Construction and Building Materials 85 (2015) 57–64

Contents lists available at ScienceDirect

Construction and Building Materials

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

Gypsum efflorescence on clay brick masonry: Field survey and literature study

Jacek Chwast [a,*], Jelena Todorović [b], Hans Janssen [b], Jan Elsen [a]

[a] KU Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Leuven, Belgium
[b] KU Leuven, Department of Civil Engineering, Kasteelpark Arenberg 40, 3001 Leuven, Belgium

HIGHLIGHTS

- 28 Belgian cases of persistent masonry efflorescence were investigated.
- Gypsum is the major persistent efflorescence component.
- The formation mechanism is related to moisture transport and not to air pollution.
- Both brick and mortar can be the source of gypsum efflorescence.
- Many aspects remain hypothetical, rising important research questions.

ARTICLE INFO

Article history:
Received 30 September 2014
Received in revised form 19 January 2015
Accepted 26 February 2015
Available online 31 March 2015

Keywords:
Gypsum
Efflorescence
Masonry

ABSTRACT

Belgian masonry facades are being increasingly affected by unsightly persistent efflorescence. This results in disappointed customers and consequently creates a threat for the brick industry. Our paper presents a field survey and literature review on the topic. An investigation of Belgian cases reveals gypsum abundance in the deposit. The specific characteristics and literature review indicate masonry as the source and moisture transfer as the transport mechanism. However, there is currently no sound explanation for the crystallisation of gypsum on the surface and its only recent occurrence. One hypothesis points at mortar additives, which may affect the transport and crystallisation of gypsum.

1. Introduction

Salt efflorescence, the growth of salt crystals on a surface caused by evaporation of salt-laden water, is a typical surface defect commonly observed on brick, mortar and concrete facades. Mostly, it concerns whitish deposits of water soluble salts, like alkali sulphates or sodium chloride, which generally appear soon after erection of the facade. Due to their high solubility, these salts are easily brought to the facade's surface via moisture flow, and they are similarly easily washed away from the surface by natural weathering. Since the 1980's however, a grey-white efflorescence has started appearing on a number of clay brick masonry facades, in the UK, in the Netherlands as well as in Belgium, with a particular efflorescence rich in gypsum [4,6]. This specific efflorescence type usually appears a couple of years after construction. The main efflorescence constituent is slightly soluble gypsum, what explains its persistence against natural weathering. The field survey and literature review presented in this paper are motivated by the progressively growing number of gypsum efflorescence (GE) cases reported in Belgium. The paper aims at setting the stage for further research into the potential causes and possible solutions for this growing problem of aesthetic deficiency. The field survey confirms the occurrence of gypsum efflorescence; the literature review reveals the complexity of its underlying processes.

From their investigations of ten gypsum efflorescence cases in the UK, Bowler and Winter [4] deduced a number of crucial observations. Firstly, it is a recent phenomenon, appearing only since the 1980's, solely affecting newly erected facades. Older facades constructed with similar bricks do not suffer from such surface staining. Moreover, this staining is commonly only perceived after a number of years, contrary to the earlier efflorescence of more soluble salts. Gypsum efflorescence furthermore mainly affects facades with a high wind-driven rain load, and these facades often – but not always – comprise cavity insulation. There is no clear relation with the brick type however, as gypsum efflorescence is observed on bricks with both low and high sulphate contents.

* Corresponding author.
E-mail addresses: jacek.chwast@ees.kuleuven.be (J. Chwast), jelena.todorovic@bwk.kuleuven.be (J. Todorović), hans.janssen@bwk.kuleuven.be (H. Janssen), jan.elsen@ees.kuleuven.be (J. Elsen).

http://dx.doi.org/10.1016/j.conbuildmat.2015.02.094
0950-0618/

Although calcium sulphate is one of the major salts present in building materials [10], it is commonly believed that, due to its very low solubility, its presence in bricks does not lead to efflorescence or sulphate attack [2]. Steiger and Heritage [29] similarly noted that gypsum is considered fairly inactive with respect to changes in RH and temperature, hence not undergoing phase transitions, and therefore not likely to cause damage like other salts. These are the main reasons for the lack of research activity on gypsum in porous materials. Consequently, even though gypsum efflorescence has been occurring for some decades, the physico-chemical processes behind this phenomenon are still unclear. This paper therefore has a double objective. The reported field survey establishes the occurrence of gypsum efflorescence in Belgium and confirms and widens the earlier observations by Bowler and Winter [4] and Brocken and Nijland [6]. The presented literature review gathers the current knowledge in relation to gypsum efflorescence, and formulates the main research questions to be tackled in order to come to further insight in this phenomenon.

