Title

"Development of facade elements with pyrolyzed surface for improved fire protection properties"

Background / Scope

Wood has been used as a sustainable material for facade cladding for centuries. The classification as ‘normally flammable building material’, according to German building code, only allows the use of wood as facade material for buildings up to and including building class three of the code. With surface pyrolysis, a method is shown to increase the fire resistance of facade timber without further chemical treatment to such an extent that it can be classified as a flame-retardant building material to be used in buildings above class three.

Objective of the research project

The increased fire resistance of pyrolyzed wood is based on the low thermal conductivity of the surface carbon layer. The effect of this is that if exposed to fire again, the native wooden parts underneath are heating up much slower to the temperatures required to ignite the wood gases. Shou Sugi Ban is the name of the handicraft method in which pyrolysis layers have been applied to wooden facades in Japan since the Middle Ages for the purpose of fire protection. The research project PyroForCE demonstrates technical processes involving the targeted application of layers of coal on facade boards so that the resulting pyrolyzed wood may be classified as a flame-retardant building material.

The development of a self-sufficient pyrolysis facility based on a gas-air ribbon burner for direct flame treatment allows the generation of defined and repeatable pyrolysis layers on different types of wood and facade profiles. This treatment produces a pyrolysis layer of approximately three millimetre thickness on the facade timbers in one pass at a relatively high speed. This means that the process is both economically advantageous with regard to further industrial application, and it creates only a minor deformation of the facade boards during the quick, one-sided surface treatment.

Using abrasion tests according to DIN ISO 9352 and cross-cut tests according to DIN EN ISO 2409, the surface properties of the pyrolysis layers were determined for the respective types of wood and thicknesses. As expected, the result showed very little resistance to mechanical abrasion.

In a next step, different types of coating for the pyrolyzed surfaces were tested in order to increase resistance to weather-related abrasion. The choice of materials was narrowed down by assessing their ecological impact on the one hand, and the requirement not to introduce any further fire load into the system. Consequently, in addition to cement slurries, water glasses - sodium and potassium water glass - were tested in different concentrations. With the water glasses, one substance group was

identified that is already used as a fire protection agent and is characterized in particular by the fact that it is purely mineral and therefore has a smaller ecological impact.

Different application methods were tested to improve the surface properties of the treated wood: The water glasses were applied both in a vacuum process and as a brush application. This way, conclusions could be drawn between the applied quantity and the corresponding increase in abrasion resistance and/or fire resistance.

Another focus of this research was to investigate facade systems made out of pyrolyzed wood. The focus was on the one hand on design principles, which specifically took into account the particular visual appearance of the glossy black surfaces. On the other hand, all systems were assessed with regard to their buildability according to the relevant technical rules or practical criteria during construction.

In order to provide evidence that the surface pyrolysis of facade timber can produce a construction product that meets regulatory requirements, these first had to be determined, and then the corresponding test procedures carried out. The fire behavior of construction products is classified at European level in accordance with DIN EN 13501. Here, the untreated wood is classified as category “D” of normal flammability. In contrast, building products that are used for facades up to building class 5 must meet the “B” flame-retardant category. Fire tests according to DIN EN 13823 (SBI test) were used to classify the fire behavior of individual facade systems. The “B” flame retardant classification was achieved for a vertical slat-lid facade made of spruce boards impregnated with sodium water glass.

Conclusion

A pyrolysis facility prototype was developed for the production of defined and reproducible pyrolysis layers on different facade woods. Pyrolyzed wood can now be integrated into the classification system for building materials. The thickness of the pyrolysis layer needed to sufficiently increase the fire resistance has been determined for various wood types.

Mineral solutions to stabilize the surface were found in the form of sodium or potassium water glass and their suitability has been demonstrated in subsequent qualifying fire tests. Hence the goal of using surface pyrolysis in conjunction with stabilization with water glasses for facade wood in order to reach the desired flame-retardant classification and thus being allowed to use it as facade material in an urban context was achieved.

However, preliminary results of long-term weathering tests on the stability of the treated surface proved unsatisfactory. This raises further research questions as to the extent to which the durability of the surfaces can be increased on the basis of water glasses and possibly two-stage coating methods.

Eckdaten

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