RECENT RESEARCH ON TALL AND HYBRID WOOD STRUCTURES

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The structural use of wood in North America so far was mostly related to low-rise and mid-rise residential light-frame construction. Lately, legislative changes and the emergence on new mass-timber engineered products enable the use of wood in tall and large buildings. Two of the most promising solutions involve the notions of “mass-timber” such as cross-laminated timber (CLT) and hybrid construction such as timber-steel and timber-concrete systems. The prospect of building larger timber structures creates challenges, amongst them the increased lateral forces created by wind and earthquakes and the increased demand on floor serviceability. The presentation will discuss the state-of-the-art research on the challenges and innovative solutions of adopting mass timber structural systems.

ENHANCEMENT OF BOND IN CONCRETE REPAIRS THROUGH FIBER REINFORCEMENT

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Concrete-concrete bond becomes a relevant topic when new concrete layers are cast against existing reinforced concrete members for repair, strengthening, or seismic retrofit of structures. Poor bond can jeopardize overall mechanical performance and durability, and is caused by improper surface preparation (that is, inadequate roughness, cleanliness, and soundness), poor concrete placement, or lack of compatibility. Introducing fiber reinforcement in the new concrete layer can improve both structural performance and durability. Fibers increase crack growth resistance, mitigate the effects of poor compatibility (such as mechanical, shrinkage, or thermal incompatibility), and thus prevent damage propagation since early age. A few studies have shown that also concrete-concrete bond is improved by fibers; however, comprehensive data are required to understand fibers' bond enhancing mechanisms and quantify these effects for structural applications.

In this study, shear bond strength between a plain concrete substrate and fiber reinforced repair mortars is investigated. Poly-Vinyl-Alcohol (PVA) and steel fibers are compared. Bond strength is assessed through Modified Slant Shear Cylinder (MSSC) test with different bond plane inclinations, corresponding to different normal-shear stress ratios. Cohesion and friction coefficients are extrapolated from experimental results using the Mohr-Coulomb approach. The main objective is to assess the effect of fiber reinforcement on concrete-concrete cohesiveness (pure shear strength), a relevant factor for durability and for applications with limited or no compressive stress at the interface. Cohesion is plotted in Figure 1 as a function of fiber reinforcement and interface treatment (sandblasted with maximum depth of 4 mm vs smooth).

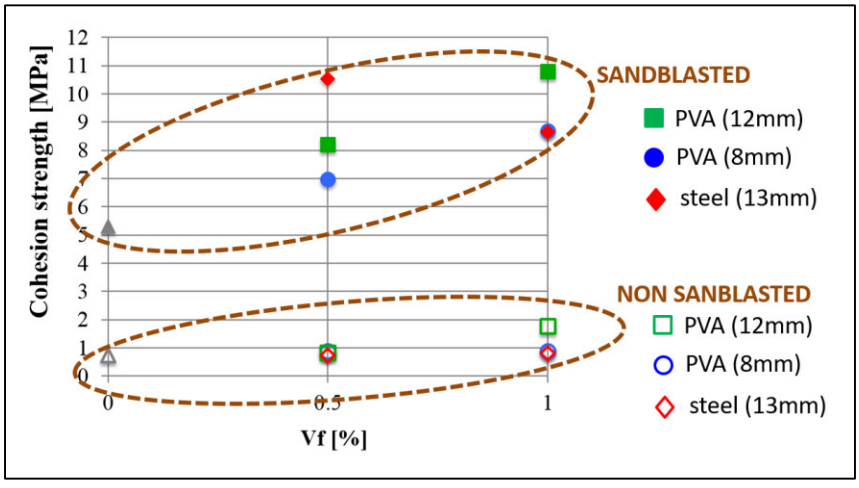

Figure 1: Cohesion strength vs fiber volume fraction (V_f)[1,2]

Major results can be summarized as follows[1,2]:

- Steel fibers increase cohesion strength up to 98% in sandblasted interfaces. A dowel mechanism is observed in the fibers at the concrete-concrete interface after failure;

- In sandblasted interfaces, PVA fibers offer a substantial increase of interfacial adhesive bond strength (from 5 MPa up to 11 MPa), resulting from micro-crack deviation and blunting, as well as from minimization of shrinkage cracking and operational damage;

- With sandblasting, interfacial roughness promotes deviation of the fracture plane from the bond plane and fibers are thus intersected and activated at failure. Furthermore, interlocking, overriding, and localized crushing are promoted by the tortuosity of the interface. In smooth interfaces, those slip resisting mechanisms are not activated, and, as a result, cohesiveness is lower, the effect of fiber reinforcement is mostly negligible, and poor statistical confidence is obtained.

