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Salts in Reused Fired Clay Bricks: Content and Related Challenges

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Abstract

The present work sheds light on the missing information of active soluble salts in CE-marked reused fired clay bricks and examines the content and related challenges. The salt content in twenty and nineteen CE-marked, reused fired clay bricks from the two largest suppliers in Denmark was examined, and the existing limited results from previous examinations of CE-marked fired clay bricks and historical bricks were included to provide a more general picture. A systematic approach to measuring ion content at realistic, relevant locations in bricks was used, yielding results for total ionic content (electrical conductivity and summed single-ion contents) and for single ions (both anions and cations). To discuss the severity of the ionic content, the measured ionic contents were compared with various approaches (ÖNORM B 3355-1, WTA Merkblatt 4-5-99/D, experience-based DK, experience-based B). Dependent on the assessment approach, 16–45% of the CE-marked reused fired clay bricks had ionic content that was too high, ranging from just above the limit to significantly higher. While a discussion of appropriate threshold values for CE-marked reused fired clay bricks is needed, some of the bricks contained levels above all threshold values, indicating a problematic high salt content. This paper is a contribution to the SWBSS2026 Conference.

Keywords

reuse, fired clay bricks, CE-marked, salts, threshold values

1 Introduction

The societal need to reduce consumption of raw materials and energy is urgent, and the potential for reuse of construction materials is substantial. The highest environmental impact is obtained when the use of new raw materials and energy is avoided (R0-R2) according to Potting et al. [1]. The second-best solution is to extend the lifespan of products (R3-R7), and with the highest environmental value in this group, R3, if the discarded product is still in good condition and fulfills its original function, it is "Reused by another consumer". This rare possibility exists with fired clay bricks, a material with a tradition of reuse.

A study on the status of reuse of fired clay bricks in [2] revealed that while only 2% of the material was reused, an additional 47% of the newly produced fired clay bricks could be replaced with material already collected as brick waste, neglecting challenges to reuse (Fig. 1).

Experience with the reuse of fired clay bricks is frequent in the history of many countries, e.g. Hirschholm Castle, Denmark, was left due to an invasion in the late 1771, considered renovated from 1772, but put on hold and 1810-1812 the main building was demolished for reuse for the second Christiansborg (rebuild 1803-1828 after a fire) [3], the national parliament.

The historical reuse of fired clay bricks occurred at a different time and in a different context. In history,

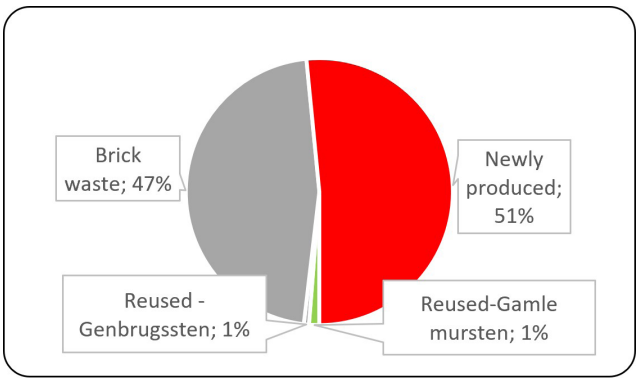


Fig. 1 Potential for reuse from waste in Denmark [2]

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construction materials were reused due to the high production prices; today, the societal challenge is the overconsumption of raw materials and energy.

In historical times, documentation requirements were nonexistent, whereas today CE-marking is required. Although CE-marked fired clay bricks are already available for purchase, the only material descriptions for CE-marked reused fired clay bricks are a minimum compressive strength of 15 N/mm^2, a density of 1650 ± 30% kg/m^3, and an exposure class description (related to durability classes). The exposure class declaration is handled by producers, who each declare all their products to the same exposure class [2]. This level of information contrasts with product-specific material information for newly produced fired clay bricks, including specific material values for the material properties:

1. compressive strength,
2. density,
3. initial rate of absorption,
4. 24 hours of capillary water absorption,
5. frost resistance,
6. content of active soluble salts.

To offer a real alternative to newly produced fired clay bricks, reused fired clay bricks must be well-described as similar to new fired clay bricks.

