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Reclaiming earth blocks using various techniques

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Abstract. Earth block masonry offers a low-impact alternative to conventional building methods. Despite the growing need for circular construction practices, the reuse of earth blocks remains underexplored. This initial study addresses this gap by empirically assessing the reclaimable potential of various earth block masonry configurations. Moulded non-stabilised and compressed cement-stabilised earth blocks are combined with three types of mortar. Ten sample walls and a prototype partitioning wall are deconstructed, and blocks are cleaned using standard tools. Reusable and damaged fractions are measured quantitatively, while qualitative evaluations gauge the effort and speed of the processes. Findings reveal that both earth blocks combined with earth mortar exhibit high reclaimable potential, followed by walls with an earth adhesive mortar. Conversely, walls with bastard mortar containing earth show low reclaimable potential, making them more suitable for demolition and recycling. These outcomes contribute to the ongoing discourse on end-of-life scenarios for masonry, providing a foundation for life cycle assessment considering earth block reuse. Further research is initiated to correlate earth block masonry bond strength with suitable reclamation techniques. Other research tracks worth exploring are economic and organisational challenges associated with earth block reclamation.

1. Introduction

In research and practice, earth construction resurfaces as a sustainable response to the excessive deployment of conventional building materials such as concrete, steel and bricks [1,2]. Earth blocks, composed of locally available resources such as loam, sand, and aggregates, are increasingly manufactured by revalorising excavated soils from urban infrastructure or construction sites [3]. Unlike fired clay bricks, earth blocks are unfired, thus bypassing the need for fossil fuels as a primary energy source for the baking process and mitigating the substantial greenhouse gas emissions associated with it [4]. If no stabilisers are added, loam contains clay that acts as a physically reversible binder in earth blocks [5], rendering earth-building products fully recyclable or disposable in their chemically unaltered form at the end of life [4]. However, the common use of hydraulic binders such as lime or cement to improve strength and durability raises concerns about the circularity of earth block masonry [6]. As it challenges the environmental benefits of earth's reversible properties, stabilisation is prompting the consideration for reusing stabilised earth blocks. Previous studies have indeed identified a knowledge gap in end-of-life scenarios, particularly concerning reuse possibilities [7,8].

Reusing masonry bricks or blocks involves a reclamation process wherein a masonry wall is deconstructed, and the masonry units are cleaned [9]. The reclaimable potential of masonry units hinges on the bond strength between the units and the mortar [10]. Demolition contractors prioritise the value of bricks in buildings constructed with soft mortars like lime, ash, clay-based or bastard mortars containing lime and cement [9,11]. However, Portland cement mortars and thin-layered adhesive mortars have increasingly been used since the 1970s [9]. Advanced mechanical or thermal treatments are being explored to salvage highly adherent masonry [10,12], but their scalability and economic viability remain uncertain [9]. Despite the generally lower bond strength of earth block masonry compared to conventional masonry [13,14], it is deemed sufficient for many building applications. Hence, exploiting these weaker bonds offers an opportunity to reclaim earth blocks. Therefore, this study is the first exploration in a planned series of experiments aiming to identify factors affecting the reclaimable potential of earth blocks. The main objectives of this study are:

- to assess the recovery rates for different combinations of earth blocks and mortar;
- to evaluate various deconstruction and cleaning techniques to reclaim earth blocks;
- to gain insights into the labour intensity of reclamation practices for earth block masonry.

2. Materials and methods

2.1. Earth blocks

This study considers two types of earth blocks: a moulded earth block (MEB) and a compressed earth block (CEB) stabilised with 3.85% of cement CEM III 42.5. The MEBs are developed by an earth product company in Brussels and industrially manufactured using the machinery of a fired brick company in Flanders, Belgium. Similarly, the CEBs are developed by the same company employing the vibro-compacting mechanism of a concrete block manufacturer in Flanders. MEBs are dried in three days from 30°C to 80°C in ventilated chambers using the residual heat of the factory, while CEBs are cured for ten days in unventilated chambers at 23°C and RH varying between 50% and 78%. The earth blocks were transported shortly after curing and stored indoors. Dimensions of the blocks are (238 ± 2 × 78 ± 2 × 57 ± 3) mm for MEBs and (290 × 130 × 90) mm for CEBs. Both contain revalorised loess loam from urban excavations in construction sites and infrastructure works. Additionally, the MEBs contain alluvial Scheldt clay and fired brick waste, and the CEBs contain Rhine sand and washed crushed concrete. MEBs and CEBs have 85% and 80% of secondary resources, respectively. Technical properties of the blocks are given in **Table 1**, following the European EN 772 standard for masonry units, the German DIN 18945 and the French AFNOR XP P13-901 standards for earth blocks.

