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Slutrapport

Energimyndighetens titel på projektet – svenska

Hållbar hantering av befintliga tegelfasader: Identifiering av kunskapsluckor och framtida behov inom rivning och cirkulära metoder

Energimyndighetens titel på projektet – engelska

Sustainable management of existing brick masonry: Identifying knowledge gaps and future needs in demolition and circular practices

Organisation

Lunds universitet
Lunds Tekniska Högskola, Avdelningen för Konstruktionsteknik
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Nyckelord: 5–7 stycken

cirkulärt byggande, tegelmurverk, återbrukat tegel, återanvändning, energi- och resurseffektivitet, rivning och separerbarhet

Datum

2026-02-21

2026-202152-0003 2026-02-23

Förord

Detta projekt har genomförts vid Lunds universitet, Lunds Tekniska Högskola, Avdelningen för Konstruktionsteknik, inom ramen för Energimyndighetens forsknings- och innovationsprogram Resurseffektiv bebyggelse. Projektet har finansierats av Energimyndigheten. Medfinansiering har tillhandahållits av Lunds universitet samt Richertska stiftelsen. Därutöver har projektet haft stöd genom samverkan med externa aktörer.

Projektet har genomförts i samarbete med projektparterna Lunds universitet, TMPB – Tungt Murat och Putsat Byggande, samt Morneon Fasad AB. Arbetet har även stöttats av en referensgrupp bestående av representanter från konsultföretag, rivningsentreprenörer, fasadentreprenörer, materialleverantörer och fastighetsägare. Projektet har även genomförts i dialog med akademiska samarbetspartners, bland annat Danmarks Tekniske Universitet (DTU), och har bidragit till internationell samverkan genom initieringen av ett arbete inom RILEM med fokus på sortering och klassificering av återbrukat tegel.

Författaren vill rikta ett tack till Energimyndigheten för finansiering och stöd, till projektparter och referensgrupp för deras engagemang och bidrag, samt till samtliga aktörer inom akademi och näringsliv som genom diskussioner, fältstudier och kunskapsutbyte har bidragit till projektets genomförande.

2026-202152-0003 2026-02-23

Innehåll

2026-202152-0003 2026-02-23

Sammanfattning

Bygg- och rivningssektorn står inför betydande energi- och klimatutmaningar kopplade till materialproduktion, rivning och avfall. I Sverige utgör tegelfasader en stor del av byggnadsbeståndet, med mer än 200 miljoner m². Trots teglets höga beständighet och goda potential för återbruk domineras dagens rivnings- och materialhantering av linjära arbetssätt, vilket leder till förluster av inbäddad energi och materialvärde genom nedklassning eller deponi.

Detta projekt har analyserat hur befintligt tegelmurverk kan hanteras mer cirkulärt och energieffektivt, med särskilt fokus på efter-rivningsfaser där stora materialflöden idag går förlorade. Arbetet har kombinerat en strukturerad litteraturstudie, dialog med branschaktörer, platsbesök vid rivningsprojekt samt riktade experimentella studier av separerbarhet, rengöring och underhåll.

De experimentella resultaten visar ett tydligt samband mellan murbrukets egenskaper, vidhäftningshållfasthet och möjligheten till återbruk. Cementbaserade murbruk gav hög vidhäftning, låg separerbarhet och omfattande skador på tegelstenarna, medan kalkbaserade murbruk möjliggjorde avsevärt högre andel intakta återvunna tegel. Även tegelns hållfasthet hade stor betydelse, där starkare tegel bättre klarade rivning och efterföljande hantering. Kompletterande studier visade att omfogning är en effektiv underhållsåtgärd för att minska vatteninträngning och förlänga livslängden, vilket kan skjuta upp rivning i linje med de högre nivåerna i 9R-hierarkin.

Fältstudier bekräftade att kontrollerad rivning och varsam hantering är avgörande för höga uttagsgrader. Projektet visade också att cirkulära lösningar inte enbart handlar om återbruk i fasader. När detta inte är möjligt kan tegel med fördel omdirigeras till andra högvärdiga användningar, såsom sekundära byggnadsdelar, landskapsarkitektur eller arkitektoniska tillämpningar, vilket bevarar mer materialvärde och inbäddad energi än återvinning eller deponi.

Ett centralt hinder är avsaknaden av standardiserade metoder för bedömning och klassificering av återbrukat tegel avseende hållfasthet, beständighet och användbarhet. Denna osäkerhet begränsar marknadens förtroende och storskalig tillämpning, trots tydliga energi- och resursvinster. Som ett direkt resultat av projektet har ett initiativ tagits för att etablera en teknisk kommitté inom RILEM med fokus på bedömning och klassificering av återbrukat tegel.

Sammantaget visar projektet att en övergång från linjär rivning till cirkulär och energieffektiv hantering av tegelmurverk är både tekniskt möjlig och nödvändig ur ett systemperspektiv.

