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Impacts of environmental exposure on thermal and mycological characteristics of insulation wools

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ABSTRACT

Fieldwork was conducted on 138 energy efficient buildings, to check if building site practices induced exposure to weather of thermal insulation. In nearly 80% of cases, insulation was exposed to weather due to insufficient protection. Therefore insulating wools were exposed, divided into three parts (control, exposure under shelter, exposure to weather). After the exposure period these samples were submitted to thermal conductivity measurements and infrared spectroscopy. A numerical study was carried out to evaluate the influence of weather conditions on thermal performance. Identifications of molds were realized by direct cultures of each sample. Mycological analyses provided the most significant results, showing a significant effect of exposure condition, with possible consequences in human health (toxinogenic, allergenic or pathogenic species) and material properties (cellulolytic species). Infrared spectrometry also showed some changes in sensitivity to water. These results show the interest to study in more detail the variations in the sensitivity, to moisture and mold, of insulation material throughout its ageing on site, and the interactions with the practices of the building process.

1. Introduction

Research work is made in France to guarantee energy and environmental performance of buildings in context of uncertainty propagation (Lahrech et al., 2013; Pannier et al., 2016), in the follow-up of the work already undertaken at international level (De Wit and Augenbroe, 2002; Macdonald, 2002). It does not take into account variations of physical parameters of the insulation material (IM) along ageing on site, like sensitivity to moisture or mold. Of course, there are studies likely to allow taking into account moisture (Spitz et al., 2013) and mold growth (Moon and Augenbroe, 2004; Moon, 2005; Viitanen et al., 2015) but their reading emphasizes that improvements are still needed.

When insulation is found to be exposed to the weather during the insulation laying process, the question of the impact on energy and environmental performance of a building arises. In other words, what impact weathering (succession of wind, rain, sun, snow, hail, frost …) and the capture of fungal spores have on the characteristics and performance of IM?

Impact assessment does not bring answers to this question, because it is not designed to identify the impacts of a building on the environment, as a consequence of the environmental impacts on this building. Furthermore, the transposition of the European directive 2014/52/UE (OJEU, 2014) has led to the exclusion of many building sites from the field of impact assessment. Additionally, since 2014, that is since the upgrade to EN 15804 + A1 (ECS, 2012), French environmental product declarations (EPDs) for insulation wools no longer include a mold growth index.

The review of mold characterization of IM brings to light that fungal resistance tests are not harmonized, and have difficulty reflecting the actual conditions of mold seeding and growth. Indeed, all the French EPDs available for the IM samples analyzed in the present paper claim some fungal vulnerability according ISO 846 protocol (ISO, 1997), except one which claims no fungal vulnerability according a Food and Environment Research Agency protocol (FERA, see Section 2.3 above, fifth line of Table 2). The FERA protocol is not detailed but might be BS 1982–3:1990 (BSI, 1990). Since fungal resistance tests are conducted at high relative humidity, Johansson (2014) proposes a test based on the

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Table 1
Exposure of insulation materials: number of construction sites concerned, classified by duration of exposure, type of insulation and type of protection.

A- Exposure length			B- Insulation of exposed buildings			C- Presence of protection (EI)		
Unknown	18	13%	Glass wool	38	35%	None	66	65%
None	11	8%	Stone/slag wool	21	19%	Building safety nets	13	13%
< 8 days	6	4%	Expanded polystyrene	5	5%	Tarpaulin, rain barrier	16	16%
8 to 20	14	10%	Graphite EPS	2	2%	Fast covering	4	4%
21 to 59	16	12%	Polyurethane	3	3%	Prefabrication	2	2%
60 to 120	31	22%	Mixed mineral	4	3%			
121 to 180	17	12%	Mixed foam	4	3%			
181 to 364	15	11%	Foam + mineral	29	27%			
365 and +	10	7%	Mixed biosourced	3	3%			
Total	138	100%		109	100%		101	100%

A refers to all building sites observed. B is A without the two first lines. C refers only to buildings with external insulation (EI). EPS means expanded polystyrene.

lowest relative humidity at which mold can grow. This test is based on artificial inoculation, and the results cannot be applied to outdoor exposure and give no mold growth (microscope detection) for glass wool. Viitanen et al. (2010) found low mold growth index (1 and 2, microscope detection) for glass wool after artificial inoculation and 11 months of field exposure. These last results are used for mold prediction modeling but Vereecken and Roels (2012) claims that comparing mold prediction models shows differences in results or even contradictions, and stress that all models are deterministic.

