Journal of Cleaner Production 83 (2014) 256–262

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

The comparison of thermal insulation types of plaster with cement plaster

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ARTICLE INFO

Article history:
Received 23 November 2013
Received in revised form
3 July 2014
Accepted 17 July 2014
Available online 1 August 2014

Keywords:
Thermal insulation plaster
Cement plaster
Life cycle assessment
Net ecological effects
Energy savings
Economic benefits

ABSTRACT

Plaster plays an important role in buildings. First of all it becomes the protection of external walls from the influence of weather conditions. In the paper it was checked whether it is beneficial to use thermal insulation bims granule or EPS plaster on the external walls of the building instead of cement plaster. The ecological and economic analyses were conducted for these three kinds of plaster depending on the heat source used in the building and the parameters of a wall without a layer of plaster. The calculations were done in Polish conditions. For the indication of the environmental impact LCA technique was used. Bims granule and EPS plaster brings an improvement of thermal insulation properties of walls and as a consequence the reduction of energy consumption to heat in the thermal phase of the building usage. A net ecological effect is positive, related to the use of these types of plaster, after 2–5 years, depending on the source of heat used, whereas for cement plaster it is as long as after 30 years while using an electric energy boiler. For ecological reasons, using bims granule plaster or EPS plaster becomes far more beneficial than using cement plaster. For economic reasons, profits do not fully cover the cost of using the plaster, even after 50 years. The biggest part of the cost is reimbursed in case when the electric energy boiler is used as a heat source: about 22% for bims granule plaster, about 25% for EPS plaster and about 2% for cement plaster.

1. Introduction

LCA analysis is more and more commonly used in the building sector. The examples of application of this analysis can be found in the following studies: Erlandsson and Borg (2003) as well as Oritz et al. (2009). According to Ardente et al. (2008) and Audenaert et al. (2012) it can be used, among the others, for the evaluation of building materials as well as for the selection of the most favourable ones for regard of the impact on the environment. In the study by Hoxha et al. (2014) relative contribution of each building material to the environmental impact of building is examined. In accordance with Dylewski and Adamczyk (2011) it can also be used for the assessment of the thermal phase of using the building depending on the heat source used and the whole life cycle of the building (Oritz et al., 2009). In Europe about 40–50% of final energy is used in buildings (Perez-Lombard et al., 2008; Yan et al., 2010). The energy efficiency of many existing buildings is non-acceptable. According to Żmijewski and Sokołowski (2010) thermal insulation (thermal modernization) of buildings becomes a great potential for the reduction of final energy consumption in the building industry. The improvement of energy efficiency of the building is possible to obtain with, among the other things, the use of thermal insulation materials (see e.g. Dylewski and Adamczyk, 2012; Ozel, 2012). The other way is the application of Phase Change Material (see e.g. Caliskan et al., 2012; Menoufi et al., 2012) or active thermal insulators (see e.g. Van Dessel and Foubert, 2010). Many other works were also interested in the selection of optimum thickness of a thermal insulation layer for economic reasons (see e.g. Bolattürk, 2008; Kaynakli, 2012).

Plaster plays a significant role in the building sector. It provides the protection of the external walls from the influence of weather conditions, e.g. acid rain (Panas, 2004). It also becomes the protection from the influence of internal conditions, e.g. water vapour. It plays an aesthetic function as well (Springer and Adamczyk, 2010).

The article checks whether it is beneficial to use thermal insulation plaster on the external building walls instead of cement plaster. The efforts were made to include in the broadest context

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http://dx.doi.org/10.1016/j.jclepro.2014.07.042
0959-6526/

economic and ecological aspects related to plastering. The ecological and economic analyses were conducted for three kinds of plaster (bims granule plaster, cement plaster and EPS plaster) depending on the heat source used in the building and the parameters of a wall without a layer of plaster. The calculations were done in Polish conditions. Both cement plaster and thermal insulation plaster used on the external building walls brings the improvement of the thermal insulation properties of the wall. As a consequence the consumption of energy to heat in the phase of the building usage is reduced. The ecological analysis was conducted with the use of LCA, whereby not only the increase of the environment burden/load as a result of the plaster production was taken into consideration, but also the reduction of the environmental load as an effect of smaller energy consumption in the phase of the building use. Similarly, the economic analysis included the costs related to applying plaster as well as the benefits connected with smaller energy consumption to heat the building.

2. The properties of cement plaster, thermal insulation bims granule plaster and EPS plaster

Cement mortar is one of the most frequently used on the Polish construction market. Bims granule-based plaster mortar is a novelty on the above mentioned market. The main ingredient of this mortar is bims granule. It is created as a result of freezing basalt lava mixed with volcanic gases (water vapor and carbon dioxide) and ash. Bims granule plaster is an industrially mixed dry mortar consisting of: mineral binder according to DIN EN 459 (2.8% of lime), mineral binder according to DIN EN 197-1 (1.2% of cement) and natural filler (96% of bims). This mortar, after being mixed with water, is ready to use and binds hydraulically. It is plastic and durable in the raw state.

