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Innovative bracing for durable structures

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Across the world, severe earthquakes regularly shake entire regions. More than two billion people live in danger zones – many of them in structures not built to withstand an earthquake. Together with partners from industry, researchers at the Fraunhofer Institute for Wood Research WKI are developing building materials designed to prevent buildings from collapsing in a natural disaster.

Earthquakes repeatedly claim too many lives, a fact that experts trace back to a lack of preventative measures – particularly when it comes to construction and the failure to comply with standards. All too often, structures in danger areas are not built to withstand an earthquake – a state of affairs that the Center for Light and Environmentally-Friendly Structures of the Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut WKI, is now urgently seeking to address. Working together with the Technical University of Braunschweig's Organic Building Materials and Wood Materials division from the Institute for Building Materials, Concrete Construction and Fire Protection, as well as industry partners such as the company Pitzl Metallbau from Altheim, the researchers are developing solutions for the construction industry that could save thousands of lives. Currently, the engineers at Fraunhofer WKI are working on ultra-durable bracing that will protect even high-rise buildings during an earthquake. The bracing consists of sensor-controlled steel connectors that provide a high level of rigidity while remaining elastic enough to maintain structural integrity in the face of severe shaking. Numerous tests have demonstrated that the connectors work exactly as intended. In one test, the researchers investigated the nature of the stress being placed on structures by applying static, cyclical and dynamic forces; in another, the structure's service life was tested using environmental simulation. The approach is based on the successful EU SERIES project, which examined earthquake-resistant structures under dynamic loads.

Structures that sway but do not fall

The earthquake-resistant bracing has been designed for buildings with a mullion-and-transom design, and connects the horizontal beams with the vertical post. When exposed to wind or tremors, the connectors must be rigid enough to keep deformation to a minimum – but also elastic enough to withstand strong earthquakes. If deformation does occur, it does not lead to critical stress – in other words, the building sways, but does not collapse.

In an earthquake, the connectors slide over each other, converting kinetic energy into frictional energy – and preventing the building from collapsing. Norbert Rüther, project manager at Fraunhofer WKI, explains: "The trick is using friction to dissipate the force. The individual parts of the connector are pressed against one another applying a significant, pre-defined force. When the specified stress limit is exceeded, they begin to slide over each other." As a result, it is possible to accommodate structural deformation without compromising structural integrity. Even after a strong earthquake, such a structure maintains the same capacity as before, and is still able to cope with the stress placed on a multistory building. This means that buildings can withstand several quakes without suffering significant damage. In a sense, they surf the earthquake wave. "All the weight-bearing, safety-critical materials are just the same after the earthquake as they were before it," says Rüther.

Installing the bracing within a building is a simple task, and it does not require any maintenance. On top of this, the Fraunhofer Institute for

Surface Engineering and Thin Films IST has developed pressure and temperature sensors integrated into the connector, which means it is possible to measure the forces and stress associated with an earthquake.

A case for the use of wood in high-rise buildings

Fraunhofer WKI has developed its bracing connectors so that they can be set to accommodate the requirements of the individual application – the way in which bolts are attached and tightened, for instance. It is also possible to adjust the connector geometry to suit the size of the structure and the materials used. Rüther: "Our high-performance connectors are compatible with any material and support structure – including concrete, steel, brick and wood." He makes a case for using wood in multistory buildings. "Wood is extremely durable, light but still stable, and perfect for earthquakes. In its mechanical properties, it compares very well with highly durable composites – though at a significantly lower material cost." Most countries are skeptical of using wood in such cases, citing the danger of fire. However, there are already good solutions that counter this threat. Solid wood elements with large profiles, for instance, are highly resistant to fire and can preserve their load-bearing integrity even after hours of exposure to fire.

The connectors are currently in the prototype stage, and are expected to be ready for full-scale production in one to two years. Currently, the experts are exploring the connectors' economic viability with a view to testing in real buildings. Since all the other components are exposed to linear-elastic stress, there is no need for any further safety contingency – in turn boosting the overall cost-effectiveness of the structure.

Provided by Fraunhofer-Gesellschaft

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