2026-202152-0003 2026-02-23

Summary

The construction sector faces a significant energy and climate challenge related to material production, demolition, and waste generation. In Sweden, brick masonry constitutes a substantial share of the existing building stock, with more than 200 million m² of brick façades. While brick is a durable material with high potential for long service life and reuse, current demolition and material-handling practices remain largely linear. This leads to unnecessary losses of embodied energy and material value, as bricks are often downcycled or disposed of instead of being reused or repurposed. From an energy-system perspective, this represents a missed opportunity to reduce energy demand, emissions, and resource use.

This project addressed how existing brick masonry can be managed in a more circular and energy-efficient manner, with particular emphasis on post-demolition phases where large material flows are currently lost. The work combined a structured literature review, dialogue with industry stakeholders, site visits at demolition projects, and targeted experimental insights related to separability, cleaning, and maintenance.

Experimental studies investigated the relationship between bond strength and brick separability using masonry wallettes with different brick types and mortar compositions. The results demonstrate a clear link between mortar characteristics, bond strength, and reuse potential. Strong cement-based mortars resulted in low separability and higher brick damage, whereas lime-based mortars enabled significantly higher recovery rates of intact bricks. Brick strength also influenced outcomes, with stronger bricks better able to withstand mechanical handling during demolition and cleaning. Complementary studies showed that repointing mortar joints is an effective maintenance measure for reducing water penetration and extending service life, thereby delaying demolition, in line with the upper levels of the 9R hierarchy.

Field studies confirmed that controlled demolition and careful handling are critical for achieving high brick recovery rates. The project also demonstrated that reuse in façades is not the only relevant circular route. When bricks cannot be reused as intact façade units, alternative higher-value applications, such as repurposing for secondary construction elements, landscaping, or other architectural uses, can retain material value and embodied energy. These strategies are preferable to recycling or disposal and align with the project's aim to prioritise higher-ranked options within the 9R framework.

A key barrier identified is the lack of standardized methods for assessing and grading reclaimed bricks with respect to strength, durability, and suitability for different applications. This uncertainty limits stakeholders' confidence and constrains market uptake, despite the clear energy and resource benefits of reuse and repurposing. As a direct result of the project, an initiative has been taken to

2026-202152-0003 2026-02-23

establish a RILEM Technical Committee focused on the assessment and grading of reclaimed bricks, representing a concrete continuation of the project at an international level. The proposed committee aims to bring together approximately 30 international experts from academia, industry, and standards bodies to develop a scientific and practical framework for characterizing reclaimed bricks.

Together, these efforts can support a transition from linear demolition practices to a more circular, energy-efficient approach to brick masonry management.

2026-202152-0003 2026-02-23

1 Introduction/background

The construction and demolition sector is a major contributor to waste generation and greenhouse gas emissions. In Sweden, the building sector is responsible for approximately 20% of national greenhouse gas emissions and around 40% of the total annual waste [1]. Reducing this impact requires a shift from linear practices toward more circular management of existing buildings, where material value is retained for as long as possible. In this context, brick masonry represents a particularly suitable candidate due to its durability and reuse potential [2].

Brick masonry was widely used in Sweden between 1860 and 1970, when many dwellings, public buildings, and industrial facilities were constructed. A substantial share of the existing stock also originates from the Million Programme (1965–1974). While masonry is durable, decades of exposure to climate agents and ageing can impact both structural performance and durability; many buildings from that era are now close to, or beyond, their intended service life. The brick masonry stock in Sweden is estimated to exceed 200 million m², and this large stock requires strategic management.

Today, many masonry buildings are demolished due to ageing, insufficient maintenance, and pressure from urban development. Industrial buildings are particularly affected, as many are vacant or deteriorated because their original functions are outdated. Demolition is often followed by low-value material handling, in which bricks are treated as a low-priority resource and landfilled. At the same time, demolition generates a large material stream: according to recent industry reports, approximately 10 million bricks result from demolition each year in Sweden, of which only a limited share is reused.

A circular management hierarchy implies that preservation should be prioritized wherever technically and functionally feasible. When demolition cannot be avoided, reuse should be preferred over recycling and other lower-value routes. From an energy and resource-efficiency perspective, conventional demolition practices are therefore problematic. Brick production is energy-intensive and associated with significant CO_2 emissions. At the same time, demolition typically results in substantial material losses, with masonry treated as waste or downcycled into low-value applications. These practices are inconsistent with Sweden's long-term climate and energy objectives, including the ambition to achieve carbon neutrality by 2045. There is thus a growing need to reconsider how existing brick masonry is managed throughout its lifecycle, with particular emphasis on waste reduction.

2026-202152-0003 2026-02-23

1.1 The challenge and problem formulation

The central challenge addressed in this project is the mismatch between the technical potential of brick masonry for long service life and reuse, and the predominantly linear practices currently applied in demolition and material handling. This indicates that reclaimed flows are not integrated at scale into mainstream construction supply chains.