The material property, the content of active soluble salts, is influenced by both the original raw materials and the materials' exposure during their first lifetime, where they may have been exposed to salt pollution, the most common pollution source in masonry. Such salts may originate from many sources [4], and their presence is a standard examination criterion for historical constructions, since exposure to salt sources inevitably accumulates over time. The oldest historical masonry constructions, churches, having been exposed to many different salt sources for centuries, more often than not suffer from the presence of salt, and the search for a suitable desalination treatment of the wall paintings [5] is urgent and has been ongoing for many years, likely reflecting a frequent salt problem. The development of salt-induced deterioration with time was approached in [6], as originally used in reinforced concrete by [7] (Fig. 2). New materials are expected to be undamaged ($t = 0$), with time the material may be subjected to salt exposure, the deterioration degree initiates, whereas the following deterioration velocity depends on varying factors (e.g. salt content, the number of damaging crystallization-dissolution cycles and material properties).

This material-dependent development is shown in Fig. 3, which shows varying degrees of deterioration for

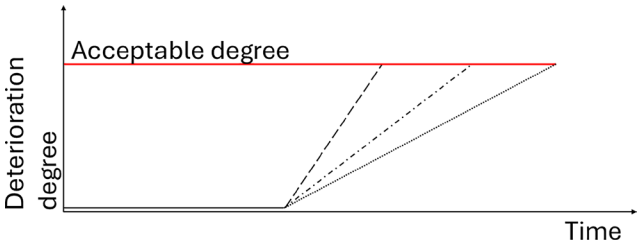
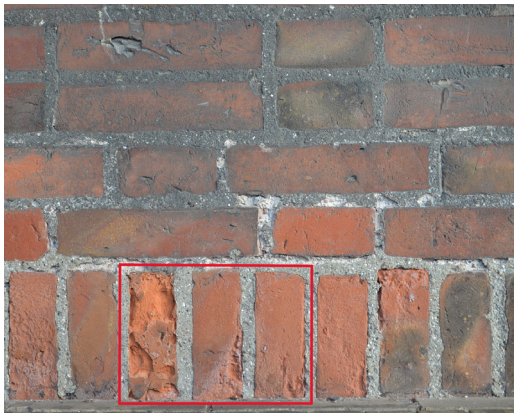


Fig. 2 Degree of damage as a function of time, where the slope of the dotted lines indicates the severity of degradation velocity, where a greater slope accounts for faster deterioration. (Adapted from [7])



(a)



(b)



(c)

Fig. 3 Visualization of varying deterioration degree within 1 year, dependent on the specific material. (a) Overview picture, (b) from the area within the red box 4th Nov. 2024, (c) from the same area one year later (18th Nov. 2025).

the 3 different fired clay bricks under an assumed identical weathering exposure, in an area where de-icing is used.

To avoid salt contamination in reused fired clay bricks, site visits are conducted prior to demolition to exclude areas with visible salt deposits and those at high risk of salt contamination (e.g., lower areas of buildings suspected of exposure to deicing salts) by the reuse suppliers.

However, previous, unsystematic examinations of historical bricks [8] and CE-marked fired clay bricks revealed that some of them had higher electrical conductivity than in new materials [9]. Increased electrical conductivity, although not showing specific ionic concentrations, is associated with increased ionic content [10].

This work addresses the lack of information on the content of active soluble salts in reused CE-marked fired clay bricks, examines current salt levels in selected reused fired clay bricks, and related challenges.

2 Materials

Fired clay bricks from the largest suppliers in Denmark of CE-marked reused fired clay bricks: Gamle Mursten, Genbrugssten were examined, together with a typical contemporary fired clay brick also used in [11] (Table 1).

3 Methods

To determine the ionic content in the CE-marked fired clay bricks, a 10 mm drill was used for sample extraction, and powder was collected until a depth of 10 mm from the stretcher side (25 mm from shiner, 20 mm from header side) (Fig. 4).

Table 1 Overview of tested materials, all CE-marked

Supplier	Reused/New	Number of examined materials
Gamle Mursten (GM)	Reused	20
Genbrugssten (GS)	Reused	19
Wienerberger (type: bright red – BR*)	New	1

* Used for elaboration of [11].



Fig. 4 Sampling position: 25 mm from shiner, 20 mm from header side

Subsequently, the powder was dried to constant weight. 1.00 g dried powder sample was added to 12.5 mL of demineralized water, agitated for 24 hours, and filtered through 0.45 µm prior to measuring the anions with IC (Dionex ISC1100, Column AS14) and cation contents with ICP (Agilent 5800 ICP-OES).

