



# LUND UNIVERSITY

## Towards simplified grading of reclaimed fired clay bricks

### Links between density, water absorption, and strength

Kahangi Shahreza, Seyedmohammad; Rörig-Dalgaard, Inge

*Published in:*

International Masonry Conference 2026. State of the Art in Masonry Research.

*DOI:*

[10.60628/9783738810400-837](https://doi.org/10.60628/9783738810400-837)

2026

*Document Version:*

Publisher's PDF, also known as Version of record

[Link to publication](#)

*Citation for published version (APA):*

Kahangi Shahreza, S., & Rörig-Dalgaard, I. (2026). Towards simplified grading of reclaimed fired clay bricks: Links between density, water absorption, and strength. In B. Gigla, M. Molnár, & N. Shrive (Eds.), *International Masonry Conference 2026. State of the Art in Masonry Research.: Proceedings of the 11th International Masonry Conference (IMC 2026)* (pp. 837-839). Fraunhofer IRB Verlag.  
<https://doi.org/10.60628/9783738810400-837>

*Total number of authors:*

2

#### General rights

Unless other specific re-use rights are stated the following general rights apply:

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Read more about Creative commons licenses: <https://creativecommons.org/licenses/>

#### Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

LUND UNIVERSITY

PO Box 117  
221 00 Lund  
+46 46-222 00 00





Extracted from

# International Masonry Conference 2026

## State of the Art in Masonry Research

Proceedings of the  
11th International Masonry Conference (IMC 2026), Lübeck, Germany,  
12–15 July 2026

Edited by Birger Gigla, Miklós Molnár and Nigel Shrive

Published by  
The International Masonry Society  
c/o Lucideon Limited – Stone Business Park, Brooms Road, Stone, Staffs, ST15 0SH



[Link to the full conference proceedings](#)

**Fraunhofer IRB Verlag**

# Towards simplified grading of reclaimed fired clay bricks: links between density, water absorption, and strength

*Seyedmohammad Kahangi Shahreza, Inge Rörig-Dalgaard*

**Keywords:** Reclaimed bricks; Compressive strength; 24h water absorption; Circular construction

**Abstract:** Reclaimed bricks are increasingly considered in circular construction; however, their substantial variability highlights the need for improved characterization and grading to enable reliable reuse. This study investigates the relationships among net density, 24h water absorption, initial rate of absorption (IRA), the water absorption coefficient ( $A_w$ ), and compressive strength ( $f_b$ ) in reclaimed bricks, with the aim of evaluating net density and 24h water absorption as practical screening parameters for mechanical performance. The results show strong correlations between  $f_b$  and both net density and 24h water absorption, while net density and 24h water absorption are themselves very strongly correlated. In contrast,  $A_w$  shows only moderate correlation with  $f_b$ , indicating that it is less representative of mechanical performance. These findings suggest that net density and 24h water absorption are suitable practical screening parameters for strength assessment, supporting the development of simplified grading approaches for reclaimed bricks in circular construction.

## 1 Introduction

The transition from a linear to a circular construction model places reuse above recycling in the hierarchy of material circularity [1]. Fired clay bricks represent a promising candidate for reuse, as they often retain their properties after demolition. However, reclaimed bricks originate from buildings with varying exposure conditions, production methods, and firing conditions, resulting in considerable variability in properties [2]. For reclaimed bricks to be reused safely and compete effectively with newly manufactured bricks, their suitability for different applications needs to be assessed based on relevant material properties. These include parameters such as compressive strength, density, and moisture-related properties, which together govern both structural performance and durability. In particular, water absorption parameters are closely linked to pore structure and are relevant to frost and salt resistance [2]. This study focuses on the relationships among net density, 24h water absorption, IRA,  $A_w$ , and  $f_b$  to facilitate the grading of reclaimed bricks for reliable reuse with a statistical approach.

