Short report for the research project

Fire behavior of primary beam- secondary beam connections in timber structures

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1 Objective and initial situation of the research project

General regulations and normative design methods for assessing the fire safety of engineered joist to beam and joist to column connections are rare, respectively do partly not exist. Commonly, the assessment of engineered shear force connections in timber structures can only be done by experimental tests. Due to the high costs of this approach, the load bearing capacity of such connections is often inadequately taken into account.

General statements regarding the behavior in fire, failure mechanisms, calculation methods, detailing and the fire resistance are only available to a minor degree. Objective of this research project therefore is to investigate the thermo-mechanical behavior of typical shear-force timber connections, on this basis derive recommendations on calculation, design and get a comprehensive understanding of the properties of timber connections exposed to fire. Typical existing connection types are assessed, and protection measures as cladding an fire protective coating are investigated as necessary.

2 Realization of the research project

The initial step of the investigation was to gather typical boundary conditions, types of application, sizes and load carrying capacities of shear force timber connections, especially joist hangers and full thread screws. Based on that compilation, a range of typical and representative specific connections types was selected. Full thread screws are mounted as crosswise applied pairs, joist hangers with rink shank nails and screws (Figure 1).

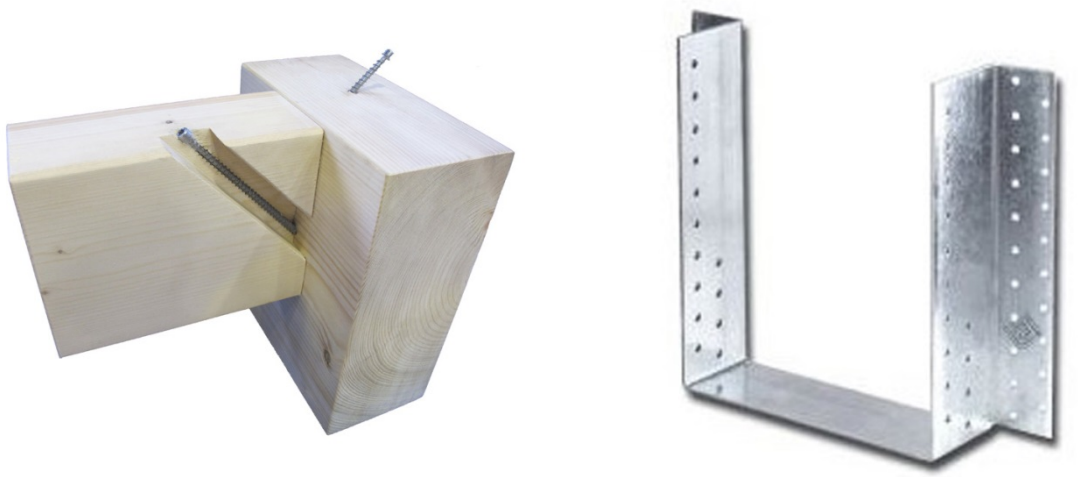

Figure 1: Examples for connections with joist hangers or pairwise crossed full thread screws. (source: GH Baubeschläge)

The selected types of connections have been assessed in unloaded fire tests using a range of boundary conditions as sizes and other geometrical parameters. Aim of these tests was to determine influencing factors on the temperature distribution, fire loss, and the expected load bearing capacity after fire exposure. The test configuration consisted of a set of U-shaped specimens made of CLT, which short glulam beams mounted on their inner sides. The connections were equipped with thermocouples and exposed to fire over 30 minutes and 60 minutes respectively (Figure 2).

