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A new approach to the Danish guidelines for fire protection of combustible insulation

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Abstract. The tendency to use thicker layers of insulation and a wider use of combustible insulation materials is identified to pose a potential risk to fire safety of buildings.

A new approach to the current Danish prescriptive code on fire protection of combustible insulation is proposed as a way to meet the concern. The new approach uses the fire properties of the insulation material itself to point out the necessary protective measures. This is contrary to the most European countries were only a reaction to fire class of the façade construction as a whole is required. The basic principle is presented but more research is needed to complete the new approach.

INTRODUCTION

Several reports conclude that the growing focus on "sustainable" buildings results in an increased thickness of building insulation and an extended use of combustible insulation materials e.g. foam plastics or cellulose fibres [1–3]. Moreover, it has become more common to apply the insulation to the external wall surface instead of on the internal wall surfaces or in the wall cavity.

The combination of increased volume and combustibility of the building insulation products is identified to pose an increased risk to the fire safety of buildings [1–3]. Though, it is difficult to find statistics on fire incidents that point out combustible insulation to be a threat to safety.

This paper presents the current Danish prescriptive code on fire protection of insulation products and proposes a new and more gradual approach that treats the individual insulation materials based on their properties. With the new approach some materials will require fewer precautions to use, while other materials will require more precautions. The overall goal is to achieve a sufficient fire safety level for a building regardless of the insulation material used.

This paper only considers fire protection on the outside of the building façade but with some adjustments the principles might as well be used for internal fire protection.

CURRENT REQUIREMENTS WHEN USING "COMBUSTIBLE" INSULATION

In most European countries only a reaction to fire classification for the façade as a whole (end-use) is required [4, 5]. Depending on the risk class of the building, the end-use requirement is often followed by a minimum reaction to fire requirement to the insulation material itself.

The chapter on fire safety in the Danish Building Regulation [6] is performance based, that is, there are no specific requirements to the fire classification of building products. There are only performance criteria which can be met by following a pre-accepted prescriptive code [7]. Alternative solutions can be used but then the building owner or contractor is responsible for proving that the performance criteria on fire safety are met.

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Table 1. Required protection of insulation that is poorer than material class D-s2,d2 according to the prescriptive code [7].

Single-family house	**Building height < 9.6 m**	**Building height > 9.6 m**
Covering class K_1 10 B − s1, d0 a) [9] *or* Construction class EI 30 [7] *or* SP Fire 105 test [10] for the façade system as a whole (no requirement to the insulation material alone)	Covering class K_1 10 B − s1, d0 a) [9] *or* Construction class EI 30 [7]	Construction class EI 30 A2-s1,d0 b)

a) The covering must consist entirely of materials classified as material class B-s1,d0.
b) The protecting construction must consist entirely of materials classified as class A2-s1,d0.