## 2 Materials and methods

Four groups of reclaimed fired clay bricks were investigated, each group corresponding to one pallet supplied by the manufacturer. The bricks were delivered as one red pallet and one yellow pallet with a modified Swedish format (nominal dimensions approximately 250 × 90 × 65 mm) and one red pallet and one yellow pallet with a Danish format (nominal dimensions approximately 228 × 108 × 54 mm). Within each pallet, substantial variation in colour, shape, quality, and dimensions were observed, indicating that each group consisted of heterogeneous bricks sourced from multiple origins. Thus, the groups represent supplier-defined colour-format categories rather than uniform brick types. The reclaimed bricks were CE-marked and documented in accordance with the relevant European Assessment Documents [3]. From each pallet of reclaimed bricks (120 units), 30 bricks were selected for initial testing of net density and 24h water absorption using a combined random and subjective approach. First, every sixth brick was selected, yielding 20 bricks through random sampling. An additional 10 bricks were then selected subjectively based on visual characteristics, primarily colour. Of these 30 bricks, 10 were chosen for further testing, including IRA,  $A_w$ , and  $f_b$ . The 30 bricks were ordered according to net density, and the 10 bricks for extended testing were selected to span the full density range, including the bricks with the lowest and highest densities. The following properties were determined according to European standards: net density (EN 772-13), 24h water absorption (EN 772-21), IRA (EN 772-11),  $A_w$  (EN 1925), and  $f_b$  (EN 772-1).

### 3 Results and discussion

Figure 1 shows the relationships among selected properties of reclaimed bricks, along with a Pearson correlation heatmap summarizing their correlation coefficients. The results from 40 bricks reveal substantial variability in density, water absorption, and  $f_b$ . This variability is noteworthy, as in the current market reclaimed bricks from a given supplier are typically marketed under a single product sheet, even though they originate from different sources.

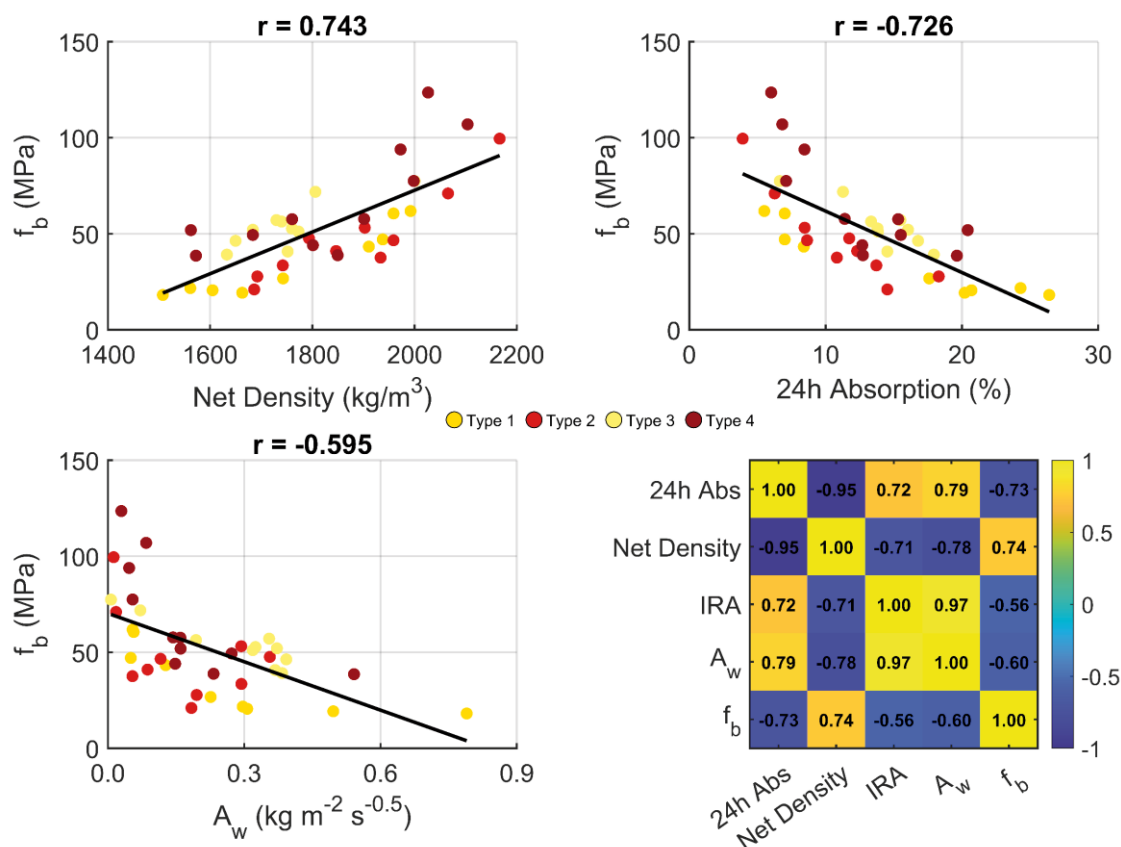


Figure 1: Relationships between selected properties of reclaimed bricks, together with a Pearson correlation heatmap; numbers indicate correlation coefficients.

