 kN (drifts of ~1.5%). Initial failure manifested itself by a combination of diagonal shear cracking and spalling of the side of the panel without mortar (Figure 5). The steel mesh was found to stabilise the diagonal compression strut in the remaining mortar, and the ultimate failure mode was local buckling and crushing of this mortar.

The test panels achieved the design horizontal load before the initial cracking load was reached. The design for the strength of the panels assumed no ductility reduction factor (i.e. to Eurocode 8 behaviour factor $q = 1$, or to IBC response modification factor $R = 1$). In addition, the relatively stable hysteresis demonstrates that these forms of panels have some ductility, in the region of an R value of 2 to 3 for drifts under 1% and assuming the elastic capacity is approximately 15–20 kN. In addition, the variables used in the tests, such as the mortar strength, were all lower bounds suggesting that the system will have some additional overstrength. The testing suggests that the panels more than meet the design capacity assumed, and that in future a response modification factor greater than 1 could be used.

Out-of-plane

For out-of-plane response, because the cane is placed horizontally, the only reliable load-path is using the cane flexurally. Testing at Cambridge University on their small uni-directional shake-table has been conducted in order to determine the failure mechanism and extent of spalling out-of-plane (Figure 6) (Davies, 2014). This is important as spalling can be dangerous to people and also reduces the capacity of the panel to resist in-plane loads. Static 3-point bending tests indicated that the mortar tensile capacity is more reliable than anticipated, and once the mortar has failed in tension the cane and the mortar on the compression side attempt to work compositely, until the bond between them breaks down and the cane resists the load flexurally by itself. The cane by itself was found to be able to resist loads greater than the full design out-of-plane load. The dynamic tests also indicated that the bond between the cane and the mortar was more reliable than expected, however that once the bond has failed the mortar may spall off quickly. This risk was shown to be reliably mitigated by introducing chicken mesh on both sides of the panel with through-ties connecting each face.

Full-scale shake-table testing

In early 2015 a bi-directional shake-table test of a room at full-scale built using the design will be conducted at the *Universidad Mariano Gálvez* in Guatemala City on their newly constructed 3 m × 3 m shake-table (Figure 7). The aims of the testing will be to provide evidence to potential donors that the house performs well in the design earthquake, as well as to verify the level of cracking in the frequent earthquake event.

Conclusion

The testing conducted so far provides evidence that such a house constructed using cane, timber and mortar has considerable ductility and exceeds the design capacity both in-plane and out-of-plane. The technology is also of comparable cost to the alternative blockwork housing yet is considerably more sustainable, is popular amongst the community and is simple to construct. With the correct treatment measures and detailing, it can also become a durable form of housing system with a lifespan exceeding 30 years.

References

Benito, M., Lindholm, C., Camacho, E., Climent, Á., Marroquín, G., Molina, E., Rojas, W., Escobar, J., Talavera, E., Alvarado, G., & Torres, Y. (2012). A new evaluation of seismic hazard for the Central America region. *Bulletin of the Seismological Society of America*, **102:** 504–523.

Chan, C. (2014). The mechanical properties of the local cane in El Salvador and its utilisation in wall matrix structure of bespoke housing. *MSc Dissertation*, Coventry University.

CEN (2005). *EN12512: Timber Structures – Test Methods.* Comité Européen de Normalisation, Brussels.

Davies, E. (2014). Out-of-plane shake table testing of cane and mortar walls. *Graduate Dissertation*, Cambridge University.

Elghazouli, A., Málaga-Chuquitaype, C., Lawrence, A., Kaminski, S., & Coates, K. (2013). Seismic testing of sustainable composite cane and mortar walls for low-cost housing in developing countries. *Project Report*, Institution of Civil Engineers, Research and Development Enabling Fund.

El Salvador Project 2012 (2012). Low-cost earthquake-resistant housing. *Project Report*.