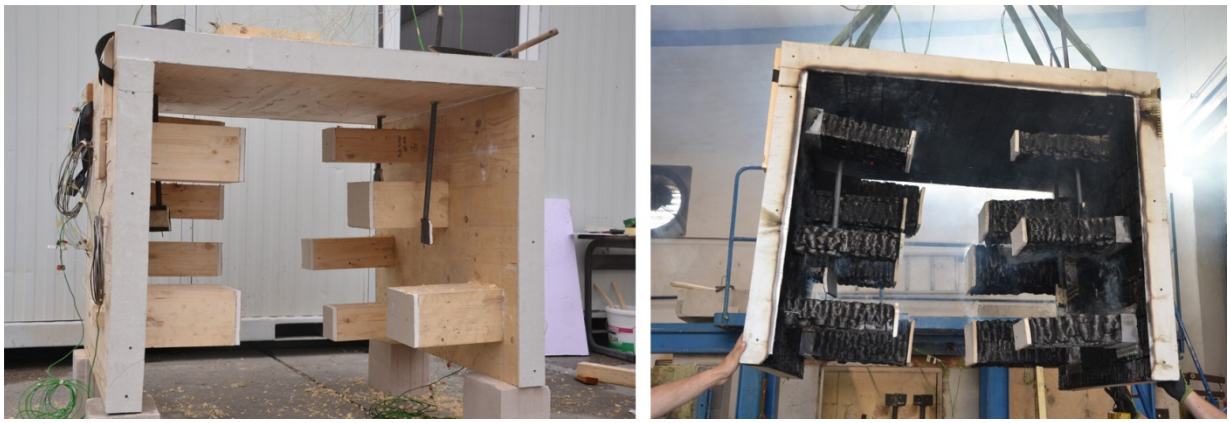

Figure 2: Specimen for the unloaded fire tests. Left: before the test, Right: After the test.

Based on the test results, substantial knowledge on the thermal behavior could be gained. Recommendations were made, which types, sizes, and geometries of connections are predictably able to bear sufficient loads in the following loaded fire tests. Several versions could be excluded on this time, clear statements on necessary boundary conditions made for the others. Regarding the full thread screws, recommendable side distances, timber coverages, and mounting angles were determined.

A further preparatory measure was to investigate the withdrawal capacity of screws in relation to the temperature and angle to the grain by experimental tests (Figure 3).

Figure 3: Investigation of the pull out resistance of full thread screws in regard to the temperature

The next step of the research project was the planning, realization and evaluation of nine loaded fire tests over 30 and 60 minutes with connections selected by the results of the unloaded tests. Aim was to determine the load bearing capacity and the load bearing behavior during fire exposure (Figure 4, Figure 6, Figure 7). The loaded T- shaped specimens were assembled each of a primary beam and a secondary beam, they were supported on three points and fixed against lateral buckling (Figure 4). The length of each primary beam was 2000 mm and of each secondary beam 1200 mm. The relative vertical displacement at the connection was measured by two displacement transducers fixed on the primary and secondary beam. The load was applied by a force controlled hydraulic cylinder mounted on a steel frame. A constant load of 40 % of the estimated capacity after fire exposure was applied during the time of classification (30 resp. 60 minutes). At the end of this timespan the load was increased until the connection reached failure. The load was measured by a load cell and logged during the test time (Figure 5). This proceeding enables the identification of the load bearing capacity of the connection after an aspirated time of fire exposure. Based on that data, reduction factors for the load bearing capacity under fire exposure were calculated.