[1] Zanotti C, Banthia N, Plizzari G (2014) A study of some factors affecting bond in cementitious fiber reinforced repairs. Cement Concrete Res 63:117-126.

[2] Rostagno G, Tingley B, Zanotti C (2017) Bond strength of steel FRC repairs to concrete substrate: investigation on adhesion strength, friction, and bond enhancing mechanisms. fib Symposium, Maastricht (NL), June 12-14, 2017.

ASSESSMENT OF CONFINEMENT EFFICIENCY IN FRP RETROFITTED CONCRETE COLUMN

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Keywords: FRP; confinement efficiency; concrete column.

The mechanical behavior of concrete with FRP confinement has been widely investigated within the latest two decades. The confinement efficiency, which is key feature for the design, was assessed from the point of strength in the past. In this study, the plasticity-based method was developed for the confinement efficiency classification criterion, in which the mechanical behavior due to different confinement level can be evaluated from the perspective of strength and ductility. This work initially targeted the circular column. With the develop of first true-triaxial testing system fitting FRP confinement characteristic in Tongji University, it has built the possibility of assessment the confinement efficiency within non-circular column. For the new test system in Tongji, key issues have been solved, such as biaxial passive confinement apparatus and end-friction reduction. Since the achievement of 3D constitutive test, the stress-strain model has been developed. Furthermore, the numerical approach for obtaining the principal confinement stiffness distribution was used to achieve an analytical stress-strain model for FRP confined concrete of square section with different corner radius. With assistant of the triaxial data-based approach, it can not only directly capture the axial stress-strain behavior of FRP confined square section with different corner radius, but also unveil the characteristics of effective confinement filed under FRP confinement associated with the confinement efficiency classification criterion. Compared with traditional arching action method, the assessment method demonstrated its advantages on unveiling the correlation between the confinement field within the section and the mechanical behavior.

TIMBER STRUCTURAL SYSTEMS FOR LOW SEISMIC DAMAGE

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Around the middle of the last decade, research was initiated in New Zealand on applications of post-tensioning in structural members made of engineered wood products. The capacities of connections are increased due to post-tensioning and the arrangement is self-centering once loads are removed. Additional replaceable mild steel elements are used for seismic loading, which absorbs energy during seismic events but protects the main structural members from serious damage. Engineered wood products have been found to be particularly suitable for this type of application because of their superior strength characteristics compared to rough sawn timber, and the concept has been applied to different engineered wood products such as Laminated Veneer Lumber (LVL), Glue Laminated Timber (Glulam) and Cross Laminated Timber (CLT). One of the common energy dissipating connections consists of axially loaded steel bars. A high level of deformation can be achieved by these elements with the possibility of replacing them after a major earthquake. Initiatives are currently underway to utilize the concept in Canada with locally available materials and expand the possibilities of applications through further understandings and new developments.

As part of a comprehensive research investigation into the development of innovative seismic resisting systems for timber construction, a number of different hybrid solutions for frame and wall systems have been successfully tested for implementation in multi-storey LVL buildings at the University of Canterbury, Christchurch, New Zealand. The tests confirmed the behaviour of the assemblies as well as the feasibility of adopting the system in a building structure. With increasing acceptance of multi-storied timber buildings, further developments of the technology are currently underway. Building on the knowledge of the subassemblies and basic systems advanced structural systems with different arrangements of members and connections are being explored. One of the objectives of the research is to investigate the prospects of low-damage structures with wood in the context of expectations and realities of society regarding performance of structures during earthquakes. The study covers post-tensioned structural systems for Hybrid (wood with steel or concrete) buildings. Implementation issues with post-tensioned timber structural systems are also investigated to provide details for practical applications of the proposed solutions.

Based on recent experiences in other countries such as New Zealand and Chile, the concept of structures that exhibit low seismic damage is very appealing, and this needs to be considered seriously for future applications. This research presents the benefits and facilitates adoption of the low-damage philosophy in design of timber structures through knowledge and details useful for practical applications.