Farbiarz, J. (2001). Behaviour of bamboo bahareque walls and assemblies. *Proceedings of the International Workshop on the Role of Bamboo in Disaster Avoidance*, Guayaquil, Ecuador, 98–105.

González, G., & Gutiérrez, J. (2003). Cyclic load testing of bamboo bahareque shear walls for housing protection in earthquake prone areas. Materials and Structural Models National Laboratory, School of Civil Engineering, University of Costa Rica.

Kaminski, S. (2013). Engineered bamboo houses for low-income communities in Latin America. *The Structural Engineer*, **91:** 14–23

López, M., Bommer, J., & Méndez, P. (2004). The seismic performance of bahareque dwellings in El Salvador. *13th World Conference on Earthquake Engineering*, Vancouver, Canada, paper no. 2646.

López, M., Bommer, J., & Pinho, R. (2004). Seismic hazard assessments, seismic design codes, and earthquake engineering in El Salvador. *Natural Hazards in El Salvador*, Geological Society of America, Special Paper 375, 301–320.

Málaga-Chuquitaype, C., Kaminski, S., Elghazouli, A., & Lawrence, A. (2015). Seismic response of timber frames with cane and mortar walls. *Structures and Buildings*, in press.

Ministerio de Obras Públicas (MOP) (1994). *Norma Técnica para Diseño por Sismo, Reglamento para la Seguridad Estructural de las Construcciones*. San Salvador, Ministry of Public Works of El Salvador.

UN-Habitat (2011). *Affordable Land and Housing in Latin America and the Caribbean*. Nairobi, UN-Habitat

USGS (2011). *Worldwide Seismic Design Values Database.* Available at: http://earthquake.usgs.gov/hazards/designmaps/wwdesign.php (accessed: April 2014).

Editor's note: As this issue was being prepared, the shake-table testing described in this paper was being carried out at the *Universidad Mariano Gálvez* in Guatemala City. The lead author of this article, Sebastian Kaminski, is providing updates from his Twitter account, @SebKamin. For more details about Twitter, refer to the editorial in SECED Newsletter, Vol. 24 No. 2.