Table 1. Technical properties of earth blocks.

Name	Density [kg/m³]	Compressive strength [N/mm²]	E-modulus [N/mm²]	Application Class
MEB	1620	2.5	750	II = CL 3 *
CEB	1970	9	1500	CL1 (> IA) **

* Interior insulated masonry ** Exterior masonry exposed to elements (according to DIN 18945 and XP P13-901)

2.2. Mortars

Three types of mortars are used: an earth mortar (EM), an earth adhesive mortar (EAM), and a bastard mortar containing earth (BME). The EM, EAM, and earth additive for the bastard mortar are acquired from the same company providing the earth blocks. All mortars contain the same loess loam from urban excavations in Brussels. Both EM and EAM also contain *Brusseliaan* sand from urban excavations. The EM additionally contains Rhine sand and Dordogne clay, while the EAM contains 1% cellulose. The bastard mortar M10 was acquired from a cement manufacturer in Flanders and mainly contains sand, cement, and lime. The proportion of bastard mortar to earth additive is 3:1. The EM, EAM, and BME have 50%, 99%, and 33% secondary resources, respectively. The EM contains 96% particle sizes < 2 mm, while the EAM and earth additive contain 99.5% particle sizes < 1 mm and < 2 mm, respectively. The earth mortars were prepared according to EN 1015-2 in a planetary mixer. Technical properties of the mortars are given in **Table 2**, following the German DIN 18946 standard for earth mortars.

Table 2. Technical properties of mortars.

Name	Density [kg/m³]	Compressive strength [N/mm²]	Initial shear strength [N/mm²]	Shrinkage
EM	1.8	2.5	0.04	1.93%
EAM	1.6	2.5	0.12	4%
BME	1.6	4.5	0.22	0.5%

2.3. Earth block masonry walls

Ten sample walls are constructed by combining the two types of earth blocks with the three types of mortar. The MEB-BME combination is excluded since a low-strength water-soluble earth block combined with a high-strength water-resistant mortar has little chance of being implemented in practice. The resulting five block-mortar combinations were tested in two masonry bond types: a stretcher bond (showing narrowest block face) and a header bond (showing smallest block face) for MEB walls, and a stretcher bond and a shiner bond (showing widest block face) for CEB walls. The sample walls are laid by applying a mortar layer of 10 ± 2 mm for the EM and BME and a mortar layer of 1 ± 1 mm for the EAM. Before laying, the bed faces of the blocks are soaked for one second, as recommended by the manufacturer. The sample walls are laid and stored indoors at room temperature and humidity for 28 days before testing. A more detailed summary of the walls is given in **Table 3**. Finally, a prototype partitioning wall was deconstructed after testing its acoustic performance. The prototype contains CEBs with dimensions (290 × 140 × 130) mm with hand grip holes, is laid with BME and finished on one side with a flax mesh reinforced earth plaster containing the same ingredients as the EM.

Table 3. Summary of earth block masonry walls.

Block	Mortar	Bond	Sample size*	Full blocks	Half blocks	Surface area [m²]	Volume [m³]
MEB	EM	Stretcher	n = 60	54	12	0.92	0.07
		Header	n = 64	60	8	0.34	0.08
	EAM	Stretcher	n = 60	54	12	0.79	0.06
		Header	n = 64	60	8	0.28	0.07
CEB	EM	Stretcher	n = 32	28	8	0.94	0.12
		Shiner	n = 32	28	8	1.32	0.17
	EAM	Stretcher	n = 32	28	8	0.86	0.11
		Shiner	n = 32	28	8	1.23	0.16
	BME	Stretcher	n = 32	28	8	0.94	0.12
		Shiner	n = 32	28	8	1.32	0.17
CEB	BME	Stretcher	n = 221	213	16	9.56	1.34

