STSM scientific report:
Potential of use of innovative dissipaters and isolators in cross-lam buildings

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by

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1 Purpose of the visit

In frame of my current PhD research project, starting in 2010 with collaboration of University of Trieste, Italy and CNR-IVALSA research institute from San Michelle all'Adige in Italy, an extensive experimental programme on typical cross-laminated timber (X-Lam) connections and X-Lam shear wall panels has been conducted. The aim of this research project is to understand better the seismic behaviour of cross-laminated timber buildings and energy dissipation capacity of subassemblies such as shear walls and connections between cross-lam structural elements. In addition, experimental results were used to calibrate newly developed theoretical numerical models, developed at the University of Trieste, which are being used for numerical analyses of seismic behavior of X-Lam buildings. Furthermore, analytical models of connections behavior (1-D models), wall behavior (2-D models) and building behavior (3-D models) are being developed.

Cross-laminated timber panels (X-Lam) are very rigid in comparison to the anchoring connections and connections between panels, so the most of the flexibility and energy dissipation during earthquakes are concentrated in connections, such as nails, screws, metal hold-downs and angle brackets. In general, earthquakes and other large disturbances cause a significant and damaging structural dynamic response, often nonlinear in nature. That’s why energy dissipation capacity of buildings is a very important factor while assessing their seismic resistance.

A purpose of my Short Term Scientific Mission at the University of Canterbury in New Zealand under the supervision of prof. Geoff Chase was to study the potential of use of innovative dissipaters and isolators in cross-lam buildings. Possible implementation of dissipaters and seismic isolators into multi-storey X-Lam buildings could reduce the impact of earthquakes and consequently reduce the damage of X-Lam buildings during such events. It would be a step further in the development of this construction system.

In addition, the purpose of my visit was to exchange knowledge of my research project and ongoing and recent research projects at the University of Canterbury. In scope of that, attendance of seminars and meeting was planned, visit of the University laboratories and giving a seminar on my PhD research topic to students and professors from the College of engineering.

2 Description of the work carried out during the visit

During my visit at the University of Canterbury, my work was divided in two parts:
i) exchanging knowledge with students, researchers and professors at the department of Civil engineering;
ii) working on the project of potential of use of innovative dissipaters and isolators in cross-lam buildings under the supervision of prof. Geoff Chase and Dr. Geoff Rodgers from the department of Mechanical engineering and prof. Massimo Fragiacomo, my PhD supervisor.

2.1 Exchanging knowledge with students, researchers and professors at the deparmtnet of Civil engineering

- Getting familiar with the previous research done in the timber engineering area at the department of Civil engineering. Literature review and evaluation of a current stage of ongoing research projects.

- Experimental, analytical and numerical research done on earthquake behavior of multi-story cross-lam buildings during my ongoing PhD program was presented to the board of professors from timber section of Civil engineering department and to their students at the seminar: Seismic analysis of cross-laminated timber buildings. The seminar took place at the College of Engineering, Department of Civil Engineering, July 23rd 2012.

- I attended the Workshop on Earthquake Engineering: Using Timber in the Re-build of a Resilient Christchurch, University of Canterbury, July 20th 2012. This workshop was consisted of on-site tour of earthquake damaged Christchurch with visit of damaged areas and new construction sites; and lectures on various seismic topics in timber engineering.

- Guided visit of Civil engineering laboratories, getting familiar with the experimental research projects and participation at experimental tests on gravity loading of post-tensioned LVL frame (performed by PhD candidate Wouter van Beerschoten) and tests on energy dissipation devices (performed by PhD candidate Francesco Sarti).

- Attended the Postgraduate Research Proposal Presentation Session on July 25th 2012. PhD research proposals and Msc research proposals were presented and discussed by candidates from the timber section of Civil Engineering department. Detailed discussion on CLT post-tensioning topic with Msc candidate Andrew Dunbar.

2.2 Working on the project of potential of use of innovative dissipaters and isolators in cross-lam buildings at the department of Mechanical engineering

- Getting familiar with the previous research done by prof. Geoff Chase and Dr. Geoff Rodgers at the Mechanical engineering department at the University of Canterbury. Literature review and evaluation of the current stage of the ongoing research projects. Theoretical background of the newly developed dissipating systems was studied.

- Studying prof. Chase's university course literature: ENME 432 – Vibrations, ENME 303 - Control Systems, ENME 433 - Modern Control Systems.

- A conceptual design of the possible implementation of dissipating systems to the X-Lam buildings was discussed at regular meetings with the hosts from Mechanical engineering department and with my PhD supervisor.

- Experimental data of 1-story, 3-story and 7-story SOFIE buildings was studied in order to be able to implement correct parameters into the numerical model for dynamic analysis of these reference buildings.

- Getting familiar with Matlab software with implemented sub-programs, developed at the Mechanical engineering department, for dynamic analyses of structures and different approaches of implementation of energy dissipation devices, seismic isolation of buildings, implementation of tuned mass dampers, etc. I used these sub-programmes to create numerical models of 1-story and 3-story SOFIE building with intention to perform dynamic analyses and compare numerical results with the experimental results, obtained with cyclic, pseudo-dynamic and dynamic experimental tests. Once the results from numerical models will match good enough with experimental results, these numerical models will be used to perform additional analyses with seismic improvement implementations (added masses at the top of buildings known as tuned mass dampers, seismic isolation, special viscous or friction energy devices, etc).

- Linear dynamic response and damping capacities of X-Lam construction system with implemented dissipative techniques were studied.

3 Description of the main results obtained

Innovative techniques for improvement of global dynamic behaviour of buildings were studied. Techniques such as passive base isolation systems, tuned mass dampers, energy dissipaters, etc. were examined for the case of X-Lam buildings with a special aim to develop strategies to reduce accelerations on top of the X-Lam buildings. Recent full scale experimental dynamic tests on this type of construction system (3-story and 7-story SOFIE building) showed very promising dynamic behaviour except for relatively high accelerations on top of the buildings. Reference buildings were numerically modelled in Matlab software using sub-programmes developed at the Mechanical engineering department of University of Canterbury. Current stage of numerical modeling is calibration of input parameters of numerical model in order to obtain matching results with experimental tests on full scale SOFIE buildings. Final results will be published in journal paper and in author's PhD thesis (see section 5).

4 Future collaboration with host institution

A collaboration with the host institution will continue in following months due to planned journal paper publication (see section 5). Regular Skype meetings and communication through e-mail are planned.

5 Projected publications resulting from the STSM

As a result of this short term scientific mission a journal paper is planned to be published. This paper will explore the use of innovative techniques (passive base isolation systems, tuned mass dampers, energy dissipaters, etc) to improve global dynamic behaviour of X-Lam buildings. Strategies to reduce accelerations on the top of X-Lam buildings will be examined. Benefits of existing X-Lam construction system with addition of the newly developed dissipaters will be studied and evaluated. 3-story and 7-story SOFIE buildings which were tested on shaking tables in Japan in years 2006 and 2007 will be used as reference buildings. More extensive analysis of aforementioned topic will be published in the author's PhD thesis (predicted publication: April 2013).

6 Acknowledgments

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Appendix

1. Confirmation by the host institute of the successful execution of the mission. (enclosed .pdf file)