Notable Earthquakes July 2013 – February 2014

Reported by British Geological Survey

Issued by: Davie Galloway, British Geological Survey, July 2014 and 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
2013	02	JUL	07:37	4.65N	96.67E	13			6.1	NORTHERN SUMATRA, INDONESIA
At least 42 people killed (with 6 still missing presumed dead), over 2,500 injured and over 20,000 buildings destroyed or damaged in the Bener/Meriah/Central Aceh area. Several landslides damaged roads, cutting off nine villages in the region.										
2013	07	JUL	18:35	3.92S	153.93E	386			7.3	PAPUA NEW GUINEA
2013	07	JUL	20:30	6.03S	149.71E	56			6.6	PAPUA NEW GUINEA
2013	15	JUL	14:03	60.86S	25.07W	11			7.3	SOUTH SANDWICH ISLANDS
2013	16	JUL	04:04	57.72N	5.72W	6	2.8			GAIRLOCH, HIGHLAND
Felt Gairloch and surrounding hamlets (3 EMS).										
2013	21	JUL	05:09	41.70S	174.34E	17			6.5	COOK STRAIT, NEW ZEALAND
Four people injured in Wellington and one in Kapiti. Minor damage reported to 35 buildings in Wellington. Localised power outages occurred in the region due to fallen power lines.										
2013	21	JUL	23:45	34.51N	104.26E	8			5.9	GANSU, CHINA
At least 94 people killed, over 1,000 injured and 5 still reported as missing, presumed dead. Over 1,970 houses collapsed and another 22,500 were damaged, 6 roads were damaged and communications were disrupted in Mianxian, Ahangxian and Lixian.										
2013	31	JUL	22:09	55.80N	6.39W	11	1.7			ISLAY, ARGYLL & BUTE
Felt Bruichladdich, Bowmore, Portnahaven, Braigo and Bridgend, Islay (3 EMS).										
2013	11	AUG	06:05	53.27N	2.32W	10	2.1			KNUTSFORD, CHESHIRE
2013	13	AUG	15:43	5.77N	78.20W	12			6.7	OFFSHORE COLOMBIA
2013	16	AUG	02:31	41.73S	174.03E	12			6.5	COOK STRAIT, NEW ZEALAND
Some minor injuries, homes and buildings damaged and power outages reported in Wellington, Marlborough and Seddon.										
2013	21	AUG	12:38	16.88N	99.50W	21			6.2	GUERRERO, MEXICO
One person injured and slight damage reported in the Acapulco area.										
2013	25	AUG	05:37	53.86N	3.38W	4	2.5			IRISH SEA
Felt in Fleetwood, Lancashire and in Barrow-in-Furness, Cumbria (2 EMS).										
2013	25	AUG	09:58	53.88N	3.40W	5	3.3			IRISH SEA
Felt in Fleetwood, Blackpool, Poulton-le-Fylde and Thornton-Cleveleys, Lancashire and in Barrow-in-Furness, Cumbria (3 EMS).										
2013	27	AUG	10:06	56.64N	4.37W	3	2.7			GLEN LYON, PERTH & KINROSS
Felt Bridge of Balgie, Inverar, Glenlyon and Dall (3 EMS).										
2013	30	AUG	16:25	51.53N	175.23W	29			7.0	ALEUTIAN ISLANDS
2013	31	AUG	00:04	28.24N	99.35E	8			5.6	SICHUAN/YUNNAN, CHINA
At least 5 people killed and 21 injured in Degen, Yunnan and Derong, Sichuan. Around 600 residential units collapsed and 55,000 damaged in the epicentral region displacing some 9,000 people.										
2013	31	AUG	01:19	55.62N	3.14W	5	1.8			PEEBLES, BORDERS
Felt Peebles, Innerleithen and Kirkton Manor (3 EMS).										
2013	31	AUG	06:36	53.89N	3.40W	10	2.6			IRISH SEA