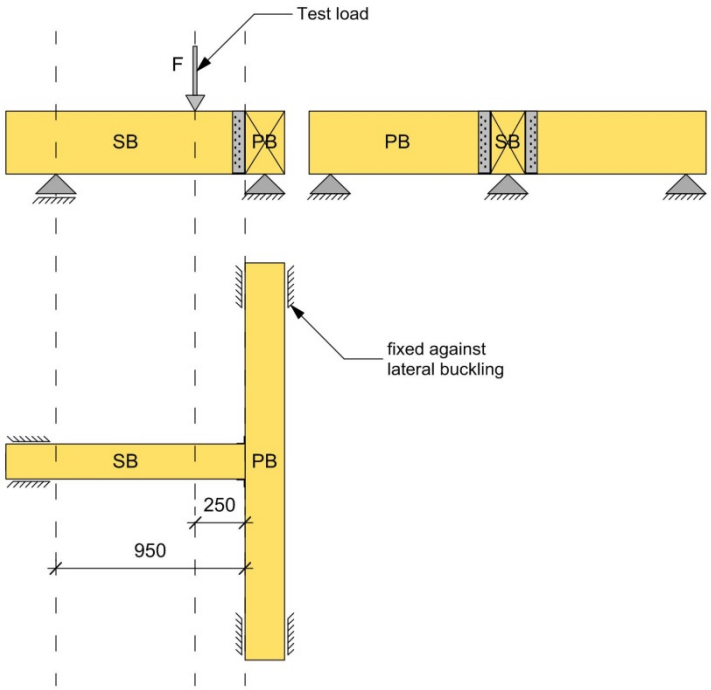

Figure 4: Specimen for the loaded fire test

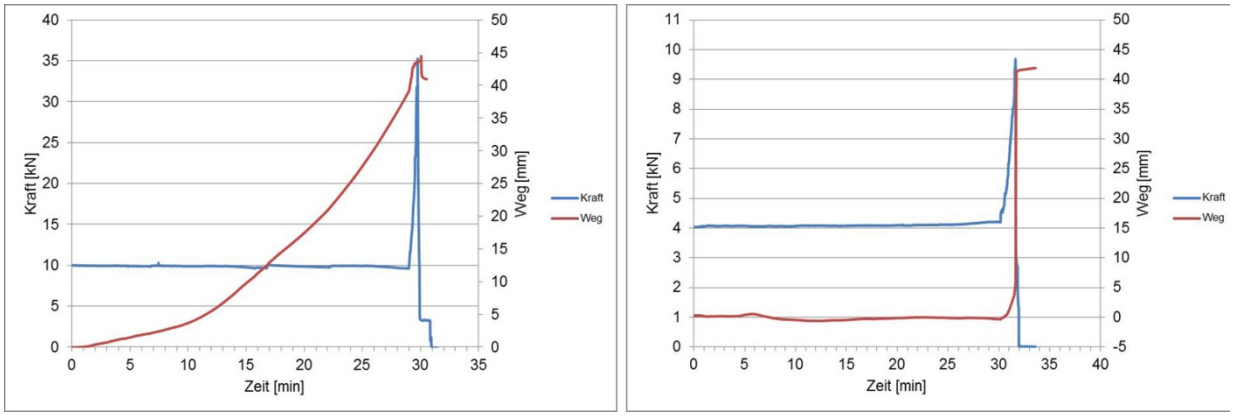

Figure 5: time-force und time-displacement diagram of the loaded fire tests, left side: for a connection with joist hanger, right side: for a connection with pairwise crossed full thread screws