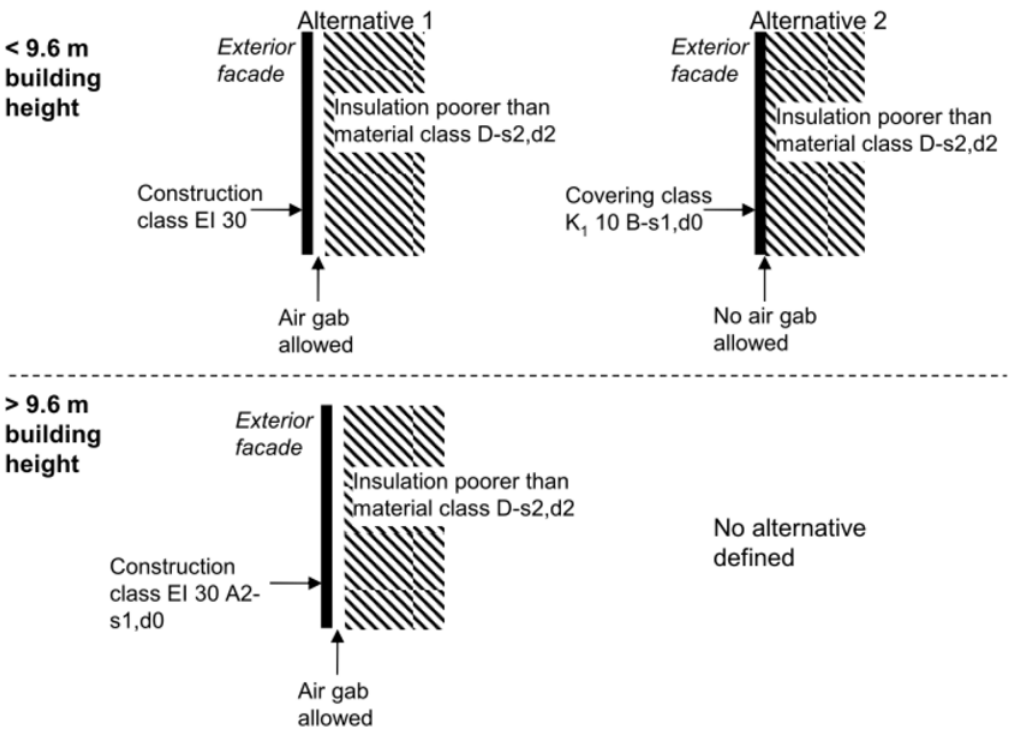

Figure 1. Protection of insulation according to the Danish prescriptive code. Use of SP Fire 105 in single-family houses is not included in the figure.

The current Danish prescriptive approach to fire protection of combustible insulation is different from most other European countries. All insulation materials that are not at least material class D-s2,d2 must be protected as described in Table 1 and illustrated in Figure 1. Note that, according to the current Danish approach, the reaction to fire class of the insulation product must be based on a fire test of each substantial component of the insulation product if it is composed of multiple layers of different materials. For example, sandwich panels must be classified by testing both the product as a whole and the insulation product alone [8]. If the classification of the insulation core alone is unknown it will be treated as class F. The prescriptive code uses the term *material class D-s2,d2* contrary to (*product) class D-s2,d2* which is standard in the European fire classification system.

A building material is regarded as an insulation material if the density is less than 300 kg/m^2 (and has a thickness of more than 1 mm).

A covering class K_1 10 B − s1,d0 is a layer that is capable of protecting underlying materials poorer than material class B-s1,d0 from a specified temperature rise and from any damage (shrinking, melting, charring). The protecting layer itself consists of materials that are all at least material class B-s1,d0.

A K_1 covering must be tested on the relevant substrate [9], e.g. the relevant insulation material.

When a covering is used to protect the insulation, the current Danish prescriptive code specifies that no air gab is allowed between the covering and the insulation.

If the insulation material is at least material class D-s2,d0 there are generally no specific requirements to protect the insulation. Though, the external surface must always be at least covering class K_1 10 D-s2,d2 or covering class K_1 10B − s1,d0 depending on the building height.

The strength of the current Danish approach is that, in theory, is does not exclude any type of insulation material (not even non-fire retarded polystyrene foam) as long as it is protected according to the prescriptive code. Only when the load-bearing structure of the building is combustible (poorer than class A2-s1,d0) there are restrictions to the choice of insulation material since it must be at least material class B-s1,d0.

WHAT ARE THE ADVANTAGES OF THE CURRENT DANISH APPROACH?

- In some EU countries the most flammable insulation materials (class F) are totally excluded from the marked.
  The Danish approach allows for the use of all insulation materials.
- The heat exposure from the diffusion gas burner used in the SBI test is 30 kW [11] simulating a burning waste basket. There are no requirements on the corresponding irradiance to the tested product but it is probably less than the 50 kW/m^2 suggested by Babrauskas for façade product testing to reflect a fully developed fire emerging from a window opening [12].
  The protective measures used in the Danish approach are based on fire tests using the ISO 834 fire curve that is more severe than the SBI test in relation to heat exposure.
- Several studies have shown that results from the Single Burning Item (SBI) test does not reflect how a building product will perform in a real fire, especially regarding joints and mounting of the product and fire spread in voids [13–16]. In fact, when the SBI method was developed it was concluded that the method gives insufficiently reproducible results for certain layered products (like steel cladded EPS insulation panels) [17]. Especially for high rise buildings it is important to assess the complete construction of façade insulation systems, and not only the reaction to fire performance of the single components [15].
  The protective measures used in the Danish approach are based on fire tests which are more severe than the SBI test in relation test specimen size, joints and mounting.
- When the classification of a façade is based only on reaction to fire properties (tested in end-use condition) the designer is often bound to use a façade system that has the required classification as a whole, that is, including the insulation. Classification reports often describe a "field of application" where the substrate material is limited to class A1 or A2 but this is often overlooked – even by the manufacturers own representatives.
  Though, the K_1 covering classification also has to be tested with the end-use substrate but fewer components of the façade system have to be included in the fire test.
- In several EU countries a national large-scale façade test must be passed. Those tests are more realistic compared to the SBI test since heat exposure, size and mounting in the large-scale tests are closer to the end-use condition [18]. The downside is that the tested system must be used as a whole, that is, without any deviations except for what is described in the documentation (the field