The literature on the thermal characterization of IM suggests that the question of the impact of weathering on IM has yet to be explored. There are uncertainties about density (Domínguez-Muñoz et al., 2010), workmanship defects (Aïssani et al., 2016), rain water leakage (Künzel and Zirkelbach, 2008; Olsson, 2015), or moisture properties even for expanded polystyrene (Šadauskienė et al., 2009), that can have incidence on the thermal performance of insulation systems. As regard building service life assessment, the measurements made concerning mineral wools (Zirkelbach et al., 2005; Achchaq et al., 2009; Tittarelli et al., 2013) insulating polystyrene foams (Exarchos and Kosmopoulos, 2010; Daniotti et al., 2012 and 2013), external render coats (Griciutė et al., 2013; Norvaišienė et al., 2013; Griciutė and Bliūdžius, 2015) and adhesives to fix insulation panels (Collina and Lignola, 2010), do not make possible to affirm that weathering cannot degrade exposed IM.

The issue of the exposure of IM during their implementation in building sites is largely unknown, whereas it addresses energy and health vulnerabilities of energy efficient buildings. It deals more broadly with the question of the choice of variables in the context of modeling by propagation of uncertainties, aiming to guarantee energy and environmental performance of buildings.

In order to reduce this lack of knowledge, the present pilot study was conducted via an original combination involving human and social sciences, thermal science and mycology: fieldwork data was collected on 138 buildings between 2012 and 2016; a selection of five buildings was studied by infrared (IR) thermography; it also included comparative exposure of IM samples; and finally thermal, spectroscopic, and mycological analyses of these samples were made.

Section 2 of this paper is devoted to an overview of the buildings and materials considered, as well as to a thermographic survey of one particular building, and the adopted exposure protocol. The effect of weathering exposure of IM was investigated by performing thermal conductivity measurements (Section 3) and IR spectroscopy (Section 4). The influence of the variations of IM thermal conductivity on energy losses of a building wall will be presented in Section 5. Finally, the fungal contamination of IM will be developed in Section 6.

2. Fieldwork data collection

2.1. Overview of investigated buildings

Fieldwork was conducted on building sites – mainly housing and offices, meeting the highest criteria of energy and environmental performance – in order to characterize the conditions of use of insulation (new buildings or renovation) and to check whether these conditions induced weathering exposure of thermal insulation. Six buildings completed before 2012 were included because they have defects exposing external insulation (coating holes or missing cladding parts). Indeed, the performance of a building depends not only on design and execution, but also on the conditions of maintenance. Therefore, a total of 138 sites were observed between July 2012 and November 2016. The method is based on discrete non-participatory observation, easier to implement and limiting the risks that the presence of the anthropologist influences the actual working behaviors on sites.

Except for the six buildings delivered before 2012, all buildings are at least in compliance with French up-to-date thermal regulation (Annex, 2013). Apart from three buildings in Germany (Coburg), all construction sites are located in the Parisian region. The sites and buildings were selected at random (according the spatial mobility of the anthropologist), but also by locating sites labeled “green district”, “new urban district”, “high environmental quality”, BREEAM (Building Research Establishment Environmental Assessment Method), etc. The current results are not statistics, but are still fairly representative of the construction conditions of low-energy buildings in France.

The initial project was on external insulation building, but the method used[1] does not allow to predetermine the insulation technology, so the final data cover 111 external insulation building sites (80%), 25 (18%) insulated otherwise (mainly internal), and two with unidentified insulation process.[2] The external insulation technologies concerned relate mainly to external thermal insulation systems with rendering and external thermal insulation systems with cladding, that is to ETAG (European technical approval guideline) 004 and ETAG 034 (EOTA, 2013, 2012a, 2012b). There are also some ETAG 016 and ETAG 017 (EOTA, 2005a, 2005b), few curtain walls according EN 13830 (ECS, 2015), and other certified external insulation systems.

In nearly 80% of cases insulation has been exposed to weather (Table 1A). In 65% of cases the duration of exposure is three weeks or more. In 52% of cases, these exposure times are equal to or greater than two months. For external insulation sites where protection has been characterized (Table 1C), only 22% deployed a system protecting insulation, but this protection often involved faults (delays, tearing of tarpaulins/rain barriers, etc.) except for prefabrication (insulation installed inside the cladding in the factory). It is not surprising, therefore,

[1] The method consisted to take only into account the insulation of the facades, not that of the roofs, since the latter are difficult to see from the ground, especially in the most common context: roofs-terraces. This limit may induce an underestimate of the problem of insulation exposure, but not an overestimation.

[2] One for which it was not possible to qualify either the process or the exposure before the delivery, despite several visits; the other for which insulation has been exposed (during storage) practically from the foundation. The total number of building sites followed is 166, but here are presented only those that have been delivered, as well as those that have not yet been delivered but whose insulation have already suffered exposures.