* Number of earth blocks within the wall

2.4. Deconstruction and cleaning methods

Except for the prototype wall, all sample walls were deconstructed the same day by 40 architecture students with little labour experience, in a workshop on the end-of-life of earth block masonry. Each wall was assigned to a mixed gender group of three to five students who were requested to document the process by photographing and completing a deconstruction and cleaning sheet. In both sheets, the students were asked to note the order of the reclaimed blocks, the tools used to reclaim them, and the eventual damage caused in the process. A number labelled every block in the wall to recognise its position within the wall, preceded by a letter to identify the bond and mortar after deconstruction: e.g. block H3.2 is a CEB laid with EAM in stretcher bond positioned on row 3 and column 2 in the wall. Various deconstruction and cleaning techniques were tried out by iteration until the succeeding (combination of) tool(s) was found. The proposed deconstruction techniques are as follows: wrenching by hand, wrenching by plastic or metal clamp, punching by rubber or plastic hammer, chipping by hammer and wide or pointy chisel, and spraying using a pressure nozzle. The proposed cleaning techniques include scraping with a stripper knife, brushing with a steel brush, and chipping with a bolster or a cold chisel. Eventual damage caused to the blocks in the reclaiming process was measured according to dimension tolerances of the French standard AFNOR XP P13-901 for earth blocks. According to the standard, the damage in the corners (chips) is only tolerated if they can fit into a trirectangular tetrahedron closed by an equilateral triangle with sides T ≤ 20 mm, and the damage in the edges (spalls) is only tolerated if they do not extend beyond a length T1 = 30 mm and a width T2 = 5 mm (**Figure 1**). MEBs generally have more curved edges than CEBs due to its production technique.

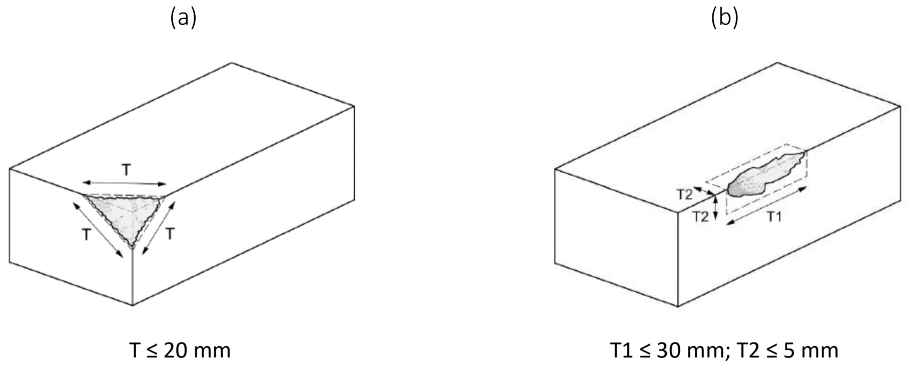

Figure 1. Tolerances according to AFNOR XP P13-901: (a) case of chipping (b) case of spalling.

2.5. Survey method

After completing the deconstruction and cleaning phases, participating students were administered a structured questionnaire containing eight closed questions and three open-ended questions. The questionnaire was designed to gather quantitative and qualitative data on the key aspects of deconstruction and cleaning: their perceived time, effort, and technique preference. A Likert scale was employed to quantify the perceived time and effort on a numerical scale. Open-ended questions allowed for qualitative insights into the reasons behind their technique preference and potential improvements. The collected data was subjected to quantitative and qualitative analysis. Descriptive statistics are used to summarise the time and effort invested in the processes, while thematic analysis was conducted on qualitative responses to identify recurring patterns.

3. Results

3.1. Recovery rates and damage analysis

The potential for reclaiming earth blocks was assessed by deconstructing and cleaning ten sample walls and one full-scale prototype. The combinations yielding the highest recovery rates are MEB-EM, MEB-EAM and CEB-EM, while the lowest is visibly CEB-BME (**Figure 2**). The observed variations underscore the influence of mortar type on the recovery rates of earth blocks, yielding differences of up to 78% when comparing CEB-EM with CEB-BME. Block type influences the recovery rate up to 20% for EAM, based on the average between masonry bond types. Masonry bonds affect recovery rates to a lesser extent, with 14% being the highest variation between CEB-EAM in stretcher and shiner bonds. **Figure 3** demonstrates the sample walls before deconstruction and earth blocks after reclamation.