4 Results

4.1 Assessment based on the total ion content approach

An overview of the present total ionic content was determined by measuring the electrical conductivity (Fig. 5). As an example of the electrical conductivity in non-salt contaminated fired clay bricks, the content in a newly produced fired clay brick (Table 1) was measured and added as the lower expected value (black, dotted horizontal line Figs. 5–10). A threshold value of 0.5 wt% in total (both anions and cations) may be proposed based on [12], and this limit is added as the red dotted line in Fig. 6 and Fig. 7, termed the experience-based limit. The 0.5 wt% in total is independent of the specific ion types, though it is influenced by many ion types, as expected in historical constructions, which accumulate ions over time. In [13] an electrical conductivity estimated to 600 µm/cm was found

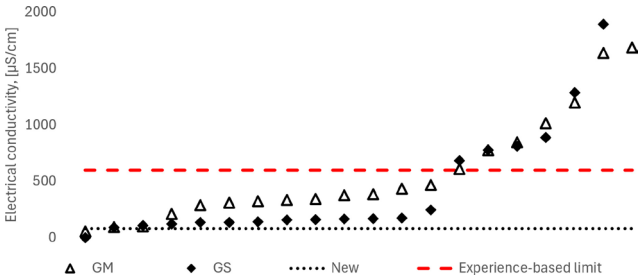


Fig. 5 Electrical conductivity measurements of two suppliers of CE-marked reused fired clay bricks, ordered after increasing electrical conductivity.

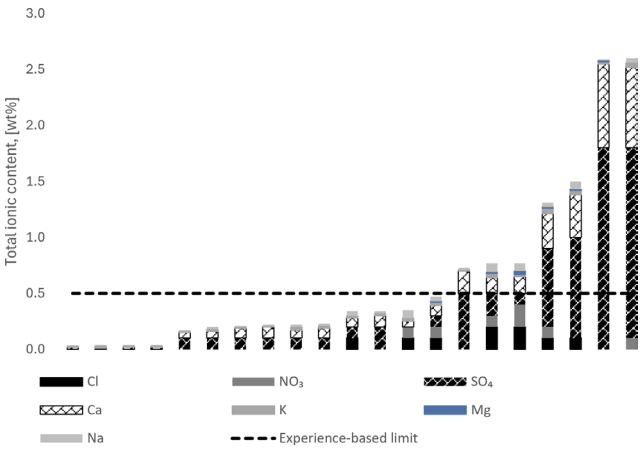


Fig. 6 The ionic content in GM samples, separately, stacked for each of the samples, ordered with increasing content. The dotted line indicates the experience-based threshold value from [12].

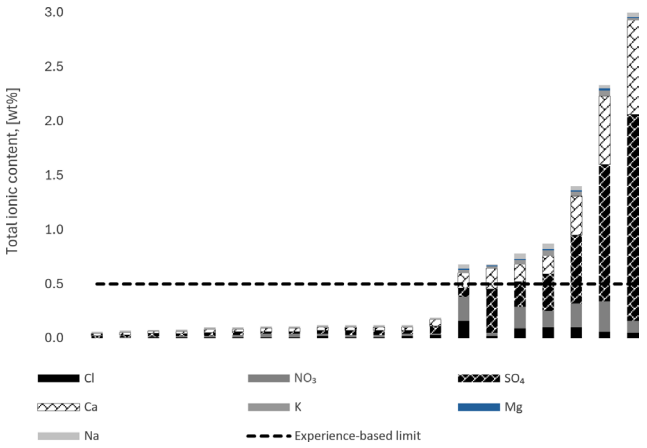


Fig. 7 The ionic content in GS samples, separately, stacked for each of the samples, ordered with increasing content. The dotted line indicates the experience-based threshold value from [12].

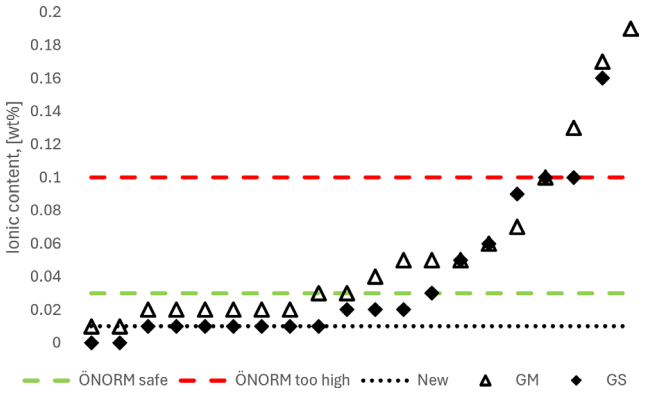


Fig. 8 The chloride content, ÖNORM B 3355-1 threshold values along with measured contents in new, GM and GS materials. Ordered after increasing content.