- Brick properties vary due to raw materials, firing, workmanship, construction practice, exposure history, and maintenance [3, 4]. This variability exists both between buildings and within a single façade. It complicates grading and quality assurance for reuse.
- Separability and brick reclamation vary across building eras due to changes in masonry design. Older façades were typically massive, load-bearing walls, often one to one-and-a-half brick lengths thick (built with lime-based mortars), which generally allow easier separation and higher brick recovery during demolition [5]. From the mid-twentieth century, construction shifted to thin, non-load-bearing brick veneer walls, usually half a brick thick and supported by a structural frame, requiring higher bond strength and leading to the widespread use of cement-based mortars, which significantly reduces separability and brick reclamation rates.
- Post-demolition processing is non-trivial. Cleaning and separation can be labour-intensive and may require mechanized equipment. These steps can introduce additional impacts, including dust, noise, safety risks, and increased energy use.

1.2 Knowledge status and identified gaps

Knowledge related to maintenance and life extension of brick façades is relatively well developed, including repair and refurbishment measures that can preserve masonry in service. In contrast, knowledge related to the post-demolition phases is more fragmented, particularly for systematic reuse at scale. The existing literature includes limited studies on selective demolition, brick–mortar separability, cleaning technologies, and reuse case studies. Further, results are often case-specific, and the evidence base is not sufficiently synthesised to support decision-making under Swedish conditions. Several recurring gaps motivate the project:

- Limited synthesis that links demolition approaches, separability, and cleaning methods, resulting in practical feasibility.
- Insufficient decision support that compares circular routes for different fractions, such as direct reuse of whole bricks, repurposing of damaged bricks, recycling into aggregates or raw materials, and low-value routes.

2026-202152-0003 2026-02-23

- Weak integration of energy and resource-efficiency considerations into technical recommendations, including how processing effort and losses influence the overall benefit.

1.3 Project scope, purpose, and approach

The project was carried out as a synthesis project with the aim of strengthening knowledge for the resource-efficient management of existing brick façades, with emphasis on post-demolition phases where large material flows are currently lost. The project uses the 9R framework as a structured lens to prioritize strategies, from preservation and repair to reuse, repurposing, recycling, and recovery [6, 7]. The purpose of the project is to:

1. Synthesise the current knowledge base relevant to circular management of brick façades in Sweden.
2. Critically assess existing practices for demolition and post-demolition handling in relation to energy and resource efficiency, including feasibility and effort.
3. Identify and prioritize knowledge gaps that limit implementation, and that should guide future research, innovation, and sector development.

The purpose of the project is to synthesise existing knowledge and identify critical knowledge gaps in the sustainable and circular management of brick façades, with particular emphasis on post-demolition phases. The project does not aim to develop new demolition or reuse technologies. Instead, it critically reviews and evaluates existing methods and practices in relation to energy efficiency, resource use, and practical feasibility. The approach is based on a structured literature review, stakeholder dialogue, and case-based observations. This is supplemented by field studies and experimental lab work to gain a better insight.

1.4 Main applicant, financing, and project period

The project has been carried out at the Division of Structural Engineering, Lund University, over a twelve-month period. The Swedish Energy Agency (Energimyndigheten) has provided the main financial support, making the project possible. Additional funding was sought from Richertska stiftelsen, Sweco, and an internal fund from the Division of Structural Engineering.

Additional contributions have been made through active engagement from industry and sector organisations. A reference group comprising façade contractors, demolition practitioners, and representatives from the masonry sector has supported the project through dialogue and feedback, ensuring relevance to current practice. The project period has enabled focused synthesis work, stakeholder interaction, and dissemination of results intended to support future research and innovation in circular brick management.

2026-202152-0003 2026-02-23

2 Implementation

2.1 Literature review and knowledge synthesis

A literature review formed the foundation of the project. The review focused on circular management of brick masonry throughout the building life cycle, with particular emphasis on post-demolition phases where material value is at risk of being lost. International scientific literature, technical reports, and industry documentation were reviewed to map existing knowledge on demolition methods, brick–mortar separability, and cleaning techniques. This literature review was carried out as part of an MSc thesis within the project, systematically reviewing demolition, separation, and cleaning methods and assessing their implications for reuse, repurposing, recycling, and recovery within a 9R framework. The MSc thesis is attached and constitutes the primary synthesis underpinning the project.

Based on the literature synthesis and expert dialogue, the project identified key knowledge gaps that limit circular management of brick masonry in Sweden. These gaps include insufficient understanding of how demolition techniques influence brick recovery rates, limited experimental evidence linking bond strength to practical separability, and a lack of consolidated knowledge on cleaning methods. Particular attention was given to the disconnect between early lifecycle decisions, such as mortar selection and workmanship, and end-of-life outcomes, such as separability and reuse potential.

