Summary

Structural fire protection is a fundamental requirement to facades as the outer surface of external walls of multi-storey buildings (independent of the used material). Goal is to prevent uncontrolled fire spread on the surface of the external wall for a fixed period.

Additionally, structural fire protection is essential to the various combustible facade specifications. Thus, timber and timber derived products can be used without reducing the aspired security level.

This article is giving a review on the state of research and the integration of research results in the construction catalogue for fire safe facades.

1. Introduction

In the past, several research projects to determine the load-bearing capacity and integrity of linear and two dimensional building components under fire attack were successfully carried out.

As a result it is now possible to assemble building parts like walls, columns and beams with a fire resistance of up to 180 minutes and with a minimization of the participation of flammable structures.

Another necessary part on the way to secure multi-storey buildings built with timber and derived timber products are fire safe constructions for wooden facades.

Wooden facades become more and more attractive for constructions. By now, most of the building regulations of the European countries allow the application of timber and derived timber products in the facade surface of buildings with a maximum of two to three storeys.

A major target is to extend the applicability of timber and derived timber products in the facade surface of buildings to a maximum of eight storeys in consideration of protection goal requirements.

Most of the knowledge regarding the fire behaviour of flammable facades was obtained through a huge research program in Switzerland.

2. Swiss research program and source data

Switzerland started a large research program called “Brandsicherheit und mehrgeschossiger Holzbau” (“fire safety in multi-storey timber constructions”).

Inevitable protection goals concerning the application of timber and derived timber products in multi-storey buildings were discussed and agreed upon with the Swiss authorities and building insurances. Performance criteria were verified through numerous fire tests on linear and two-dimensional structural elements as well as on openings, installations und facade constructions.
The start of the project was in 2001. Already by 2005, Switzerland had developed national regulations for construction and material to build with timber and derived timber products for up to six storey buildings.

→ As an outstanding result of this project, the Swiss regulations by now allow constructions of facades with inflammable materials for buildings up to eight storeys.

The experimental data of the testings performed in the Swiss project are also available for this German research program (timber engineering for the future, High-Tech-Offensive Bavaria). These collected source data allowed to start the German research project without expensive testings in the beginning.

3. **Principles of analysis and testing of facades with inflammable surfaces**

3.1 **Fire scenarios on exterior walls**

The spread of a fire on the facade of a building generally is influenced by character, intensity and location of the initial fire.

Principally, the facade can be exposed to the following three fire scenarios:

- **Scenario A**: fire of a building located next to the facade
- **Scenario B**: fire outside the building in front of the facade
- **Scenario C**: fire inside the building in a room next to the exterior wall with at least one opening in the facade

![Fig. 1 Fire scenario on exterior walls (source: Lignum Dokumentation Brandschutz [7])](image)

Several fire tests showed that the scenario with fire inside the building has the worst effect on the facade. This scenario causes the highest release of energy in front of the facade surface.

Comparing scenario B with C, conservative values for testing and evaluation of facades can be determined:

- release of energy in front of the facade: $1 - 1,5$ MW
- average extend of flames: $2,5 - 3,0$ m (max. 6,0 m)
- total time of thermal exposure: $15 - 20$ minutes
- total time of exposure to blazing fire: $10 - 15$ minutes

Real fires and fire tests show that all parts of a facade react to direct flame impact in the area of the plume dependent on their flammability. Windows or openings in the facade in this area without any performance in terms of fire protection are weak spots whether or not open or closed.
3.2 Definition of necessary objectives

Unlike for fire tests concerning linear and two dimensional building elements, for the examination of facades there are neither international nor European standardized test processes and methods. An assortment of proofing standards like ISO 13785 part 1 and 2, EN 1364 part 3 and 4 as well the pre-standard for the German DIN 4102-20 show, how different the test settings and requirements for the tests of facades internationally are. Thus, the different approaches are examination of the fire behaviour of the facade loaded by the fire in front of a window after flash-over in the room, classification of the partition and thermal insulation of a non-load-bearing cladding or on the other hand the attempt to examine the functionality of fire barriers each located one storey above the initial fire (level of the plume).