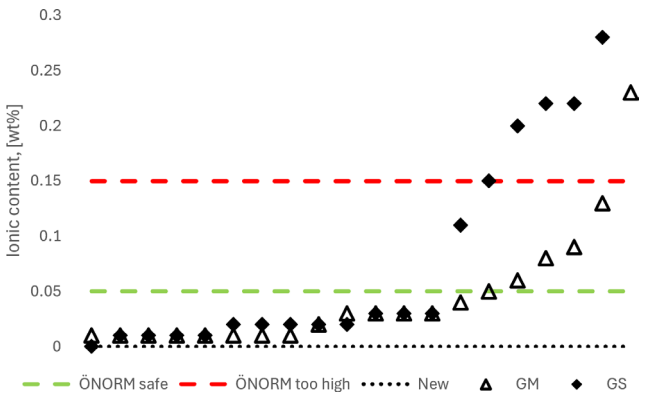


Fig. 9 The nitrate content, ÖNORM B 3355-1 threshold values along with measured contents in new, GM and GS materials. Ordered after increasing content.

to correspond to the experience based limiting value and 600 µS/cm is therefore added as a red dotted line in Fig. 5. It is observed (Fig. 5) that both GM and GS each have one sample (5%) with an electrical conductivity below the value for a newly produced fired clay brick, and 5–6 bricks

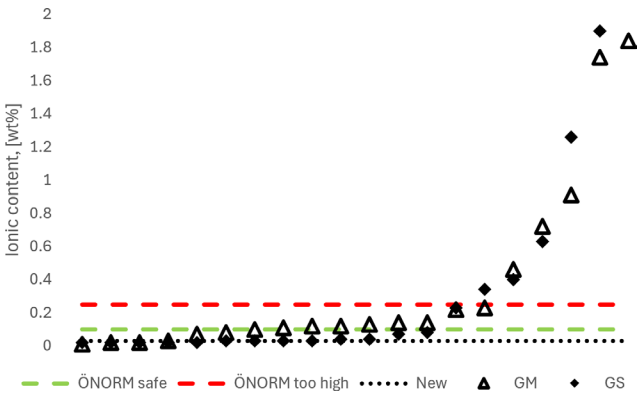


Fig. 10 The sulfate content, ÖNORM B 3355-1 threshold values along with measured contents in new, GM and GS materials. Ordered after increasing content.

above the experience-based limit (26–30% of the bricks). The majority of the bricks (70–74%) had an electrical conductivity below the experience-based limit. It is further observed that the GS bricks in general had lower electrical conductivity than GM.

To obtain a clearer picture of the ionic elements and contents, the typical present anions Cl, NO_3, and SO_4, and cations Ca, K, Mg, and Na were measured in all the bricks, and are shown in Fig. 6 for the GM materials, and in Fig. 7 for the GS materials. Further ion types were measured; however, their content was insignificant and therefore not shown. The results are shown as stacked contents to enable comparison with the experience-based limit of 0.5% in total from [12].

The contents of Ca and SO_4 were dominating in both GM and GS materials, and to visualize this, only these two ionic contents are shown with a pattern in Fig. 6 and Fig. 7. Up to 0.75 wt%, and 1.8 wt% Ca and SO_4 was measured, this is also corresponding to an equal amount of moles for Ca and SO_4, make likely the presence of $CaSO_4$.

The number of GM bricks (Fig. 6) and GS bricks (Fig. 7) with total ionic contents above 0.5 wt% is 7 (35–37%). For both GM and GS, the dominant ions are Ca and SO_4, but the fired clay bricks also contain relatively minor amounts of Cl, NO_3, Na, and K. The number of fired clay bricks exceeding the experience-based threshold value of 0.5 wt% is similar regardless of whether evaluated by electrical conductivity (Fig. 5), specific ionic content (Fig. 6 and Fig. 7), for both GM and GS bricks. Furthermore, there is complete overlap between specific bricks, with contents exceeding the threshold value determined by ionic measurements of chloride, nitrate, and sulfate, summed to the total ionic content, and the measurements by electrical conductivity.

