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Timber Framed Masonry buildings, an earthquake resistance influenced traditional architecture

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Summary

- 1. Introduction
- 2. Study on existing buildings
- 3. Retrofit solution for heritage buildings with TFM structure





Timber framed masonry (TFM) buildings in non-seismic countries



Germany



Czech Republic



Denmark



United kingdom





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Recent earthquakes showed TFM houses exhibit slight to moderate, but don't usually collapse. The damages are due to poor construction details and/or biological degradation. Out of plane collapse of the masonry panels also occurred, without producing total collapse.



Lushan 2013 earthquake, China [Qu Z., Dutu A., Zhong J. Sun J., (2014) "Seismic Damage of Masonry Infilled Timber Houses in the 2013 M7.0 Lushan Earthquake in China", Earthquake Spectra In press]



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Poor construction details for the connections



 Lushan 2013 earthquake, China [Qu Z., Dutu A., Zhong J. Sun J., (2014) "Seismic Damage of Masonry Infilled Timber Houses in the 2013 M7.0 Lushan Earthquake in China", Earthquake Spectra In press] Less than 5% of TFM houses (Gingerbread) collapsed. The rest of them experienced light to moderate damages, just like in the Lushan earthquake, most likely due to poor construction details.



Port-au-Prince 2010 earthquake, Haiti [Langenbach R., Kelley S., Sparks P., Rowell K., Hammer M., Julien O. J. (2010), "Preserving Haiti's Gingerbread Houses", 2010 Earthquake Mission Report]

Experimental study on TFM mechanical behaviour – Tokyo Tech





Loading protocol – CUREE – Caltech standard protocol



Hysteresis of the TFM wall (S2 specimen)



Component materials tests













Experimental study vs. FEM analysis



Conclusions:

- TFM is very ductile! The masonry ensures strength and stiffness, while timber is responsible for the significant deformation capacity;
- ▶ The key points are the weak mortar and the embedment of the timber;
- Numerical modeling with FINAL software was successful, but it needs to be simplified.
- Considering the fact that for some countries the TFM are important heritage... we must protect them even from experiencing those light to moderate damages. So we further focused on a strengthening method using AFRP sheets.

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S4





S5





Conclusions:

- ► AFRP retrofit is beneficial for strength and stiffness of TFM;
- It is a suitable method for TFM walls located at the interior of the building, or if they are covered with finishing;
- FRP is very easy to apply;
- Simplified evaluation method estimates the contribution of the application of one AFRP strip as an increase of almost 15 kN to the shear strength of the wall;

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Design method will further be developed.

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