FIRE RESISTANCE OF PRIMARY BEAM – SECONDARY BEAM CONNECTIONS IN TIMBER STRUCTURES

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ABSTRACT: Within the German research project “Fire resistance of primary beam secondary beam connections in timber structures” solutions for a fire-safe design will be developed. This paper describes a series of small scale furnace fire tests and associated parametrical investigations by finite Element Modelling with joist hangers and self-tapping screws. Further on the designs and first results of full-scale fire tests on loaded connections will be presented.

KEYWORDS: fire resistance, joist hangers, self-tapping screws, timber buildings

1 INTRODUCTION

The ever increasing demand for timber as a construction material is currently noticeable all over the world for both private and public buildings. This is particularly true for residential, office and administration buildings as well buildings for special events. There are many benefits of building timber structures such as visual and tactile attractiveness, high energy efficiency, quick erection time and a low carbon footprint. However the largest concerns and limitations by authorities and design codes for the use of timber as a construction material in modern buildings are normally linked to fire safety.

To consider this aspect in a sufficient way European and international design codes have been developed over the past years to assess the fire safety in buildings. The design rules for fire exposed timber structures such as the ones listed in EN 1995-1-2 [1], NZS 3606 [2] or in the U.S. AWC-DCA2 [3] are mostly focused on determining the charring and residual cross section of linear timber members, such as beams and columns. However, general regulations and design methods for assessing the fire safety of engineered joist to beam and joist to column connections do not exist [4]. Approved and reliable systems are rare.

To overcome this gap of knowledge a German research project has been started in the beginning of 2013 which seeks to investigate the thermal and structural performance of typical engineered connections for timber structures in the event of fire, such as joist hangers, screwed connections, concealed joist ties and corbels (see Figure 1).

Figure 1: typical joist connections for timber structures

2 CONCEPT AND EXPERIMENTAL INVESTIGATIONS

The investigations conducted in this research project are based on a three pillar strategy.

I. unloaded small scale fire tests, to assess the influence of geometry and material interaction,

II. mechanical testing of the connections at ambient conditions under consideration of the results and residual cross sections gained in step I,

III. loaded full scale fire tests for selected and optimized connection systems, based on the results gained in the previous steps I and II and the associated FE modeling,
Since all experimental investigations allow only a limited number of tests, the results are currently used to validate an existing FE model (based on the finite element code ANSYS) for further parametrical studies and optimization process.

Following aspects are investigated in detail:

- the temperature distribution and charring rates in the connections area
- whether concealed metal connectors and screwed connections can give sufficient protection capacity without additional protection methods, such as linings
- which influence bare parts of connectors and fasteners, (like joist hangers and exposed heads of screws, nails and dowels) have to the charring rate of timber, load bearing capacity and deformation of the connection
- what type of additional protection methods, like linings or coatings are useful under consideration of practical and economical aspects and
- how geometrical modification and additional protection methods can contribute to the fire resistance, and when these are required.

Based on the results the systems will be assessed, classified and optimized. Recommendation of geometrical modifications and additional protection methods will be developed for the full scale tests and practical application.

3 OUTCOMES AND PROSPECTS

This paper describes a series of small scale furnace tests and associated finite element modelling with ISO 834 fire exposed primary beam secondary beam timber connections with joist hangers and self-tapping screws. Further on the setups and first results of the full-scale fire tests will be presented.

The investigations conducted so far shows among others:

- Despite of designing the linear timber members for a specific fire resistance and under consideration of requirements of ambient design (e.g. edge distance, dimension of fasteners, …) for the connectors, the fire resistance of the entire connection can hardly be ensured. (see Figure 2a ) - Improvements are needed.
- Long dowel type fasteners tend to result in lower temperatures and reduced charring alongside the fastener (see Figure 2b) compared to shorter fasteners.
- Increasing the diameter of dowel type fasteners has a beneficial effect in the early stages of a fire, however shows increased charring during longer fire exposure compared to thin fasteners.
- …

The final paper reports the results of the conducted fire tests and numerical simulations including - the temperature distributions through the timber members and connectors during the tests, - the effect of geometrical conditions such as size of the connectors, number and dimension of fasteners and gap size, - the influence of metals plates and fasteners on the charring rate as well as on softening and failure modes of the connections - and the effectiveness of protection details.

First recommendations for the fire safe design and further optimizations of both joist hangers and self-tapping screws will also be provided from this on-going project.

The presented results will immensely contribute to increase the fire safety in timber structures and to the wider use of timber as construction material.

![Figure 2: test results of small scale fire tests](image)

a) remain cross section after 30 minutes fire exposure without any constructive improvement

b) influence of fastener length on charring rate

REFERENCES