4.2 Assessment based on single ion content approach

The standard ÖNORM B 3355-1 [14] provides guidelines for assessing the severity of ionic content based on single anion contents.

Within the intervals Chloride 0.03–0.1 wt%; Nitrate 0.05–0.15 wt%; Sulfate: 0.10–0.25 wt%, the severity is subject to individual assessment, below regarded as a safe content, above regarded as too high a content.

The contents in the GM and GS bricks are shown for each of the anions Chloride, Nitrate, and Sulfate in Figs. 8–10, respectively, together with the content in a newly produced brick (Table 1), and the limiting values in the ÖNORM B 3355-1.

Regarding chloride content, 6 GM (30%) and 3 GS (14%) were between safe and too high content, and 4 GM (20%) and 3 GS (14%) had too high levels (Fig. 8).

The nitrate content was between safe and too high content for 5 GM (25%) and 3 GS (14%), whereas 1 GM (5%) and 5 GS (25%) had too high a content (Fig. 9).

For sulfate content, 9 GM (45%) and 1 GS (5%) had levels between safe and too high, while for both GM and GS, a too high level was found in 5 bricks (25%–26%) (Fig. 10).

Considering the limiting values for all anions (chloride, nitrate, and sulfate), meaning a too high content in at least one of the anion contents, it is found that in total 8 GM (40%) and 9 GS (47%) have ionic contents considered as too high.

It is observed that a higher number of bricks have ionic contents that exceed the ÖNORM B 3355-1 limiting values for evaluation of each anion content (chloride, nitrate, and sulfate), exceeding the experience-based limit of 0.5 wt% in total. When studying the specific bricks and comparing them against these two criteria, it is seen that, beyond a variation in the number of bricks exceeding the threshold value, there is only partial overlap in the specific bricks exceeding the threshold value between the two methods.

5 Discussion

To evaluate the severity of the present ionic contents, several factors will influence the outcome: sampling depth and evaluation criteria.

Presently, there is no guidance on how to extract drilling samples before determining ionic content. It is, however, well-known that salt accumulates towards the surface [15] during evaporation. Therefore, reducing the sample extraction depth from the exposed surface will yield higher concentrations. Meaning extractions from 0–2 mm are expected to result in higher contents than 0–20 mm, and therefore the sampling depth of 0–10 mm was deliberately chosen to obtain a reasonable reflection of the general degree of salt content in the whole fired clay brick.

Likewise, it should also be noted that the exact measured values shown in Figs. 5–10, and the severity of the present ions, can only be compared with the results based on samples with a similar extraction depth of 0–10 mm.

In addition, the sampling position of 25 mm from shiner and 20 mm from header was deliberately chosen:

1. for all the samples to eliminate the influence from different positions
2. as a location with similar evaporation to all surfaces, and with a relatively higher expected content as of compared to the interior of the brick, to examine for existence of ion contents may be problematic in the materials.

Beyond ÖNORM B 3355-1 [14], WTA Merkblatt 4-5-99/D [16] also uses single anion threshold values for chloride, nitrate, and sulfate, although the threshold values are slightly higher (above safe and below too high, chloride: 0.05–0.2 wt% instead of 0.03–0.1 wt%; nitrate 0.1–0.3 wt% instead of 0.05–0.15 wt%, and sulfate: 0.2–0.5 wt% instead of 0.10–0.25 wt%). The challenge with the single-ion approach in general is that ions rarely exist alone [17], that the presence of multiple ion types influences each other, and that ion mixtures deviate significantly from the behavior of single ions [18].

To work around these single-ion-induced challenges, [12] was used as an experience-based approach, derived from measuring ionic content on damaged and undamaged fired clay bricks in a church vault (3 bricks, sampling depth: 0–20 mm), where the undamaged brick had less than 0.5 wt% total ionic content.

In Belgium, a total content of 1 wt% is used as the threshold value. Although this was discussed during the presentation by Rörig-Dalgaard [19], no official documentation has been found about this value, which was mentioned by De Kock [20] during the session.

It should, however, also be kept in mind that higher ionic contents will result in faster deterioration (Fig. 2), and selecting a threshold value should be considered guidance for defining acceptable ionic values that result in acceptable deterioration degrees. Further, ionic contents that significantly exceed the threshold values result in a greater deterioration rate (a steeper slope, Fig. 2).