2.2 Experimental studies

2.2.1 Field study on bond strength and separability

There is an ongoing PhD project at the Technical University of Denmark (DTU) entitled "Lime mortars for reuse of fired clay bricks". In connection with this work, I have had the opportunity to participate in parts of the experimental and field-based investigations, which provided insights relevant to the present project. The PhD project is not funded within the scope of the current study.

The experimental programme is relevant to addressing a key knowledge gap identified in the literature: the lack of empirical evidence linking bond strength to practical reuse outcomes. Masonry wallettes were constructed using different brick types and a wide range of mortar compositions, including air-lime, hydraulic lime, cement–lime, and designed mortars. Bond strength was assessed using bond-wrench testing in accordance with EN 1052-5 [8], while separability was evaluated through a controlled demolition and handling sequence intended to represent typical brick recovery conditions. The results provide quantitative evidence of an

2026-202152-0003 2026-02-23

inverse relationship between bond strength and separability, confirming that mortar choice is a decisive factor in the reuse potential of fired clay bricks.

2.2.2 Laboratory study on repointing

A complementary experimental study focused on repointing as a maintenance and repair strategy for masonry façades. Masonry specimens were constructed and exposed to controlled water-spraying intended to simulate wind-driven rain, one of the dominant climate agents in Sweden. The study aimed to assess water penetration in brick masonry veneer [9] and how repointing could affect it. Figure 1 shows masonry wallettes prepared for laboratory testing together with a schematic illustration of the laboratory setup.

Following the initial exposure, the specimens were repointed, and the water spray tests were repeated in order to quantify the impact of repointing on moisture ingress and time to penetration. The results show that repointing eroded mortar joints could be an effective measure to reduce water penetration and delay moisture ingress. From a circularity perspective, repointing can be classified as a maintenance and repair action within the Repair (R) level of the 9R framework.

Figure 1. Masonry wallettes prepared for laboratory testing and schematic illustration of the laboratory setup

2.3 Site visits

Site visits were conducted at demolition projects involving brick masonry, including a school building scheduled for demolition (as shown in Figure 2 and Figure 3). These visits enabled direct observation of demolition methods, handling practices, and initial sorting of masonry materials. The field observations confirmed that cement-based mortars significantly reduced separability, while controlled demolition and careful handling increased the proportion of bricks suitable for reuse or repurposing.

2026-202152-0003 2026-02-23

Figure 2. An excavator carefully dismantles masonry walls during the demolition of a school in Ängelholm

Figure 3. Reclaimed bricks collected after demolition are to be delivered to Brukspecialisten

2.4 Expert dialogue and stakeholder engagement

Throughout the project, continuous dialogue was maintained with industry experts, including façade contractors, demolition contractors, reuse specialists, and municipal actors. This dialogue was supported by site visits and case discussions, including visits to buildings constructed using reclaimed bricks (see Figure 4), and provided practical feedback on the feasibility of proposed circular strategies, current barriers to implementation, and perceived needs for guidance.

2026-202152-0003 2026-02-23

Figure 4. Site visit with stakeholders to a masonry façade constructed using reclaimed bricks in Helsingborg

2.5 Dissemination activities

Project results were disseminated through multiple channels. Dissemination activities included publication of an extended abstract and an oral presentation at the International Conference on Moisture in Buildings (ICMB 2025) in Portugal; publication of a popular science article in Bygg & Teknik; presentation at the international workshop "New and Reused Bricks in Masonry" at the Technical University of Denmark (DTU) in March 2025; supervision of an MSc thesis within the project scope; and presentations to industry actors and professional and sector-specific networks.

3 Results

The project generated results at material, component, and system levels, addressing how existing brick masonry can be managed in a more energy- and resource-efficient manner across its remaining lifecycle. The results show that significant energy savings and reduced material losses can be achieved by prioritising higher-ranked strategies within the 9R hierarchy, particularly repair, reuse, and repurposing, rather than recycling or disposal.

3.1 Demolition, separation, and cleaning of reclaimed bricks

The results indicate that demolition practices have a strong influence on the circular potential of brick masonry. Controlled demolition methods, reduced drop

2026-202152-0003 2026-02-23

heights, and careful handling are associated with higher proportions of bricks remaining intact and suitable for further use. In contrast, conventional demolition practices often result in extensive brick damage and mixing with debris, limiting reuse potential and leading to downcycling or disposal.

Several separation methods relevant to reclaimed bricks were identified for feasibility, brick damage, and energy demand. Manual dismantling or selective mechanical demolition generally provides the highest recovery rates of intact bricks, but is labour-intensive and time-consuming. Mechanical separation through controlled toppling and handling is more representative of current demolition practice; in these cases, separability depends strongly on mortar type and brick strength.