Both kinds of plaster have comparable mechanical properties. Bims granule plaster can be used to build walls with the controlled capacity of water vapor (it has also a tendency to dry rooms) whereas a wall with cement plaster prepared in this way loses this attribute completely due to using a cover (acrylic or vinyl texture) (Adamczyk and Springer, 2010). Bims granule plaster does not absorb water due to a suitable ratio of adhesive powers to cohesive ones. Therefore, it can be used on bases and other walls endangered with moisture or salt (Proiso, 2010). After applying cement plaster a grey surface is obtained and additionally a colourful texture is used. After plastering with bims granule-based plaster mortar a snow-white elevation is obtained, where mechanical damages do not become an aesthetic problem (substance is uniform) (Adamczyk and Springer, 2010) and if the colour does not suit the investor, an additional advantage of the plaster is the lack of cost connected with the purchase and performance of painting the elevation. Moreover, it can also be applied inside rooms and covered with mineral paints (lime, cement or silicate) according to DIN EN 13300 of any colour (Proiso, 2010).

EPS plaster is made of hydraulic binders (cement and lime) in combination with an organic aggregate (polystyrene – EPS) and additives to improve physical properties. It is used for plastering almost all walls without restrictions as to the type of construction material applied. It can be used on the internal and external side of the wall, as well as on the old and new walls. The only restriction of the internal use concerns the rooms with high humidity (e.g. kitchen, bathroom). This plaster can be installed manually and mechanically. The minimum thickness of the layer cannot be smaller than 2 cm, while assuming that the maximum thickness of the plaster layer for one plastering operation cannot be greater than 6 cm. However, the maximum thickness of EPS plaster that can be applied on the external wall cannot be greater than 10 cm (two plastering operations).

In Table 1 the parameters of bims granule plaster, cement plaster and other thermal insulation plaster – EPS plaster were presented. Bims granule plaster has a density equal to 334 kg/m^3, almost five times smaller than cement plaster. A lower density is attributed to thermal insulation EPS plaster, it is about eight times lighter than cement plaster. This advantage is significant in the context of transport cost of these construction materials. Moreover, the thermal conductivity for bims granule plaster amounts to 0.068 W/mK and for EPS plaster – 0.070 W/mK. It fulfils the conditions required for plastering heat-insulating mortars ($\lambda < 0.21$ W/mK and earthwork density in a loose state smaller than 700 kg/m^3) (Jasiczak, 2007).

The durability of cement-lime plaster is 50–80 years (Informator, 2006). For types of plaster based on bims granule and EPS according to norm ISO 15686-1:2000 and the coefficient method to estimate the life period of the sub-component of the building (ISO, 2000), the durability equals 50 years was assumed. The durability of plaster is dependent to a large extent on the inclusion of a number of determinants, e.g.:

- proper project and selection of suitable plaster or plastering system;
- corrosion of metal parts built in;
- suitable project of connections;
- penetration of rain;
- results of atmospheric pollution; etc. (PN-EN, 2009).

In order to reduce the impact of one of the above mentioned determinants on the durability of plaster – penetration of rain – it is advisable to use at least two undersides of the plaster.

3. The ecological analysis of plaster

Cement plaster, bims granule plaster as well as EPS plaster was subject to LCA analysis of the life cycle of the product in order to define the impact of the production of these materials on the environment. According to Löfgren et al. (2011) LCA analysis is an

Table 1
Technical parameters for bims granule plaster, cement plaster and EPS plaster.

Plaster →	Bims granule plaster	Cement plaster	EPS plaster
Appearance and consistency	White powder	Grey powder	Grey powder
Density of dry mass	334 +–10% [kg/m^3]	1600 +–10% [kg/m^3]	200 +–10% [kg/m^3]
Thermal conductivity (after 120 days)	0.068 [W/mK]	0.930 [W/mK]	0.070 [W/mK]
Resistance to compressing	CS II 1.84 [N/mm^2]	CS II 5 [N/mm^2]	≥0.5 [N/mm^2]
Adhesion	0.46 [N/mm^2]	0.5 [N/mm^2]	≥0.08 [N/mm^2]
Moisture absorption	W1 0.204 [kg/m^2] min 0.5	W1 0.235 [kg/m^2]	W1 ≤0.2 [kg/m^2] min 0.5
Diffusion coefficient (after 120 days)	4.80	10	≤10
Consumption for 1 cm of thickness	4.0 [kg/m^2]	about 14.7 [kg/m^2]	2.27 [kg/m^2]

Source: Elaborated on the basis of (Proiso, 2010; Schwepa, 2012).