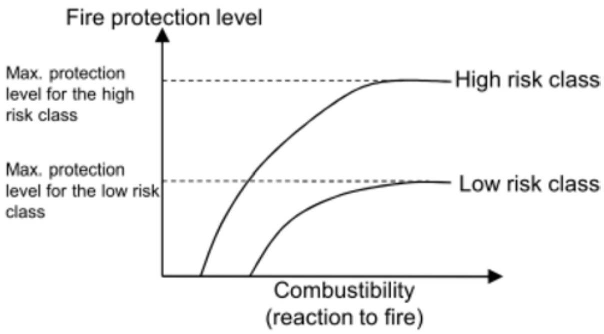

Figure 2. Proposed concept for the relationship between insulation properties and choice of protection.

of application). Therefore, the designer cannot choose from various materials to assemble a façade that is tailor-made to a specific building.
The Danish approach allows for combining various products to assemble a façade that is tailor-made for the building.

WHY DO WE NEED A NEW APPROACH?

- The present way of treating insulation materials in Denmark is overly strict to some insulation materials (especially in the mid-range of the reaction to fire scale). The Danish prescriptive code does not take into account that an insulation product classified as e.g. class B-s3,d0 has much better fire properties than a product classified as class E or F. Foam plastic insulation like EPS (polystyrene) and PUR (polyurethane) are treated in the same way even though they are known to have very different fire properties.
- World-wide, the main focus in legislation and research on façade materials has been on flame spread on the external surface. Though, as presented in the introduction, there is an increasing concern regarding the safety risk when insulation thickness increases combined with an increasing use of combustible insulation products.

PROPOSAL FOR A NEW APPROACH

In order to acknowledge the fire properties of a specific insulation product and give products with a low combustibility an advantage over products with a high combustibility, a more gradual approach is proposed based on the current Danish approach (i.e. combining combustible insulation materials with a protective layer). The new approach should differentiate insulation products by using the full range of reaction to fire classes from the European classification system [19].

Based on the risk class of the building and the reaction to fire of the insulation product in use, an appropriate fire protection measure can be determined as illustrated in Table 2. For non-combustible insulation products no protective measures need to be specified. In that case, the reaction to fire performance for the construction as a whole is considered sufficient.

The first step is to determine the risk classes. Since a vertical external fire spread is one of the most hazardous risks associated with fire safety of facades, the risk category should primarily be based on the height of the building. Though, important factors like the use of the building and relevant fire installations (e.g. sprinkler systems) may also be considered. The use of the building can be difficult to take into account as it might change during the life-time of the building.

Table 2. Example of protective measures.

Risk class	Reaction to fire classification of insulation (material level)		Sufficient external protection measure or surface classification					
	Combustibility	Droplets	Nothing[c)]	B-s1,d0[d)]	K_1 10[e)]	$K_1$30[e)]	EI 30	EI 60
RC2	A1	-	X					
	A2	d0	X					
		d1		X				
		d2			X			
	B	d0	X					
		d1		X				
		d2			X			
	C	d0		X				
		d1		X				
		d2			X			
	D	d0		X				
		d1			X			
		d2			X			
	E	d0			X			
		d1			X			
		d2			X			
	F	-				X		

c) No protection measures required on the basis of the choice of insulation material.
d) Reaction to fire classification for the façade system as a whole (product level).
e) The protective measures should be made entirely of materials that are at least material class B-s1,d0 (the best classification achievable based on the SBI test).

