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Fire safety evaluation of different internal insulation measures in European and Danish context

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Abstract. In about the last 10 years there has been an increased focus on energy upgrading the existing building stock. This have included several international and national projects dealing with internal insulation. Many of the studies have considered the internal insulation as a measure to achieve a specific energy consumption of buildings. Later, the focus has been on the durability of the 'new' structure with additional insulation on the internal side of walls, i.e. if the measure is moisture safe. These measures have been applied in both theoretical studies, laboratory and real buildings. None of the studies have reported whether or not the suggested retrofit measures fulfil respective fire regulations. The height of the building is also considered in fire regulations, and therefore, measures that are applicable in e.g. single-family houses might not be applicable in apartment buildings. This study includes a review of a number of different insulation materials and – systems used for internal insulation. These measures are evaluated against the EU-harmonized and Danish fire regulations, as many countries might have adapted national requirements. The study evaluates, whether the measure is applicable at all floor levels or not.

1. Introduction

The purpose of this study is to review and evaluate a number of undertaken projects, where internal insulation was installed in buildings with facades worthy of preservation, to determine if the projects meet the fire regulations (45 insulation scenarios in 38 case buildings). Detailed information and references to the scientific publications for each of the examined case projects are available in [1].

All construction materials used in EU countries, as internal insulation on walls, must be classified according to the classification standard EN 13501:2018 *Fire-safety classification of construction products and building elements (part 1 or 2)*. Part 1 is the classification with respect to "reaction to fire of construction products" of materials, whereas part 2 is the classification of fire resistance of building components. The former is the part of most relevance in this paper. According to EN 13501-1 [2], the construction material should be fire tested and classified according to the EU-harmonized system. This means the construction materials have to be tested according to EU standardized testing methods by approved and accredited testing laboratories in order to find the materials reaction to fire performance, and thereby the correct fire classification. The result of this testing should prove that material to be used for internal insulation on walls is at least material B-s1,d0 and if not, the material must be covered with a material, thus the system as a whole obtain class $K_1$10 B-s1,d0 or $K_1$10 D-s2,d2 depending on the room, application category and building height.

The requirements do, to a certain degree, depend on the building height. High-rise buildings require more time for evacuation, and therefore smoke-free escape routes must be maintained for longer time compared to low-rise buildings. This is the common requirement among the EU-member countries. Some non-EU countries have other requirements, however, many of these countries use requirements similar to the EU requirements. Worth to mention is that EN 1366-3 *Fire resistance tests for service installations (penetration seals)* [3] must be taken into account, if the actual wall is fire-rated and penetrated by pipes, cables or the like. According to Danish fire regulations [4], insulation that is not at least material class D-s2,d2 may be used in buildings with a top floor level of up to 9.6 m above terrain if protected by $K_1$10 B-s1,d0 cladding or a EI 30 building component and up to 22 m if protected by a EI 30 A2-s1,d0 building component. Insulation that is at least material class D-s2,d2 may be used in buildings up to 22 m if protected by $K_1$10 D-s2,d2 cladding.

2. Methods

Information were collected for different case buildings (actual projects with internal insulation, not hygrothermal simulations). The collected data include: information about the case buildings and their state, types of insulation systems installed (λ-values and thicknesses), and the hygrothermal performance of the systems. The selection of insulation systems presented in this study was based on the hygrothermal measurements presented in the reviewed case studies, where the systems should not show critical relative humidity levels in the insulation-masonry interface or in the embedded wooden beam ends. If a system showed good hygrothermal performance, then it would be included in the evaluation, even though the identical system had poor hygrothermal performance in other projects. For systems where contradicting hygrothermal measurements were found between the reviewed case studies, these systems were also included in this study. Fire classification of the insulation and cladding materials were obtained from performance documents and the insulation systems were evaluated against the EU-harmonized and Danish fire regulations described in the introduction, by assessing the insulation material and the type and thickness of the internal cladding in relation to the building in question.

3. Results

The results of the data collection and evaluation of projects and internal insulation systems can be found in [1] and an extract of these results are summarized in Table 1.