In addition to conventional mechanical demolition, alternative techniques with lower vibration and impact have been identified as potentially beneficial for brick recovery. Soundless chemical demolition agents (SCDAs), which induce cracking through controlled chemical expansion rather than impact loading, have been shown to weaken mortar while largely preserving brick integrity [10]. Although primarily developed for concrete and stone, these methods show potential for masonry applications, particularly in sensitive environments or where preservation of units is a priority. Their practical applicability for large-scale brick recovery, however, remains limited and requires further investigation. Another potential option is robotized selective dismantling, which has been demonstrated in other disassembly contexts and may reduce manual labour while improving precision and consistency [11]. However, application to masonry demolition would require further development, adaptation to site variability, and investment before large-scale implementation is feasible.

Following demolition, separating bricks from mortar is a critical step that largely determines the reuse potential. Mechanical separation via controlled toppling and handling is consistent with current practice and is strongly influenced by mortar type and brick strength. Lime-based mortars generally allow separation with limited damage, whereas cement-based mortars significantly reduce separability. To address this challenge, alternative separation methods have been examined. Thermal separation methods, in which cement-based mortars are weakened through elevated temperatures, show potential to improve brick separability. The associated energy demand is lower than that of new brick production, although risks related to colour changes and cracking remain [12]. Pressure-wave-based methods, including ultrasonic treatment, have also been identified as a promising concept [13]. These methods exploit differences in material response at the brick–mortar interface, potentially enabling separation without extensive mechanical damage. At present, such techniques are mainly confined to laboratory or pilot-scale applications and are not yet viable for widespread industrial use.

2026-202152-0003 2026-02-23

Once bricks are separated, they must be cleaned to remove residual mortar and prepare them for reuse. The effectiveness of cleaning depends on the mechanical force applied, the chosen technique, and the characteristics of both brick and mortar. Within the project, commonly available cleaning methods were qualitatively assessed as shown in Figure 5. Manual and semi-mechanised techniques, such as chiselling and grinding, can remove mortar efficiently when brick strength is sufficient and bond strength is moderate, but they carry risks of brick damage, dust generation, and operator exposure. Wet cutting consistently produces clean, flat surfaces and is applicable across mortar types, though it introduces moisture and may reduce brick dimensions, requiring additional drying and quality control.

Other methods, such as oscillating chisel machines, were found to be less effective for hydraulic mortars and may increase the risk of brick damage when bond strength is high. Raking and friction-based methods are primarily suitable for weak air-lime mortars and ineffective for modern cement-based systems. Overall, no single cleaning method is universally optimal; the choice must be adapted to mortar type, brick quality, scale of operation, energy demand, and safety considerations.

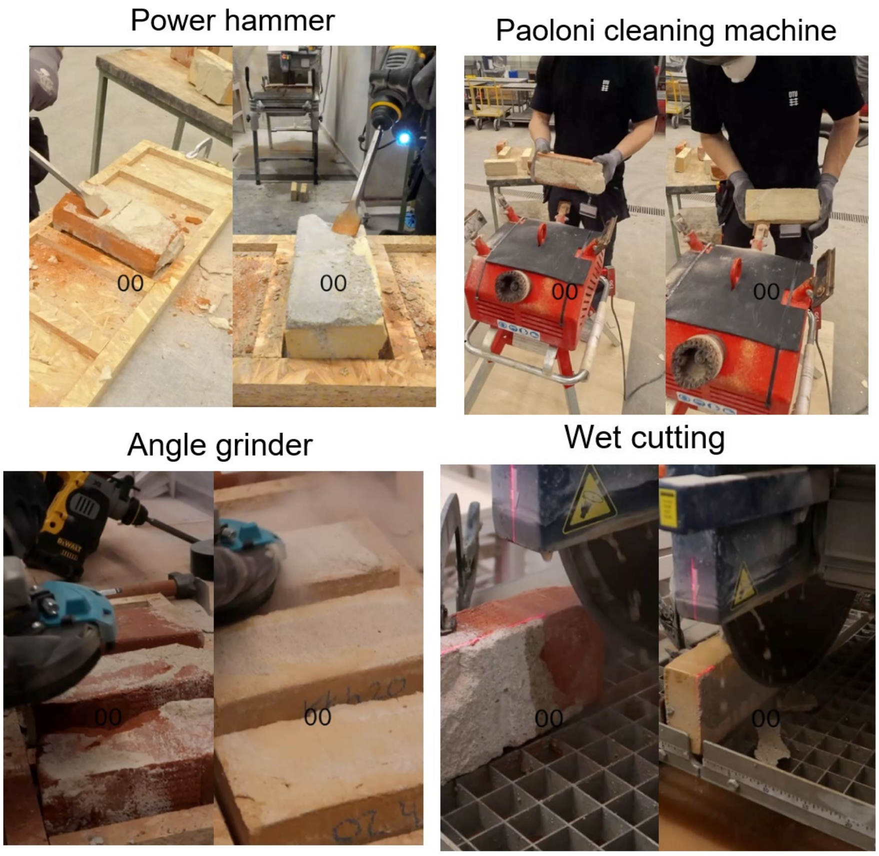

Figure 5. Examples of brick cleaning methods assessed within the project include power hammer, Paoloni oscillating chisel machine, angle grinding, and sawcutting

2026-202152-0003 2026-02-23

3.2 Experimental studies on bond strength and separability

The experimental results demonstrate a clear, systematic relationship among mortar type, brick type, bond strength, and the separability of bricks during demolition and handling. Across all tested configurations, separability was strongly governed by the bond strength between brick and mortar, with higher bond strengths consistently leading to lower recovery rates of intact bricks.