While there may be a pending need for a discussion of appropriate threshold values to interpret measured ionic

contents, it should be emphasized that the damaging potential also depends on the material strength, pore-filling degree, and ion mixtures (crystallization pressure on the pore wall) [21]. This, however, is not the focus of the present work; instead, discrepancies are noted, and existing threshold values are used.

Producers of reused fired clay bricks are aware of the potential for salt pollution, especially from deicing (mainly with NaCl). Therefore, lower areas of the buildings may be deselected for reuse. This awareness appears to be quite consistent, as only 3 GM (15%) and 1 GS (5%) exceed the ÖNORM threshold value for chloride. In contrast, 1 GM (5%) and 4 GS (21%) exceed the ÖNORM B 3355-1 threshold value for nitrate, though none exceed the WTA limiting value for nitrate. However, the most challenging ion to detect is apparently sulfate, even with the less strict WTA limiting value, 4 GM (20%) and 3 GS (16%) bricks, respectively, exceed acceptable limits. Traditionally, chlorides and nitrates are commonly present in construction materials [22]. The dominant factors of Ca and SO_4 may result from the focus on the effects of de-icing salts and on avoiding the reuse of fired clay bricks from these areas.

To further complicate the matter, the deselection of areas in existing constructions is highly dependent on the evaluator's actual experience. Also, it is challenging to detect fired clay bricks with salt present as non-visible sub-efflorescence and decide to what height (and/or how large areas) are to be discharged when the visible salt concentration is continuously decreasing with increasing distance from the ground, as e.g., in Fig. 11.



Fig. 11 Lower part of exterior wall, Oviedo, Asturias, Spain. Continuously decreasing visible salt efflorescence with increasing height.

While this study aimed to shed light on possible ionic content in reused fired clay bricks, the examination of 20 and 19 randomly selected CE-marked bricks from the two largest suppliers in Denmark cannot be considered a complete mapping, nor representative. However, to improve representation, the Danish suppliers of reused fired clay bricks, "Nordsten" and "Munkesten", of which "Nordsten" supplies CE-marked bricks, were contacted but they were apparently not interested in providing materials.

The observed variation in ionic content in GM and GS in this study, from below all threshold values to beyond two existing threshold values, was also reported in [23], where a fraction of the bricks distributed throughout the vault exhibited the same variation, not limited to a specific area. Further, these varying ionic contents were measured in purchased reused CE-marked fired clay bricks in [9]. A likely general tendency caused by ionic exposure from many different sources [5] and varying material properties [24]. Historically, fired clay bricks, produced before 1960 (prior to the use of a tunnel kiln), were fired in-homogeneously throughout the batch, resulting in materials with significantly different material properties (exemplified in Fig. 3) [24] (most relevant in this regard: pore size distribution and porosity), resulting in significantly different water transport properties, and thereby significantly different ionic accumulations and contents.

In addition to the various limiting values for existing constructions (ÖNORM B 3355-1 [14] and WTA Merkblatt 4-5-99/D [16]) and experience-based limiting values [12, 19], requirements for new fired clay bricks are: S0 (No limit specified), S1 (Na + K ≤ 0.17 wt%; Mg ≤ 0.08 wt%), S2 (Na + K ≤ 0.06 wt%; Mg ≤ 0.03 wt%) [25].

Depending on the evaluation approach used, a variable number of bricks (i.e., a percentage of bricks) have ionic contents that are too high (Table 2), as compared to ÖNORM B3355-1 [14], WTA Merkblatt 4-5-99/D [16], and CEN EN 771-1:2011 [25].

Table 2 Percentage of bricks with too high ionic content based on different evaluation approaches ÖNORM [14], WTA [16] and CEN EN 771-1:2011 [25]

Evaluation approach	GM	GS
ÖNORM	40%	47%
WTA	25%	16%
Experience-based, 0.5 wt%	35%	37%
Experience-based, 1 wt%	20%	16%
CEN EN 771-1:2011, S0	0%	0%
CEN EN 771-1:2011, S1	0 %	0%
CEN EN 771-1:2011, S2	35%	26%

Comparing the results based on electrical conductivity and total ionic content, there is complete overlap in the bricks to be opted out (Figs. 5–7). This general connection between increased total ionic content and increased electrical conductivity is consistent with the findings in [10].

It is, however, to be noted that no limits are given for Ca (nor the anions, including SO_4, and contents of these are not accounted for) in CEN EN 771-1:2011 [25]. Sulfate salts are, in general, considered the most damaging, and therefore, using the threshold values in CEN EN 771-1:2011 is inappropriate for reused fired clay bricks.