A very strong negative correlation was observed between net density and 24h water absorption ( $r = -0.95$ ), confirming that these parameters describe complementary aspects of the same underlying pore structure. Both parameters also showed strong correlations with  $f_b$ , with a positive correlation between net density and  $f_b$  ( $r = 0.74$ ) and a negative correlation between 24h water absorption and  $f_b$  ( $r = -0.73$ ). These relationships are physically consistent with the Ryschkewitch concept, which describes an exponential reduction in strength with increasing porosity. Since porosity is directly related to net density and, consequently, to 24h water absorption, both parameters can be regarded as indirect measures of the pore volume fraction [2]. An increase in density, therefore, corresponds to a reduction in porosity, resulting in higher compressive strength, whereas higher water absorption reflects a larger accessible pore volume and thus lower strength.

Nevertheless, despite these strong correlations, neither net density nor 24h water absorption can be considered a fully reliable standalone predictor of compressive strength. The observed correlations do not fully capture the influence of additional microstructural factors, such as clay composition, internal cracks or damage, and pore-size distribution. However, they may still serve as useful proxy indicators of mechanical performance when destructive testing is not feasible.

Only a moderate negative correlation was observed between  $A_w$  and  $f_b$  ( $r = -0.60$ ). This indicates that  $A_w$ , which characterizes moisture transport kinetics and is primarily governed by pore-size distribution and pore connectivity, cannot be used as a reliable predictor of mechanical performance. The IRA represents the first measurement

point in determining  $A_w$  and therefore shows a very strong positive correlation with  $A_w$  ( $r = 0.97$ ). IRA also showed strong correlations with net density and 24 h water absorption, though weaker than those observed for  $A_w$ . Given that IRA can be determined within 1 minute of testing, it may nevertheless be of practical relevance as a rapid screening parameter when time-consuming  $A_w$  measurements are not feasible.

The observed variability among the tested bricks further indicates that the number and selection of test specimens are critical to achieving representative material documentation. Future work should address both the minimum number of samples required and the development of systematic sampling capable of capturing the inherent variability of reclaimed bricks. The obtained results highlight the need for a systematic methodology for grading reclaimed bricks, which inherently exhibit large variability in their properties. Such variability poses significant challenges when assessing the hygrothermal performance and durability of masonry walls.

## 4 Conclusions

Reclaimed fired clay bricks exhibit substantial variability in properties, despite being classified under the same product designation. This study shows that net density and 24h water absorption, both closely linked to porosity, correlate strongly with  $f_b$  and serve as practical screening parameters for mechanical performance. In contrast,  $A_w$  shows only moderate correlation with  $f_b$  and should not be used as a standalone strength indicator. IRA, while primarily linked to  $A_w$ , may offer value as a rapid proxy when full  $A_w$  measurement is not feasible. These findings highlight the potential to develop simplified, non-destructive grading methodologies for reclaimed bricks based on density and water absorption measurements.

## Acknowledgement

The authors gratefully acknowledge financial support from FORTE, the Swedish Research Council for Health, Working Life and Welfare (grant no. 2025-00053), and the Swedish Engineers' Environmental Fund (Sveriges Ingenjörers Miljöfond).

## References

- [1] Munoz, S., Hosseini, M. R., & Crawford, R. H. (2024). Towards a holistic assessment of circular economy strategies: The 9R circularity index. *Sustainable Production and Consumption*, 47, 400-412. <https://doi.org/10.1016/j.spc.2024.04.015>
- [2] Rörig-Dalgaard, I. (2025). Production of historical, new and reused fired clay bricks, and its influence on properties. 15th International Congress on the Deterioration and Conservation of Stone, Paris 8-12 Sept 2025
- [3] European Assessment Document (EAD) 170005-00-0305. Re-cycled clay masonry units. July 2017