For masonry built with yellow bricks (compressive strength approximately 35 MPa), air-lime mortar with 9% lime content exhibited the lowest bond strength, on the order of 0.05 MPa, combined with high variability. Despite this variability, separability was exceptionally high: all bricks remained intact after toppling, and more than half remained reusable after repeated handling. The low bond strength allowed cracks to localise in the mortar rather than propagating through the brick. In contrast, cement–lime mortars with higher cement content achieved substantially higher bond strengths, typically 0.48-0.61 MPa. These mortars showed markedly reduced separability, with fewer than one quarter of the bricks remaining intact after the full handling sequence. Figure 6 shows the test procedure used to assess bond strength in accordance with the EN 1052-5 bond wrench test [8]. Figure 7 shows the assessment of separability in masonry specimens, including the procedure for counting intact full bricks and half bricks as representative measures of reuse potential.

Figure 6. Test setup the so-called bond wrench to assess the bond strength between brick and mortar

2026-202152-0003 2026-02-23

Figure 7. Different steps were taken to assess the separability, showcasing the demolition practice in reality – Number of full and half bricks salvaged after separation and demolition

For masonry built with red bricks (compressive strength approximately 18 MPa), the same overall trends were observed, but with consistently lower separability levels. The lower strength and more brittle behaviour of the red bricks made them more sensitive to impact and handling damage. Even when bonded with weak air-lime mortar, separability after repeated handling was substantially lower than for yellow bricks. Nevertheless, the air-lime mortar still performed best, achieving complete separation after toppling and retaining roughly one-third of the bricks after the full handling sequence. Cement–lime mortars again showed the poorest performance, with separability generally below 15% and, in several cases, close to zero.

Taken together, the results show that high bond strength is already common in many modern masonry systems and is a key reason for low reuse rates in current demolition practice. Overall, the experimental results provide clear evidence that mortar selection has long-term consequences for circularity. Mortars that develop high bond strength improve structural performance but significantly reduce the potential for future brick reuse. From a circular and energy-efficiency perspective, this trade-off must be considered already at the design and construction stage.

3.3 Results on repointing as a repair strategy

The experimental results show that repointing eroded mortar joints is an effective repair measure for reducing water penetration and delaying its onset in brick masonry façades. The tests were carried out on masonry specimens with two brick types (solid and perforated), constructed by two masons using two workmanship techniques (pushing and buttering), and exposed to three wind-driven rain intensities of approximately 28, 12, and 4.5 kg/(m²·h).

Before repointing, pronounced differences in moisture performance were observed, particularly for solid brick masonry. Specimens built using the pushing technique generally exhibited the highest water penetration rates and the shortest time to penetration. At the highest spray rate, average penetration rates frequently exceeded 1.0 kg/(m²·h), and water penetration often occurred within 1–2 hours. In contrast, specimens constructed using the buttering technique showed substantially lower penetration rates, typically below 0.4 kg/(m²·h), and longer times to

2026-202152-0003 2026-02-23

penetration. Differences between the two masons were also evident, confirming that workmanship quality plays a significant role in moisture performance, especially in solid brick masonry. For perforated bricks, the influence of workmanship was less pronounced, and overall penetration rates were lower. Figure 8 shows the average water penetration rate before and after repointing for masonry specimens.

After repointing, all specimens were re-exposed to the highest spray rate. A clear improvement in moisture resistance was observed across all configurations. Average water penetration rates were reduced by more than 50% in many cases. At the same time, the onset of water penetration was substantially delayed. For several specimens, the time to penetration increased from less than 2 hours before repointing to 5-8 hours after repointing, demonstrating a pronounced improvement in resistance to wind-driven rain.

At the same time, existing studies indicate that repointing is labour-intensive and involves non-negligible use of material and energy, particularly when applied over large façade areas [14]. The observed variability in performance before repointing suggests that targeted or selective repointing, guided by systematic condition assessment and moisture performance evaluation, may achieve similar benefits with lower resource use [15]. These findings highlight the need for improved assessment frameworks to determine when repointing is technically necessary and energetically justified, and when alternative maintenance or monitoring strategies may be more appropriate. Within the 9R framework, repointing can therefore be classified as a Repair measure that supports circular management by extending service life, but whose application should be based on careful technical and resource-efficiency considerations rather than routine.