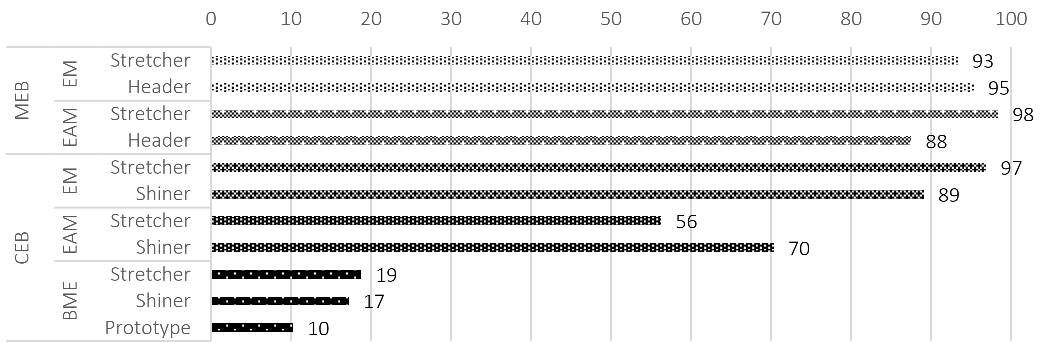

Figure 2. Percentage of reclaimed earth blocks per wall type.