In course of the Swiss research project a general protection goal was defined together with the authorities.

Discussed general performance requirements

In case of a fire on the outer surface of a building, the extension of the fire to more than two storeys above the initial fire shall not be possible before selective fire fighting.

This protection goal implicates the following requirements:

- By using timber or derived timber products for claddings meaning adding fire load to enclosing walls, the defined protection goal is not to be failed or disregarded.
- Claddings for external walls are only to be used for buildings up to a height which can be reached by selected fire –fighting from outside the building. Additionally, the application of such claddings is limited to buildings of classification 5 (h < 22,0m; turntable-ladder vehicle h < 24,0m).
- Within a defined time, the fire may not expand beyond an accepted area. Taking into account the results of the tests, a lateral (horizontal) extension is as well without additional measures sufficiently limited (factor horizontal versus vertical fire spread in timber an derived timber products circa 1:10).

4. Experiments and research

The comprehensive tests at the Materialforschungs- und Prüfanstalt Leipzig (MFPA; Material Research and Test Laboratory) by order of the LIGNUM (Swiss timber industry) were defined to include the most types of facades regarding construction and design. The evaluation is composed of "large-scale" and “full-scale” fire tests. Additionally, a series of flammability tests on various wood species as well as on coated surfaces.

The methods of the testings are described below.

4.1 SBI-Test (single burning item)

The SBI test is an intermediate scale corner test that is used for classification of construction products in Euro classes C or D.

Various commercially available paints, glazes and coatings were examined regarding their effect on flammability with small test modules under the terms of DIN 4102-1 ("Kleinfrennertest für deutsche B2-Klassierung von Baustoffen"). Accordingly, various wood species and wooden composite boards were tested. By these tests, critical material compositions could be determined.

In total, forty sawn, planed and polished surfaces were tested.
4.2 “Large Scale” Tests (Material Research and Test Laboratory MFPA, Leipzig, Germany)

4.2.1 Test specimen

Wooden facade systems as exemplary described in fig.1 are applied to the facade test facility. In more than thirty tests many different types of timber and derived timber surfaces were combined with several fire barrier constructions made of rust-proof steel sheet or timber panels.

![Fig. 2 Exemplary test specimen](image)

1. wall of test rig (240mm lime-sand brick)
2. X-lam timber board (60mm)
3. gypsum fibre board (15mm)
4. optionally moisture protection foil
5. lathing, substructure
6. horizontal fire barrier between storeys
7. horizontal cladding

4.2.2 Facade test rig, test procedure and results

The arrangement of the test setup and the test procedure follows the knowledge of the calibration tests and the German preStandard prDIN 4102-20 “Besonderer Nachweis für das Brandverhalten von Außenwandbekleidungen” (“Special test of fire behaviour of claddings for external walls”).

The test facade is arranged on a 240 mm thick lime-sand brick wall. To provide an easy erection of the different test setups, the wall is covered with additional layers: a 60mm massive 3-layer Xlam timber board and a 15mm gypsum fibre board (XELLA Fermacell HD).

An opening at the bottom is to simulate a window. The flames from a wooden crib located in the opening attack the cladding of the facade. A crib of 50 kg is used as fire load (fig. 4), simulating the fire load in front of the facade after flash-over.

Temperature measurements are carried out at the surface and in the rear ventilation layer. The test and observation time lasts normally 20 minutes.

4.2.3 Tested facade constructions and surfaces

During two and a half years overall 33 different fire tests have been done at the facade test rig in Leipzig (Germany).

In this time, several types of surfaces (open spaced cladding, tongue and groove profile, weatherboarding and various types of derived timber boards) with horizontal or vertical arrangement were combined with common substructures.