Three almost similar risk class definitions from different sources are presented here:

- The Danish prescriptive code [7] basically suggests three risk classes regarding fire protection of insulation; single-family houses, other buildings up to a height of 9.6 m and other buildings between 9.6 m. The height is measured from ground level to the flooring at the highest storey. The 9.6 m is considered the maximum height at which the fire services are able to reach window openings with ladders carried by hand.
- Cowles [13] suggests four risk classes; Single-storey, up to 7 m, up to 28 m and above 28 m (no description of how to define the height is given).
- Wade [14] suggests three risk classes; Single-storey, "up to a height where fire services are able to apply water", "above height where fire services are able to apply water". Wade further differentiates between sprinklered and non-sprinklered buildings.

To make it simple, only the building height is considered. In real design applications credit may be given to installation of sprinklers for instance by downgrading to a lower risk class.

The authors suggest combining the Danish risk classes with the suggestions from Cowles and Wade to define four risk classes based on the capability of the fire and rescue service to reach certain levels of a building:

- RC1 Single-family houses (up to two storeys) and any other one storey building
- RC2 Buildings up to a height of 9.6 m
- RC3 Buildings up to a height of 22 m
- RC4 Buildings above 22 m.

The height is measured from ground level to the flooring at the highest storey.

The last risk class (RC4) is chosen since the Danish guideline assumes ladder trucks to be able to reach storeys at this height.

For application in other countries it might be considered to adjust the risk classes to meet national or local conditions.

An important principle when developing the new approach has been to use the European fire classification system without any alterations. Thereby, the design of a façade can be performed from the data already provided by the industry.

The combustibility/heat release rate of the insulation product is suggested to be defined using the European reaction to fire classification for construction products according to EN 13501-1 [19]. When evaluating the risk associated with a specific reaction to fire classification only the combustibility/heat release (classes A1, A2, B, C, D, E and F) and the flaming droplets/particles (classes d0, d1 and d2) are considered. Smoke production is of course relevant but is considered to be controlled by general reaction to fire requirements to the external surface of the façade.

It was decided to use class E as benchmark, i.e. the protection level is sustained for insulation products of material class E while the protection level is decreased for insulation products of class D, C, B, A2 and A1 and increased for class F products.

The protective measures are quite difficult to quantify and rank since various fire tests with different heat exposure, test duration, size of test object, data output and classification criteria must be compared and ranked.

Future work may provide a more quantitative basis for defining the right level of protection. A series of small and intermediate tests is planned with the scope of providing more knowledge on the behaviour of multi-layered products, especially products with various combustible insulation materials. Preferably, these tests are later compared to some large-scale covering or façade tests.

Table 2 illustrates an example of how the new approach may be put into practice. The suggested protective measures are qualitative considerations based on the authors' assessment rather than scientific conclusions. The designer is always allowed to choose a better protection measure, i.e. a column to the right of the "X".

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In the long run, predictive models based on results from small and intermediate tests may be used to evaluate the safety level of a specific façade construction.

As an alternative to the concept described above it should always be possible to use a classification based on a large-scale façade test. Various large-scale façade test are described and compared in [15, 18, 20].

Fire barriers to separate areas of combustible insulation are not considered in this paper but are of course relevant, especially when insulation materials which tend to melt in a fire are used.

CONCLUSION

Several reports have pointed out the risks associated with the increasing volumes of combustible building insulation used by the construction industry. The current Danish prescriptive code on fire protection of insulation products pose an effective method to meet the risks and still allow the use of all kinds of insulation products regardless of their fire properties.

The new proposed approach uses the core principles of the current Danish prescriptive code but varies the protection level in more detail. This allows for a more risk based treatment of the insulation product. This is especially relevant to products in the mid-range of the reaction to fire scale, that is, products that are combustible to a certain extent but will not cause a rapid fire spread.

The new approach cannot be fully quantified and substantiated since the necessary data is not available. Future research is expected to provide sufficient knowledge to complete the new approach.

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