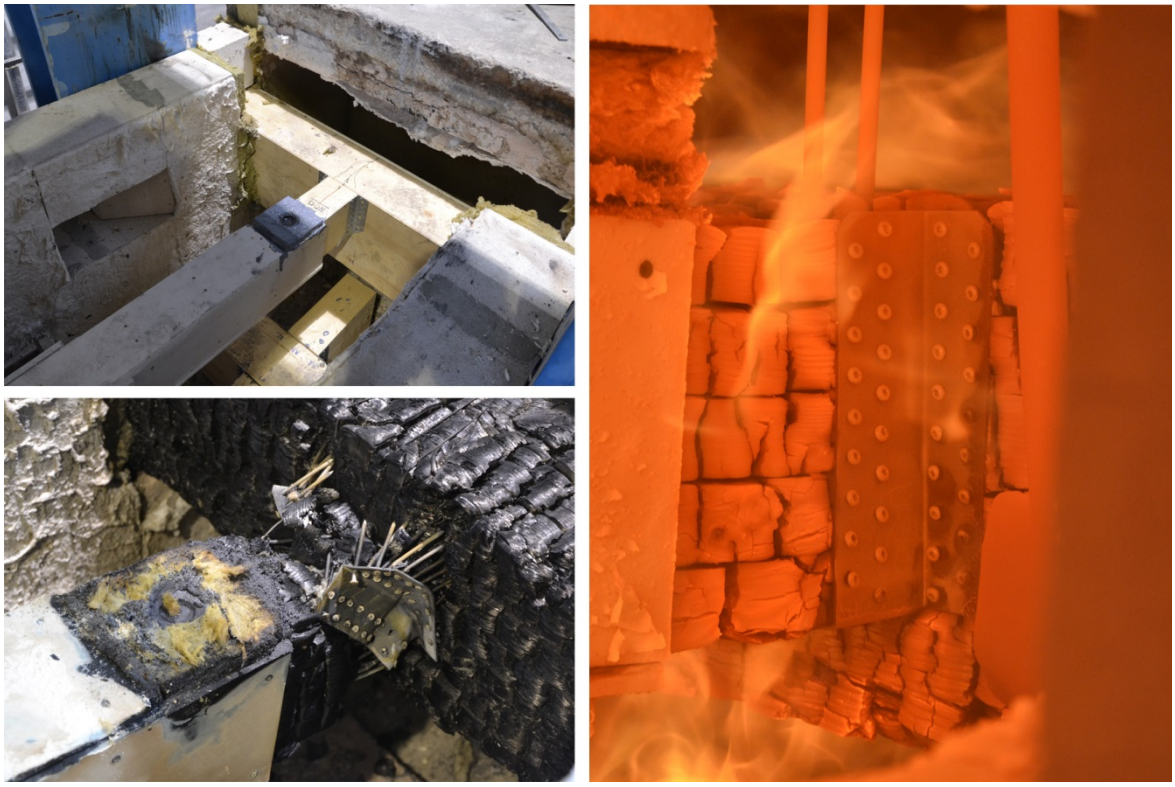

Figure 6: fire tests with joist hangers: left side: one specimen before and after the test, right side: Looking into the furnace during the test

Figure 7: fire tests with pairwise crossed full thread screws: left side: one specimen before and after the test, right side: Looking into the furnace during the test.

Based on the test results, both of the loaded and preliminary unloaded tests, clear recommendations on design and calculation for joist hangers and full thread screw connections for reaching specific load bearing capacities were developed. These data may be used for the supplement of technical approvals; by this means the transfer of the research results in practice can be ensured.

Regarding the full thread screws, substantially improved design rules compared to the recent normative recommendations could be formulated. Due to reduced side distances at the same load bearing capacity, considerable material savings are possible.

Additionally, identically constructed specimens with protective measures were assessed in fire tests. The heads of full thread screws were covered by timber boards, resp. countersunk. On the joist hangers, a fire protective coating was applied on the metal surface and on the gap between secondary and primary beam (Figure 8). The protective measures are able to reduce substantially the temperature in the connections and the fire loss. They may be used in practice, when especially high load bearing capacities are required in some cases.