			Time			Dep	Magnitude			
Year	Day	Mon	UTC	Lat	Lon	km	ML	Mb	Mw	Location
Felt in Cleveleys, Lancashire (2 EMS).										
2013	01	SEP	11:52	7.44S	128.22E	112			6.5	BARAT DAYA, INDONESIA
2013	03	SEP	06:44	56.36N	4.85W	3	1.7			DALMALLY, AGYLL & BUTE
2013	04	SEP	00:18	29.94N	138.84E	402			6.5	IZU ISLANDS, JAPAN
2013	04	SEP	02:32	51.56N	174.77W	20			6.5	ALEUTIAN ISLANDS
2013	07	SEP	00:13	14.61N	92.12W	66			6.4	GUATEMALA
2013	09	SEP	20:51	56.37N	4.81W	7	1.6			TYNDRUM, STIRLING
2013	24	SEP	11:29	26.95N	65.50E	15			7.7	PAKISTAN
At least 825 people killed, 619 injured, 300,000 displaced and over 146,000 houses destroyed or damaged in Balochistan. A mud volcano formed an island, which measured approximately 76 m (l) x 30 m (w) x 18 m (h), in the Arabian Sea around 600 m offshore Gwadar, Pakistan. A tsunami was also generated with maximum wave heights of 0.26 m recorded at Muscat, Oman.										
2013	25	SEP	16:42	15.84S	74.51W	40			7.1	OFFSHORE SOUTHERN PERU
2013	26	SEP	06:21	53.64N	1.00W	1	1.7			DONCASTER, S YORKSHIRE
2013	28	SEP	07:34	27.18N	65.51E	12			6.8	PAKISTAN
At least 22 people killed, over 50 injured and many houses either destroyed or damaged in Awaran.										
2013	29	SEP	08:54	59.58N	1.46E	27	2.8			NORTHERN NORTH SEA
2013	30	SEP	05:55	30.93S	178.32W	42			6.5	KERMADEC ISLANDS
2013	01	OCT	03:38	53.20N	152.79E	573			6.7	SEA OF OKHOTSK
2013	04	OCT	20:49	57.34N	4.44W	3	2.4			DRUMNADROCHIT, HIGHLAND
Felt Drumnadrochit, Dores, Westhill, Errogie, Brinmore, Farr, Scaniport, Culduthel, Torness and Inverfarigaog (3 EMS).										
2013	05	OCT	02:22	54.50N	3.01W	4	1.8			GRASMERE, CUMBRIA
2013	12	OCT	13:11	35.51N	23.25E	40			6.6	CRETE, GREECE
2013	15	OCT	00:12	9.88N	124.12E	19			7.1	BOHOL, PHILIPPINES
At least 222 people killed and 8 missing, presumed dead, on Bohol, Cebu and Siquijor Island. Some 1,000 people injured and 348,500 displaced; around 73,200 buildings, 18 roads, 41 bridges, 8 dams, 7 canals, 3 airports and 2 seaports either destroyed or damaged. At least 5 km of surface faulting observed in Inabanga, Bohol with as much as 3 m of vertical displacement. Damage estimated at $US 51.8 million.										
2013	16	OCT	10:30	6.45S	154.93E	35			6.8	PAPUA NEW GUINEA
2013	19	OCT	17:54	26.09N	110.32W	9			6.6	GULF OF CALIFORNIA
2013	24	OCT	19:25	58.15S	12.80W	23			6.7	SOUTH SANDWICH ISLANDS
2013	25	OCT	17:10	37.16N	144.66E	35			7.1	OFFSHORE HONSHU, JAPAN
2013	28	OCT	11:09	57.30N	2.31E	10	2.8			CENTRAL NORTH SEA
2013	31	OCT	12:02	23.59N	121.44E	10			6.3	TAIWAN
2013	31	OCT	23:03	30.29S	71.52W	27			6.6	COQUIMBO, CHILE
2013	16	NOV	03:34	60.26S	47.06W	10			6.9	SCOTIA SEA
2013	17	NOV	09:04	60.27S	46.40W	10			7.7	SCOTIA SEA
2013	23	NOV	07:48	17.12S	176.55W	371			6.5	FIJI ISLANDS REGION
2013	25	NOV	06:27	53.95S	55.00W	12			7.0	SOUTH ATLANTIC OCEAN
2013	28	NOV	13:51	29.32N	51.31E	8			5.8	SOUTHERN IRAN
Eight people killed, at least 200 injured and many buildings damaged in the Borazjan area.										
2013	01	DEC	09:48	60.73N	1.69E	24	3.4			NORTHERN NORTH SEA
2013	04	DEC	07:57	51.45N	8.92W	19	2.3			CELTIC SEA
Felt Timoleague, Courtmacsherry and Clonakilty, County Cork, Ireland (3 EMS).										