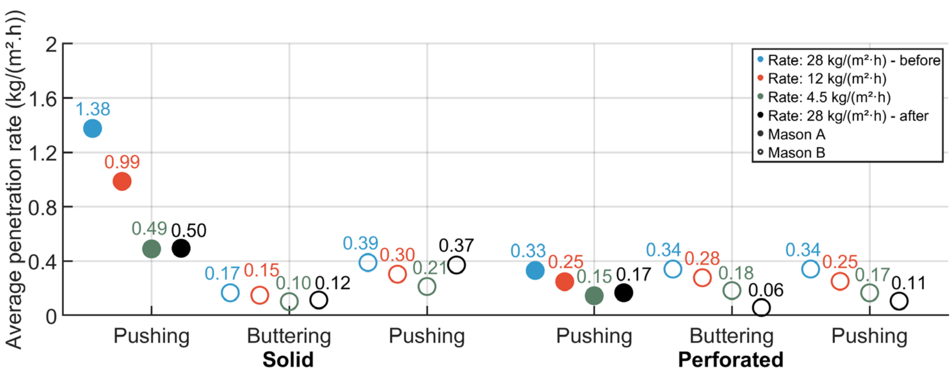

Figure 8. Average water penetration rate before and after repointing for masonry specimens before and after repointing, shown for solid and perforated bricks, two workmanship techniques (pushing and buttering), two masons, and three water spray rates.

2026-202152-0003 2026-02-23

3.4 System-level results and knowledge gaps

At a system level, the project showed that the main barriers to circular brick management are not solely technical but structural. A critical gap is the lack of standardized methods for grading and classifying reclaimed bricks based on strength, durability, and suitability for specific applications. This uncertainty limits stakeholders' confidence and constrains market uptake, even when reuse or repurposing would be favourable from an energy and resource perspective.

An important system-level insight from the project is that reuse in façades is not the only relevant circular route for bricks after demolition. When direct façade reuse is not feasible, reclaimed bricks can still be directed to higher-value alternative applications. These include use in inner walls and other non-load-bearing masonry, architectural and landscape elements, or repurposing as aggregates replacing virgin sand in mortars and concrete. Such routes preserve a substantial share of the embodied energy and material value of the bricks and are therefore preferable to conventional recycling or landfilling.

The lack of grading frameworks directly limits the ability to match reclaimed bricks to these alternative applications. As a direct outcome of the project, this gap has been formulated at an international level, leading to the initiation of a proposal for a RILEM Technical Committee focused on the assessment and grading of reclaimed bricks. The proposed committee aims to develop a scientifically grounded and practically applicable framework. The submitted proposal represents a concrete continuation of the project results and a step toward enabling circular brick management at scale.

4 Discussion

The results show that circular management of brick masonry is closely linked to energy and resource efficiency in the construction sector. The dominant share of energy demand in a brick's life cycle is associated with production, in particular the high-temperature firing process. By prioritizing reuse and high-value repurposing, a large share of this energy demand can be avoided, since approximately 90% of total energy use is embedded in the production of new bricks [16]. From an energy-system perspective, this makes existing brick masonry a highly relevant resource.

The project highlights that the greatest potential for energy savings lies upstream, before materials are treated as waste. Preservation and service-life extension should therefore remain the primary strategy whenever technically and functionally feasible. Maintenance and repair measures delay demolition and replacement, thereby reducing both energy demand and material losses. This aligns

2026-202152-0003 2026-02-23

with the higher levels of the 9R hierarchy and supports a more resource-efficient built environment.

While circular demolition and reuse practices offer clear environmental and energy benefits, their implementation is constrained by economic factors. At present, reclaimed bricks are often more expensive than newly produced bricks. This cost differential makes reuse difficult to justify in large-scale projects under current market conditions, particularly when time and cost efficiency dominate procurement decisions. Similar cost barriers apply to selective dismantling, which requires a higher upfront investment than conventional demolition. These findings indicate that wider adoption of circular practices will require supportive policy instruments, regulatory frameworks, and targeted investments.

When demolition cannot be avoided, the way demolition is planned and executed becomes decisive. Controlled demolition, selective dismantling, reduced drop heights, and careful handling substantially increase the share of intact bricks and reduce contamination. Experience from countries where controlled demolition practices are more established shows that organizational aspects, competence, and quality control are as important as the choice of equipment. For Sweden, this indicates a need to implement guidance and practice for the controlled demolition of masonry structures.

A recurring challenge identified in the project concerns mortar choice. Cement-based mortars, commonly used on many post-war façades, provide a strong bond that significantly reduces separability and increases brick damage during recovery. Lime-based mortars generally facilitate separation and cleaning, enabling higher reuse rates. Future façade design and repair practices should therefore consider not only immediate performance but also reversibility and potential for future reuse.

