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Clay brick masonry facades with cracks caused by corroding bed joint reinforcement – Findings from field survey and laboratory study

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HIGHLIGHTS

- Field survey and laboratory study of corrosion in 75 reinforced masonry window beams.
- Crack frequency is highly dependent on amount of corrosion.
- The location, wall orientation and floor height affect the corrosion.
- Moisture content and temperature can be seen as most influential parameters.
- Possibilities for further research in the field are discussed.

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ABSTRACT

Cracking due to corrosion in bed joint reinforcement over openings in masonry facades in the Scandinavian post-war building stock generates increasing retrofitting needs. Removal of the reinforcement can be both costly and labor intensive. The results of retrofitting works are often sub-optimal due to casual inspection practices and lack of knowledge concerning the actual corrosion damage. The objective of the presented research is to increase knowledge about physical factors influencing corrosion of bed joint reinforcement. The research includes a field survey by ocular examination of cracking and decay related to corrosion of reinforcement in joints above openings, and a subsequent laboratory examination of reinforcement extracted from the surveyed buildings. The investigation shows a strong dependence of crack formation on the corrosion depth of the embedded reinforcement. In turn, the corrosion depth is mainly influenced by moisture content and temperature in the façade, two factors related to geographic location, orientation and height above ground. The number of reinforcement bars in the joints has also a large influence on the crack frequency. It is suggested that a practice oriented model able to predict time until cracking, with moisture content and temperature as main factors, would be possible to develop with corrosion models from the field of concrete and the empirical data from the present research as a basis.

1. Introduction and objectives

1.1. Short historic background

Load bearing reinforced clay brick masonry was a frequently used technology in residential, commercial and public buildings raised in the Scandinavian countries during the period 1940–1975. The gross façade area consisting of clay brick masonry of the mentioned type is estimated to 80 million m^2 in Sweden only [1]. The reinforcement bars, consisting of unprotected carbon steel or galvanized carbon steel, were mainly placed in the bed joints above windows and doors to bridge these openings by means of beam action. Brick veneer walls were reinforced according to the same principles. The placement of the reinforcement in load bearing clay brick walls and brick veneer walls is shown in Fig. 1. In order to further strengthen the wall sections, reinforcement was sometimes also placed in the bed joints below windows and continuously in the entire wall. Generally, bed joint reinforcement was used also when this was not required from a structural point of view – in many cases window and door openings could have been bridged by arching action, thus making the bed joint reinforcement superfluous.

The use of reinforcement consisting of unprotected carbon steel or galvanized carbon steel was motivated by the erroneous assumption that lime-cement mortars could provide permanent chemical protection against corrosion [2,3]. Today, brick façades from the period before 1975 are often affected by corrosion related

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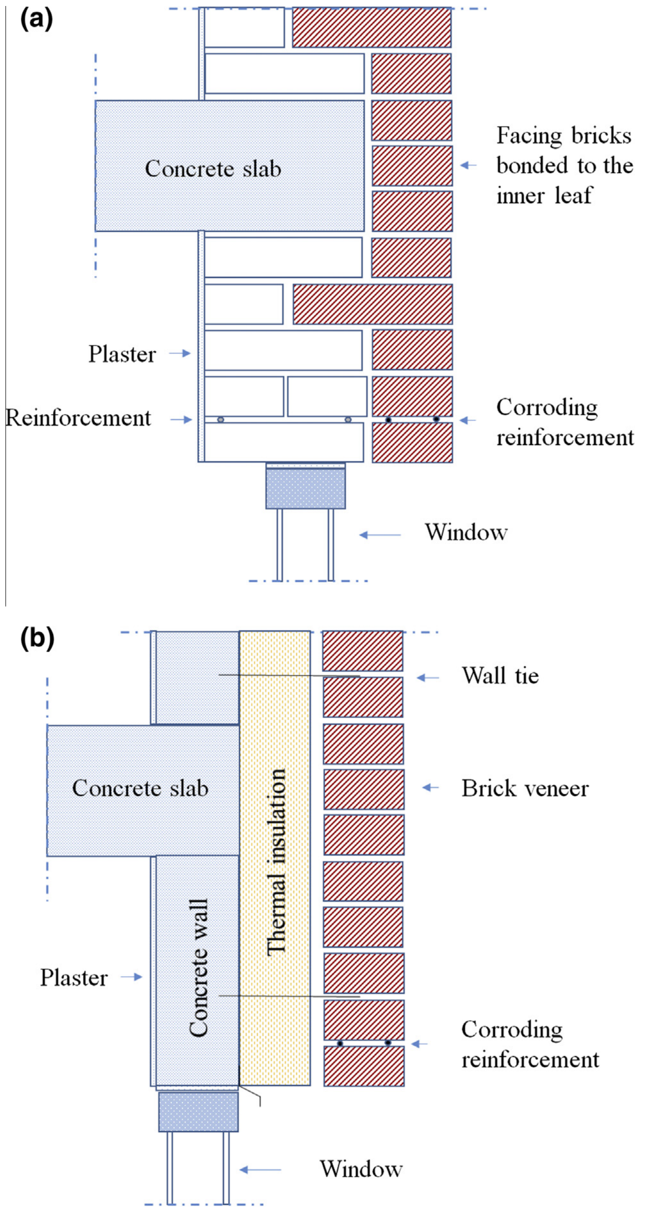

Fig. 1. Wall sections with corroding bed joint reinforcement: a) faced single leaf brick wall; b) brick veneer.

cracking [4–6]. During the 1980's, awareness concerning problems with corrosion of masonry reinforcement increased [7–9] and subsequently more strict design recommendations regarding durability of reinforced masonry have been introduced in many West-European countries [10–12]. Nevertheless, in the building practice, inadequately protected carbon steel reinforcement was still used in exposed façades more than a decade after the introduction of more restrictive regulations, which explains the occurrence of corrosion damage also in masonry façades built during the 1980's [6].

Cracks formed in bed joints containing corroding reinforcement can impair aesthetics and increase moisture up-take with associated proneness to frost damage, microbiologic growth and increased heat loss, see Fig. 2. In advanced stages of corrosion, the load bearing capacity of masonry beams may also be affected [8]. As the post-war building stock contains many culturally valuable masonry buildings, there is an increased interest in development of lenient retrofitting techniques [13].

Fig. 2. Retrofitting of window beam with corroding bed joint reinforcement.

1.2. Current retrofitting practices

In order to stop further corrosion related damage, the corroding bed joint reinforcement is usually removed and, when necessary, replaced by reinforcement of stainless steel. As a basis for decision making concerning retrofitting measures, cracked bed joints are identified by ocular inspection of the façade. In most cases, no further assessments or analyses are carried out, e.g. regarding the condition of the reinforcement or the expected development of corrosion related cracking [1,16].

The extent of retrofitting varies between partial to total removal of the reinforcement from cracked bed joints or from the entire façade. In some cases, only repointing of cracked bed joints is carried out, without removal of any reinforcement. If the corroding reinforcement is not removed, the new bed joints will crack in a few years thus making such a measure inefficient, see Fig. 3. The final choice of retrofitting strategy is influenced by factors such as: a) the extent of cracking in the façade – if the proportion of cracked bed joints is considered low, partial retrofitting is preferred while total retrofitting is often preferred when cracking is extensive; b) the competence of the client, of the building contractor or, if involved, of the technical consultant; c) the economic situation of the client; d) concerns regarding increased moisture content in the external walls with associated problems. In either case, façade retrofitting projects are costly, since scaffolding has

Fig. 3. Repointed bed joint that cracked due to further corrosion of the reinforcement.