Year	Day	Mon	Time	Lat	Lon	Dep	Magnitude			Location
			UTC			km	ML	Mb	Mw	
2013	12	DEC	03:01	53.21N	1.04W	1	1.5			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2013	12	DEC	20:06	53.21N	1.05W	1	1.6			NEW OLLERTON, NOTTS
Felt New Ollerton (2 EMS).										
2013	16	DEC	02:31	53.21N	1.04W	1	1.7			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2013	17	DEC	15:06	53.22N	1.04W	1	1.5			NEW OLLERTON, NOTTS
Felt New Ollerton (2 EMS).										
2013	19	DEC	09:30	52.05N	3.66W	5	1.9			LLANWRTYD WELLS, POWYS
2013	26	DEC	01:37	49.20N	2.07W	7	1.8			JERSEY, CHANNEL ISLANDS
Felt Jersey (3 EMS).										
2013	28	DEC	23:45	53.20N	1.05W	1	1.5			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	01	JAN	16:03	13.86S	167.25E	187			6.5	VANUATU
2014	02	JAN	03:13	27.15N	54.45E	8			5.2	SOUTHERN IRAN
One person killed and 30 others injured in Bastak, Hormozgan Province, Iran.										
2014	16	JAN	17:09	59.48N	1.50E	8	2.8			NORTHERN NORTH SEA
2014	19	JAN	05:22	53.20N	1.05W	1	1.6			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	21	JAN	06:39	60.97N	4.45E	10	2.8			SOUTHERN NORWAY
2014	21	JAN	10:12	54.89N	3.25W	7	2.1			WIGTON, CUMBRIA
2014	23	JAN	04:32	61.27N	4.46E	10	3.0			SOUTHERN NORWAY
2014	24	JAN	03:58	53.21N	1.05W	1	1.6			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	26	JAN	03:50	53.20N	1.05W	1	1.7			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										
2014	26	JAN	15:22	53.74N	1.18E	4	2.3			SOUTHERN NORTH SEA
2014	30	JAN	10:04	53.20N	1.05W	1	1.6			NEW OLLERTON, NOTTS
Felt New Ollerton (2 EMS).										
2014	02	FEB	09:26	32.91S	177.88W	44			6.5	KERMADEC ISLANDS
2014	07	FEB	04:06	53.20N	1.03W	1	1.6			NEW OLLERTON, NOTTS
Felt New Ollerton (2 EMS).										
2014	07	FEB	08:40	15.07S	167.37E	122			6.5	VANUATU

			Time			Dep	Magnitude			
Year	**Day**	**Mon**	**UTC**	**Lat**	**Lon**	**km**	**ML**	**Mb**	**Mw**	**Location**
2014	12	FEB	09:19	35.91N	82.59E	10			6.9	XINJIANG, CHINA
2014	17	FEB	17:52	53.21N	1.03W	1	1.7			NEW OLLERTON, NOTTS
Felt New Ollerton (2 EMS).										
2014	18	FEB	09:27	14.67N	58.93W	15			6.5	BARBADOS
2014	20	FEB	13:21	51.36N	4.16W	4	4.1			BRISTOL CHANNEL
Felt throughout Devon and South Wales (5 EMS).										
2014	25	FEB	07:55	49.80N	0.01E	5	2.5			ENGLISH CHANNEL
2014	25	FEB	09:23	49.76N	0.07E	5	2.4			ENGLISH CHANNEL
2014	28	FEB	01:58	53.20N	1.03W	1	1.6			NEW OLLERTON, NOTTS
Felt New Ollerton (3 EMS).										

Forthcoming Events

Date	Venue	Title	People
25/2/2015 at 18:00	Institution of Civil Engineers, 1 Great George St, London	*Seismic Restraint and Bracing for Non-structural Building Components*	*Speaker*: **Martin Deveci** (Acrefine Engineering) *Organiser*: **Ian Smith** (Atkins)
18/3/2015 at 18:00	City University London, Room B104, Northampton Square, London	*The Dynamics of Rocking Isolation (jointly organised with Research Centre for Civil Engineering Structures)*	*Speaker*: **Nicos Makris** (University of Central Florida) *Organisers*: **Andreas Kappos** (City University)
25/3/2015 at 18:00	Institution of Civil Engineers, 1 Great George St, London	*Recent Applications of Post-Tensioning Techniques to Multi-Storey Timber Buildings*	*Speaker*: **Alessandro Palermo** (University of Canterbury) *Organisers*: **Damian Grant** (Arup)
9–10/7/2015	Homerton College, Cambridge, UK	*SECED 2015 Conference: Earthquake Risk and Engineering towards a Resilient World*	See conference website for further information: http://www.jillrogersassociates.co.uk/seced-home.html

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

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. Hard copy manuscripts are also welcome.

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