The presence of polluting sources in construction materials intended for reuse after their first lifetime is not surprising and must be considered a general challenge across construction materials. Therefore, the presence of salts in reused fired clay brick is not a dealbreaker but an issue to be accounted for. The future task instead is to ensure a good quality of reused fired clay bricks, and since the existence of salts in considerable amounts and frequency, there is a need for a fast salt detection method, to enable a scan of every single material, to sort out materials with too high ionic content (too poor quality).

6 Conclusions

The need to reduce raw materials and energy consumption is urgent, and the demand for housing is fundamental. To partially accommodate this demand, the potential for reusing fired clay bricks is substantial. While the reuse of fired clay bricks has already been done in historical times, the context is now different, and there is now a demand for documentation. CE-marking of reused fired clay bricks provides significantly less information than that of newly produced fired clay bricks. One of the missing pieces of information in the CE-marking for reused fired clay bricks is the content of active soluble salts.

In this study, a considerable amount (percentages) of bricks possessed salt content exceeding threshold values, ranging from 16–47%, dependent on the assessment approach, of which all are presently used. The percentage of bricks exceeding threshold values was within the same range, and 20–40% for GM and 16–47% for GS.

While this present study and previous observations and measurements do not provide a full or representative examination of all existing CE-marked reused fired clay bricks, the results together create a picture of a general tendency of the presence of a salt content to be accounted for. The goal must be that reused fired clay bricks have a similar quality as newly produced fired clay bricks, to make them a real alternative for repair and construction of new structures.

Acknowledgements

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References

[1] Potting, R., Hekkert, M. P., Worrell, E., Hanemaaijer, A. "Circular Economy: Measureing Innovation in the Production Chain", PBl Netherlands Environmental Assessment Agency, The Hague, Netherlands, Rep. PBL publication number: 2544, 2017

[2] Rörig-Dalgaard, I. "Status on the reuse of fired clay bricks: Ready for the future?", In: Proceedings of the 11th International Masonry Conference (IMC 2026), Lübeck, Germany, 2026, pp. 3–11. ISBN 978-3-7388-1040-0
https://doi.org/10.60628/9783738810400-3

[3] Schousboe, V. C. J. "Nivaagaard Teglværk" (Nivaagaard Brickwork), Nivaagaard Teglværks Ringovn, 2021. ISBN 9788797037812 (in Danish)

[4] Bläuer, C., Rousset, B. "Salt sources revisited", In: Proceedings of the 3rd International Conference on Salt Weathering of Buildings and Stone Sculptures (SWBSS2014), Brussels, Belgium, 2014, pp. 305–318. ISBN 9782930054247
https://doi.org/10.5165/HAWK-HHG/245

[5] Bartholdy, J., Haber-Pohlmeier, S., Rörig-Dalgaard, I., Frick, J. "Water dynamics during hydrogel and traditional poultice applications on multilayered wall paintings", npj Heritage Science, 2026.
https://doi.org/10.1038/s40494-026-02959-w

[6] Flatt, R. J, Mohamed, N. A., Caruso, F., Derluyn, H., Desarnaud, J., …, Steiger, M. "Predicting salt damage in practice: A theoretical insight into laboratory tests", RILEM Technical Letters, 2, pp. 108–118, 2017.
https://doi.org/10.21809/rilemtechlett.2017.41

[7] Tuutti K. "Corrosion of steel in concrete", Doctoral Thesis, Swedish Cement and Concrete Research Institute, 1982.

[8] Rörig-Dalgaard, I. "Preservation of murals with electrokinetic – with focus on desalination of single bricks", [pdf] PhD Thesis, Technical University of Denmark, 2009. Available at: https://backend.orbit.dtu.dk/ws/portalfiles/portal/5013186/Thesis%20Inge_web.pdf

[9] Tsiakoumi, E., Rörig-Dalgaard, I. "Test of reused and non-salt-resistant fired clay bricks with the new RILEM test procedure", In: Proceedings of the 8th International Workshop on Crystallization in Porous Media (Cryspom VIII), Ghent, Belgium, 2023, p. 23.