In all, these tests covered a wide range of typically used constructions for timber buildings. The tests for the Swiss research program are finished, but further research projects with other types of facades, like e.g. external thermal insulation composite systems (ETICS) will follow. Thus the knowledge and source data pool is constantly growing.
Fig. 3  Test rig with Xlam layer and concrete window frame

Fig. 4  Wooden crib as fire load

Fig. 5  Fully equipped test rig, ready to start

Fig. 6  Fire after 15 minutes with burning surface limited to next floor

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critical height after the 15th minute

fire barrier between every storey
4.3 “Full scale” tests (concrete pier and panel construction building, Merkers, Germany)

Full scale tests were made on a building in Germany. The building was a concrete prefabricated slab construction. Before the fire tests were started, the building was fully covered with a timber surface and on the front side with a wooden balcony. The four storey building had a length of 40.2 m, width of 10.0 m and height of 14.5 m.

In total, six full scale fire tests were carried out. The tests can be classified by the type of the facade and the additional measures into three categories:

The first three fire scenarios were carried out to 27 mm thick three-layer solid timber board facade with a 20 mm projecting steel sheet fire barrier. The tests were splitted in a vandal fire in front of the facade with a 100 kg wooden crib and a single room fire (>600 MJ/m²) and a double room fire (>800 MJ/m²).

Fourth and fifth scenario were accordingly started as a room fire (>800 MJ/m²) shown in fig.8. The facade surfaces on both experiments were arranged with 20 mm tongue and groove profiles, but in the last test the rear-ventilation involved the full building height and no fire barrier was arranged between the storeys.

The sixth test was a simulation of a fire on a balcony exclusively made of timber. Therefore, a 150 kg wooden crib was ignited on the balcony located on the first floor. The facade beside the balcony had a horizontal fire barrier on each storey.

5. Technical and constructional bases

The following conclusions regarding constructions by timber or derived timber materials can be drawn from the fire tests accomplished:

- Non-load-bearing cladding for external walls ventilated at rear react in real fire scenarios (using a practice-oriented set up) noticeably better than expected from the experimental results of small fire tests.

- The self protection effect of timber through carbonization of the surface is inhibiting a rapid vertical fire spread. A significant lateral fire spread is not found or found only to a very limited and acceptable degree.

- Already by simple structural measures, fire spread in the rear ventilated area is controllable.
- In particular cases, the flammability of timber cladding systems for external walls is dependent on the influence of various parameters which if the worst comes to the worst can interfere with each other.

- Problems by fire fighting with water were not noticed in the full scale tests. As well, no extensive drop off of parts of the construction of the exterior wall endangering persons was noticed.

- A flammable exterior insulation can accelerate the fire spread.

- The tested standard coatings have no significant effect on the flammability of the cladding of the exterior wall.

Basically, the behaviour of facades under fire load is dependent
- on the type and architectural features of the facade (facade with recessed ribbon glazing, perforated facade, angled facade),
- on the type and alignment of the cladding
- on the substructure including the rear ventilation opening

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Fig. 9 Examples for influence parameters to the fire behaviour of multi-storey facades (source: Lignum Dokumentation Brandschutz [7])

6. **Creating a building catalogue for multi-storey facades**

In consideration of the defined protection goals and the test results described above, the following scheme for the conception of a construction catalogue for facades could be elaborated:

**Classification of facade type**

The different types and configurations of facades can be categorized by their characters of fire spread and behaviour.

Parts of buildings can be classified by different categories in the catalogue.

Using the facade category a specification of the facade construction according *table 1* is possible.
7. Conclusions

The development of a standard international or European instrument regarding testing and evaluation of facade constructions is essential. Based on the Swiss tests and the actual Swiss Regulations additional proposals are developed to improve also German Building Regulations. The main finding is that performance based requirements as e.g. a non combustible facade area with a height of 1 m between windows is not sufficient to limit fire spread from window to window.

Improved constructions with combustible materials lead to same or better fire safety.

8. Acknowledgements

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9. References

[1] EN 13823 Reaction to fire test for building products (SBI test)
[2] ISO 9705-1 Fire tests – Full scale room test for surface products
[3] DS/ISO 13875-1 Reaction to fire tests for facades – Intermediate-scale tests
[4] DS/ISO 13875-2 Reaction to fire tests for facades – Large-scale tests