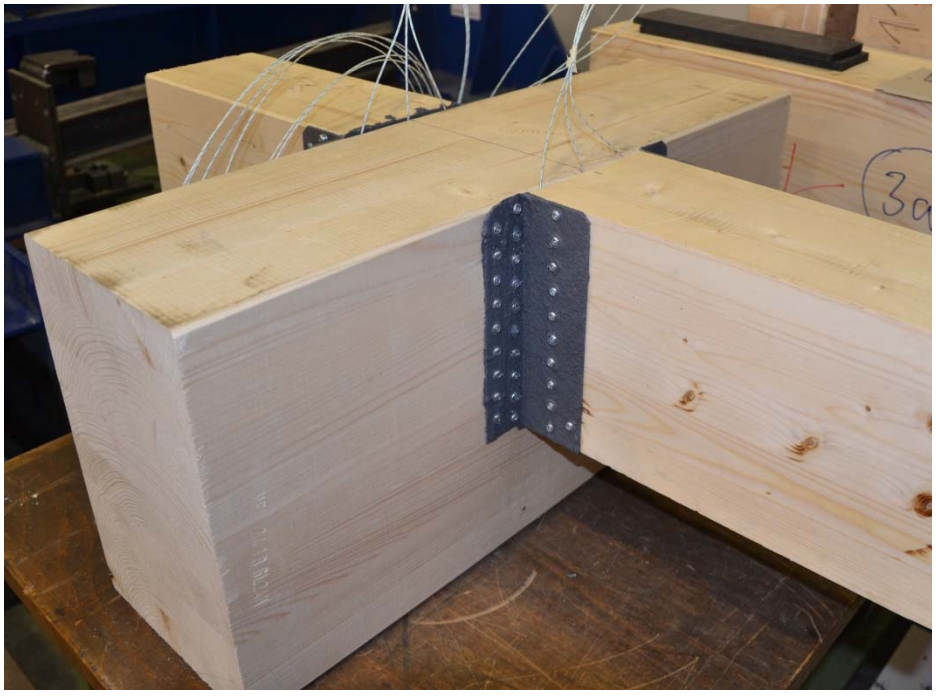

Figure 8: Protective coat on the wings of a joist hanger and onto the end grain of the secondary beam

After the experimental tests, computational parameter studies were carried out additionally. The computational models were calibrated with the experimental results, such as temperature distributions. The models showed a good accordance to the behavior in practice, and

may therefore be used for the calculation of similar connections which have not been specifically tested in this research project (Figure 9).

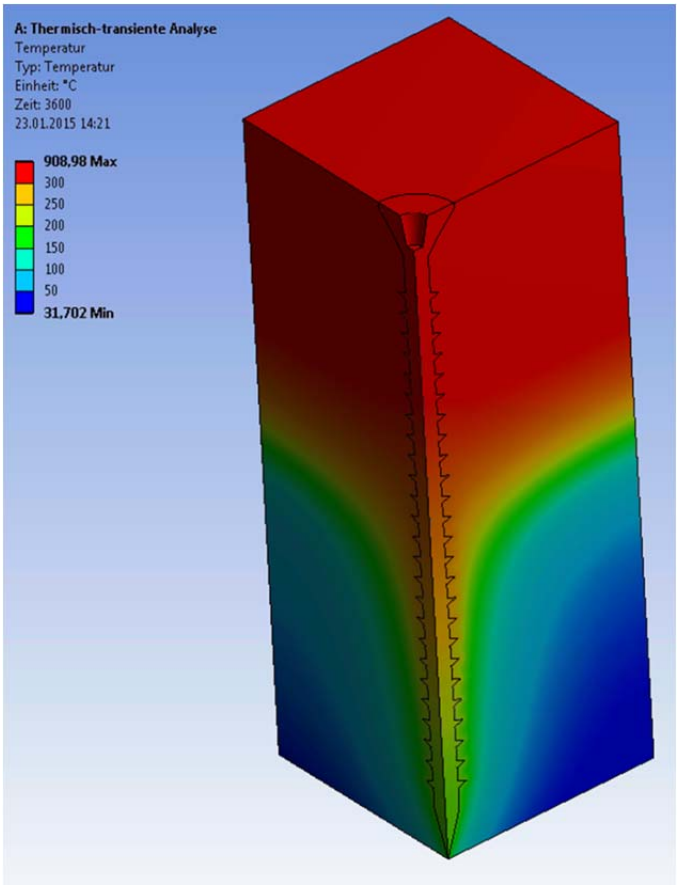

Figure 9: FE-model of a screw. Colour-shaded isotherms are presented.

3 Conclusion

The literature research, the experimental tests, the calculations and theoretical studies conducted in this research project represent and extend the current knowledge on the fire behavior of primary beam – secondary beam connections in timber structures. In addition, the fundamental knowledge of the fire behavior of dowel-type fasteners in timber structures could be enhanced. In particular, experimental tests were conducted to define the pull out resistance of full thread screws in regard to the temperature.

The load bearing capacity of connections with joist hangers or pairwise crossed full thread screws under fire exposure was determined experimentally. The tests showed, that joist hangers or pairwise crossed thread screws are suitable for primary beam secondary beam connections under fire exposure, when designed according to the proposed design rules.

The results of this research project may contribute to a better understanding of the fire behavior of the conducted connections using joist hangers or full thread screws. Furthermore the general properties of dowel-type fasteners under fire exposure were examined. This knowledge enables to assess the fire behavior of similar connections in timber structures.

4 Basic data

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