[10] Nasraoui, M., Nowik, W., Lubelli, B. "A comparative study of hygroscopic moisture content, electrical conductivity and ion chromatography for salt assessment in plasters of historical buildings", Construction and Building Materials, 23(5), pp. 1731–1735, 2009.
https://doi.org/10.1016/j.conbuildmat.2008.09.029

[11] Lubelli, B., Rörig-Dalgaard, I., Aguilar, A. M., Aškrabić, M., Beck, K., …, Vergès-Belmin, V. "Recommendation of RILEM TC 271-ASC: New accelerated test procedure for the assessment of resistance of natural stone and fired-clay brick units against salt crystallization", Materials and Structures, 56(5), 101, 2023. https://doi.org/10.1617/s11527-023-02158-0

[12] Klenz Larsen, P. "The salt decay of medieval bricks at a vault in Brarup Church, Denmark", Environmental Geology, 52(2), pp. 375–383, 2007. https://doi.org/10.1007/s00254-006-0586-5

[13] Rörig-Dalgaard, I. "Potential salt damage assessment and prevention based on micro samples", In: Proceedings of SWBSS 2021: Fifth International Conference on Salt Weathering of Buildings and Stone Sculptures, Delft, Netherlands, 2021, pp. 21–30. ISBN 978-94-6366-439-4

[14] ASI "ÖNORM B 3355-1 Dehumidification of masonry – Structure diagnosis planning principles, execution and monitoring", Austrian Standards International, Vienna, Austria, 2017.

[15] Nunes, C., Maria Aguilar Sanchez, A., Godts, S., Gulotta, D., Ioannou, I., Lubelli, B., Menendez, B., Shahidzadeh, N., Slížková, Z., Theodoridou, M. "Experimental research on salt contamination procedures and methods for assessment of the salt distribution", Construction and Building Materials, 298, 123862, 2021. https://doi.org/10.1016/j.conbuildmat.2021.123862

[16] WTA "WTA Merkblatt 4-5-99/D Beurteilung von Mauerwerk – Mauerwerksdiagnostik" (WTA guidelines 4-5-99/D Evaluation of masonry),Wissenschaftlich-Technische Arbeitsgemeinschaft für Bauwerkserhaltung und Denkmalpflege e.V., Ismaning, Germany, 1999. (in German)

[17] De Clercq, H. "The effect of other salts on the crystallization damage to stone caused by sodium sulphate", In: Proceedings of SWBSS 2008: First International Conference on Salt Weathering of Buildings and Stone Sculptures, Copenhagen, Denmark, 2008, pp. 307–315. ISBN 9788778772732

[18] Rörig-Dalgaard, I. "Direct Measurements of the Deliquescence Relative Humidity in Salt Mixtures including the Contribution from Metastable Phases", ACS Omega, 6, pp. 16297–16306, 2021. https://doi.org/10.1021/acsomega.1c00538

[19] Rörig-Dalgaard, I. "On the need to avoid salt pollution in reused fired clay bricks: detection for quality improvement", presented at 6th International Conference on Salt Weathering of Buildings and Stone Sculpture (SWBSS 2026), Budapest, Hungary, Feb. 19-21, 2026.

[20] De Kock, T. "Personal communication during presentation of Rörig-Dalgaard", 6th International Conference on Salt Weathering of Buildings and Stone Sculpture (SWBSS 2026), Budapest, Hungary, Feb. 19-21, 2026.

[21] Coussy, O. "Deformation and stress from in-pore drying-induced crystallization of salt", Journal of the Mechanics and Physics of Solids, 54(8), pp. 1517–1547, 2006. https://doi.org/10.1016/j.jmps.2006.03.002

[22] Arnold, A., Zehnder, K. "Monitoring wall paintings affected by soluble salts", In: Cather, S. (ed.) The Conservation of Wall Paintings: Proceedings of a Symposium organized by the Courtauld Institute of Art and the Getty Conservation Institute, London, UK, 1987, pp. 103–136. ISBN 0-89236-162-X

[23] Larsen, P. K. "Desalination of painted brick vaults", PhD Thesis, Technical University of Denmark, 1999.

[24] Rörig-Dalgaard, I. "Production of historical, new and reused fired clay bricks, and its influence on properties", In: Proceedings of the 15th International Congress on the Deterioration and Conservation of Stone, Paris, France, 2023, pp. 305–311. ISBN 978-2-930054-47-6

[25] CEN "CEN EN 771-1:2011 Specifications for masonry units – Part 1: Clay masonry units", European Committee for Standardization, Brussels, Belgium, 2011.