The field survey investigates 28 cases of persistent efflorescence on brick masonry. It confirms that the main component often is slightly soluble gypsum, explaining their persistent nature. For most cases, the brick type is identified, and potential relations between brick properties and efflorescence formation are analysed. Based on our data, neither the brick's hygric characteristics, nor its sulphate content appear to be significant for the formation of gypsum efflorescence. The literature review assesses different physico-chemical processes potentially underlying this phenomenon. These include mortar and brick as potential sources of gypsum, the dissolution, transport and crystallization of gypsum, and the recent changes undergone by masonry as potential triggers for gypsum efflorescence. Based on the information collected via the field study and literature review, we conclude this paper by formulating the most essential research questions related to the gypsum efflorescence phenomenon.

2. Field Survey on persistent efflorescence

Persistent efflorescence – stains of slightly soluble salts that do not wash off naturally – is a growing problem in the construction industry. Besides the occurrence in the UK and the Netherlands [4,6], the Belgian brick producers are receiving progressively more complaints, as building owners blame their products for the flaw. In the opinion of the Belgian brick producers, persistent efflorescence occurs more frequently, develops quicker than before, and gets more pronounced over time.

In order to contribute to the knowledge on this issue a field survey is carried out, to determine the major factors associated with its occurrence. In this survey, 28 cases of Belgian buildings affected by persistent efflorescence are analysed. Some of these cases were identified from the complaints of building owners to brick producers, other cases were found during an exploration of the Leuven area in Belgium by the researchers.

2.1. General observations on persistent efflorescence

The investigated cases concern a type of permanent efflorescence, which after having developed on a masonry surface does not wash off with natural weathering. In two cases the building facades had been cleaned with high-pressure water jets, which removed the efflorescence stains temporarily, but did not restore the facades' original appearance. In both cases efflorescence has reappeared, indicating that the efflorescence source is not affected by the treatment. The observed persistent efflorescences come in different appearances, ranging from a thin whitish veil present within the porous surface of a material to a locally developed thicker crust on top of the material's surface. Even while being thin and hazy from an up-close perspective, the efflorescence greatly alters the aesthetic aspect of the masonry facade when looking from a distance (see Fig. 1). In contrast to early efflorescences of easily soluble salts, often being soft and thick, these persistent efflorescences give the impression of being very compact and strongly adhering to the brick surface, while simultaneously generally being very thin. In most cases the efflorescence affects the bricks to a much greater extent than the mortar joints.

The building facades are all constructed with mechanically produced 'hand' moulded clay bricks, most commonly used for facade masonry in Belgium. In all cases, the most affected facades of the building are those oriented West to South, with efflorescence being most pronounced on the edges and the upper parts of the facade, facade orientations and locations that typically receive relatively frequent wind-driven rain.

The year of construction is known for 15 of the 28 cases, and ranges from 1997 to 2007. The other cases are probably constructed in a similar period, as they have an equally modern appearance. None of the 28 studied cases hence concerns older constructions, and the problem thus appears to exclusively affect buildings erected during approximately the last two decades. Based on observations by building owners, it is moreover noted that the efflorescence does not appear directly after construction but is instead perceived only several years after construction. However, as these observations of such delays are based on visual assessments, it is not clear whether persistent efflorescence indeed develops with a delay, or whether it is just a very slow process that goes unnoticed in its early stages.

2.2. Composition analysis of persistent efflorescence

To determine the efflorescence composition, efflorescence samples are collected and analysed, revealing four primary categories in the studied persistent efflorescence cases.

2.2.1. Methodology

Salt deposits were gently scraped from bricks in higher parts of the facades (above the 1.5 m height line), to exclude cases of salt accumulation due to rising damp. The collected samples were initially gently ground and then sieved through a 63 μm sieve, to separate the salt deposit from sand grains inadvertently removed from the brick surfaces together with efflorescence. The deposit enriched fraction was ground even further, and then sprinkled over a silicon sample holder plate. To identify the minerals forming the efflorescence, the samples were analysed via the powder X-ray diffraction (XRD) method. The diffraction patterns were gathered with a Philips PW1830 diffractometer using CuKα radiation (45 kV, 30 mA). The standard 2θ scan range was taken to be 5–70° with a step size of 0.02° 2θ and a counting time of 1s. This methodology allows a qualitative estimation of the sample composition.

2.2.2. Results

Table 1 presents the results of sample analyses and case evaluations. Out of the four identified minerals – gypsum, calcite, hematite and quartz – only the former two are potential persistent efflorescence components. In most cases where gypsum is identified in a sample, it is present in a substantial amount compared to the other identified minerals. As it is not a raw brick component, it is clear that its accumulation at the surface of masonry is due to the efflorescence formation. Unlike for gypsum, the origin of calcite is uncertain, since there are several possible sources of calcite at the brick surface. Besides being recognised as a potential efflorescence forming mineral [11], calcite also naturally occurs in clays,