4. Discussion and conclusion

The overall picture is that the EU-harmonized fire regulations are not met for all the reviewed projects, 30 out of 45 insulation scenarios met the fire regulations. In the German, Danish and some Estonian-projects the requirements are met, particularly for those where the internal insulation is plastered with a cementitious material or cladded with fire gypsum boards. For many project, especially in countries outside EU, the requirements are not met for the analysed projects in this study, see [1], which might be implied in different non-EU regulations. For some of the projects located in Ireland, Italy, Latvia, US and a single German project, it is not possible to judge whether the solutions met the requirement or not. This is due to lack of design information, i.e. the exact products and their fire classifications.

The adaption of national fire regulations is exemplified for Denmark in the two rightmost columns in Table 1. In the Danish projects, it was observed that the case studies with plastic foam insulation products (i.e. polyurethane, polyisocyanurate, extruded polystyrene, phenolic foam), met the fire regulations for low-rise buildings with a top floor level lower than 9.6 m above terrain (equivalent to a 3-storey building when assuming an average floor height of 3.5 m). However, these systems would not be suitable for high-rise buildings up to 22 m above terrain (equivalent to a 6-storey building). It was found that all four cases with phenolic foam and one case with polyurethane foam with capillary channels did not meet the fire regulations, in relation to the stricter fire requirement for buildings taller than 3 stories, as a result the occupants would have less time than intended to evacuate. The fire protection of these systems was comprised by a standard gypsum board or a thin cementitious plaster layer (B-s1,d0). However, according to the Danish building regulations, for high-rise buildings, such insulation products would instead need to be protected by a building element with a fire classification of EI 30 A2-s1,d0, which require 90 mm masonry or 75 mm lightweight concrete or lightweight clinker as internal surface layer [4]. It must be mentioned that the height-dependent fire requirement have a historical reason, individual for each country, and largely depends on the equipment of the fire rescue services. In Denmark, hand-carried ladders and small mobile ladder carts can be transported to the inner courtyards and reach up to 9.6 m, while buildings up to 22 m are reached with the large turning ladder mounted on the fire trucks. Other EU countries will most likely have similar heights requirements, as it is limited how long a hand-carried ladder can reach etc. The authors recommend that there come more focus on documentation of chosen internal insulation systems in relation to the building in question.

Table 1. Projects and fire classifications for insulation and cladding materials. Projects are grouped according to material type. Projects where fire classifications for insulation and cladding materials were not found are presented in [1]. The last two columns concerning building height and suitability are based on national fire regulations for Denmark.

Insulation		**Internal cladding**			**Building height**	
Material	**Fire classification**	**Material**	**Thickness [mm]**	**Fire classification**	**Buildings up to 9.6 m [1]**	**Buildings between 9.6 m and 22 m [2]**
Calcium silicate	A1	Plaster	2-10	A1 / B-s1,d0	Yes	Yes
Polyurethane	D-s2,d0	Gypsum board	Not given	Not given	Yes	No
Polyisocyanurate	F	Gypsum board	25	Not given	Yes	No
Extruded polystyrene	E	Gypsum board	12.5	A2-s1,d0	Yes	No
Phenolic foam	C-s1,d0	Gypsum board +/- plaster	12.5 (+ 3)	A2-s1,d0	Yes	No
Polyurethane foam with capillary channels	E	CMT plaster	10-20	A1	Yes	No
Autoclaved aerated concrete	A1	CMT plaster	5-10	A2-s1,d0	Yes	Yes
Glass wool in studwork with active dehumidification	A2-s1,d0	Fiber gypsum board + gypsum board	2 x 12.5	A2-s1,d0	Yes	Yes
Aerogel	C,s1,d0	Gypsum board	25	Not given	Yes	No
Mineral wool/aerogel	B-s1,d0	Gypsum board	10	Not given	Yes	Yes
Wood fiber board	E	Lime plaster	8	A2-s1,d0 / B-s1,d0	Yes	No
Vacuum insulation panel	F	Gypsum board	25	Not given	Yes	No

CMT: Cementitious; +/-: system applied with/without 3 mm interior finishing plaster. [1]Suitable for buildings with a top floor level lower than 9.6 m above terrain. [2]Suitable for buildings with a top floor level between 9.6 m and 22 m above terrain.

References

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