An important outcome of the project is the recognition that reuse in façades is not the only viable circular route for reclaimed bricks. A fraction of recovered bricks cannot meet the requirements for façade reuse due to damage or processing losses. However, these bricks can still be directed to higher-value applications, such as inner walls and other non-load-bearing elements. This potential has been investigated in an MSc project entitled "Återbruk av orensat tegel som stommaterial i miljöhus" ("Reclaimed uncleaned brick as structural material in small-scale waste collection facilities") [17], which demonstrated that uncleaned reclaimed bricks can be used even in structural applications with appropriate design and quality control, thereby retaining a substantial share of their material value and embodied energy. Even more damaged fractions can be processed into brick powder or aggregates to replace primary raw materials [18], thereby reducing waste and demand for virgin resources. Steering each fraction to the highest feasible application is essential to maximise energy and resource benefits.

From a technical perspective, the project shows that while many separation and cleaning methods exist, their effectiveness is highly context-dependent.

2026-202152-0003 2026-02-23

Techniques such as soundless chemical demolition agents, thermal weakening of mortar, and pressure-wave-based methods show potential to improve brick recovery in challenging cases but require further evaluation of scalability, energy demand, safety, and impacts on brick quality. Similarly, separation and cleaning should be considered as an integrated process, since cleaning choices affect brick dimensions, surface quality, damage rates, and overall energy use.

At a system level, the most critical barrier identified is the lack of widely accepted grading and classification systems for reclaimed bricks. For reclaimed bricks to compete with newly produced bricks, stakeholders need confidence in their quality and performance. Existing approaches face challenges related to variability, documentation requirements, and compatibility with current regulatory frameworks, including product marking and liability.

Further work is required to develop practical, standardized grading frameworks adapted to reclaimed materials and different application levels. Pre-demolition assessment methods should be improved to support informed decisions about preservation, reuse, repurposing, and recycling. Controlled demolition practices need to be further developed and implemented in Sweden, supported by training and pilot projects. In addition, future research should address mortar design that facilitates future reuse, without compromising durability during service life. From a societal perspective, improved circular management of brick masonry can contribute to reduced waste generation, lower energy-intensive material production, and lower greenhouse gas emissions. Overall, the project shows that brick masonry can play a meaningful role in the transition toward a more sustainable and energy-efficient built environment, provided that preservation, reuse, and high-value repurposing are systematically prioritized.

5 Dissemination and publications

The project has resulted in scientific and practice-oriented publications addressing durability, maintenance, and circular management of brick masonry. These outputs contribute to the project objectives by strengthening knowledge on long-term performance of masonry façades and by supporting knowledge transfer to practitioners and decision-makers.

An experimental study was carried out on masonry wallettes exposed to controlled water spraying to investigate water penetration. Although masonry is generally durable, long-term exposure to climate agents requires regular maintenance and, when necessary, repair measures to ensure sustained performance.

The Study focuses on conditions relevant to Northern European climates, where wind-driven rain is a dominant moisture source affecting masonry façades. Moisture ingress affects the hygrothermal performance of building envelopes and

2026-202152-0003 2026-02-23

may lead to increased moisture accumulation, with risks such as mould growth, material degradation, and reduced insulation performance.

The results show that the combined effects of material properties and workmanship influence water penetration. Workmanship was identified as a key factor, particularly regarding head joint formation. Different techniques, including pushing and buttering, were investigated. For solid brick masonry, substantial differences in water penetration were observed depending on mason skill and construction technique, whereas perforated brick masonry showed limited sensitivity to variations in workmanship. Repointing of mortar joints was also studied as a maintenance and repair measure within the 9R circularity framework. The results demonstrate that repointing can significantly reduce water penetration and moisture accumulation.

The results were published as an extended abstract in UCL Open Environment and also presented at the International Conference on Moisture in Buildings (ICMB 2025) in Portugal. The findings provide experimental evidence relevant to maintenance strategies to extend the service life of masonry façades.

To support practical implementation, a popular science article was published in Bygg & Teknik (theme Tak och Fasad). The article presents key findings and provides recommendations on repointing and maintenance of brick façades, targeting practitioners and decision-makers involved in the management of masonry buildings.

6 Attachments

Kahangi Shahreza, S. & Van Den Bossche, N., (2025)
Water penetration in brick masonry: Impact of brick type and workmanship",
UCL Open Environment 7(S1).
doi: https://doi.org/10.14324/111.444/ucloe.icmb25.a17

Kahangi, M. & Molnár, M., (2026)
Torrare väggar genom omfogning? (submitted)
Mar 26 Bygg & teknik, 2/26 3 p.

Heidar, L. (2025)
Towards circularity in brick masonry: knowledge gaps and future needs (Mot cirkularitet i tegelmurverk: kunskapsluckor och framtida behov)
In Degree Projects in Structural Engineering, Lund University
Link: http://lup.lub.lu.se/student-papers/record/9197075

2026-202152-0003 2026-02-23

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