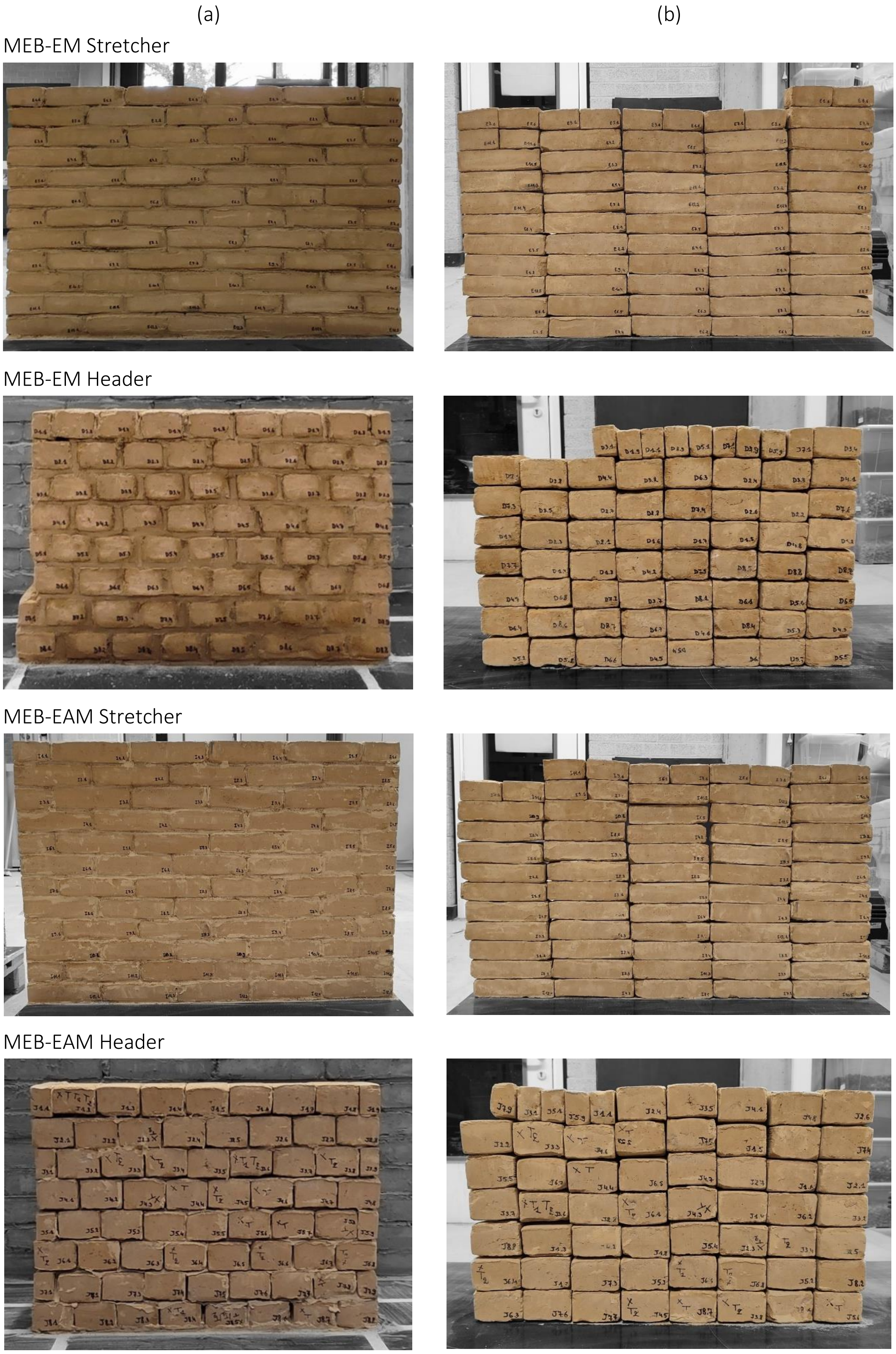

Figure 3. Sample walls before deconstruction (a) and earth blocks after cleaning (b).

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CEB-EM Stretcher

CEB-EM Shiner

CEB-EAM Stretcher

CEB-EAM Shiner

Figure 3 (continued).

CEB-BME Stretcher

CEB-BME Shiner

Figure 3 (continued).

Table 4 presents the number of reclaimed blocks and the extent of damage incurred during deconstruction and cleaning. The block's position in the wall did not significantly influence its susceptibility to damage. Overall, the damage is caused by the deconstruction rather than the cleaning process. The location of the damage is primarily situated on the edges of the blocks. The BME hinders the deconstruction and cleaning process due to increased adhesion and other factors affecting block integrity. While fired bricks built with bastard mortar are usually reclaimable in practice, the BME appears to exert an excessive bonding tension, overcoming the local cohesion of the CEBs.

Table 4. Summary of reclaimable and damaged earth blocks.

Block	Mortar	Bond	Sample size*	Reclaimed blocks	Blocks damaged by deconstruction	Blocks damaged by cleaning	Main damage location
MEB	EM	Stretcher	n = 60	56	1	3	Edges
		Header	n = 64	61	3	0	Edges
	EAM	Stretcher	n = 60	59	1	0	Edges
		Header	n = 64	56	4.5	3.5	Edges
CEB	EM	Stretcher	n = 32	31	1	0	Corners
		Shiner	n = 32	28.5	1	2.5	Edges
	EAM	Stretcher	n = 32	18	13	1	Edges
		Shiner	n = 32	22.5	9.5	0	Faces
	BME	Stretcher	n = 32	6	18	8	Edges
		Shiner	n = 32	5.5	14	12.5	Faces
CEB	BME	Stretcher	n = 88	9	73	4	Corners

* Number of earth blocks within the wall

The CEB-BME prototype wall was deconstructed until a sample size of 88 earth blocks was reclaimed. Unlike the sample walls, the prototype was built inside a concrete frame, limiting the movement of the blocks. Notably, all earth blocks on the edges of the wall could not be deconstructed without damage. In fact, due to their limited degrees of freedom, these blocks needed to be demolished to free up adjacent blocks. This demolition process, in turn, inevitably caused adjacent blocks to be damaged as well. Following the logic of freeing up movement directions of the blocks, the wall was most accessible to deconstruct in a diagonal pattern (**Figure 4**) or, according to the block's position label (row and column): 1.1, 1.2, 2.1, 1.3, 2.2, 3.1, 1.4… The earth plaster was easily detachable by hand and did not cause any damage to the blocks or leave any colour traces. Only 9 out of 88 blocks were reclaimed without damage outside dimension tolerances. Moreover, only one block could be freed from residual mortar inside the hand grip hole.

Figure 4. Deconstruction of prototype wall (a) and compressed earth blocks after cleaning (b).

3.2. Deconstruction and cleaning techniques

The sample walls were deconstructed by iteration between various tools and techniques, starting with the least invasive. Three types of actions can be distinguished: to hold the block and apply a cantilever load that increases the flexural tension at the block-mortar interface (wrenching); to apply an impact load to the block and thereby executing a shear stress at the block-mortar interface (punching), to partially demolish the mortar layer by impact (chipping) or by the combined effect of impact and disintegration (wetting). Hence, the applied deconstruction techniques are as follows: wrenching by hand or using a quick-release clamp or a metal clamp; punching by hand or using a rubber or plastic hammer; chipping using a bolster, a cold chisel or a hammer drill; or wetting using a pressurised spray. In some cases, a whole layer or a segment of the wall containing up to six blocks was separated at once and further deconstructed on the floor. **Table 5** provides an overview of the most effective techniques per block-mortar combination and masonry bond chosen by the students during the workshop.
Wrenching by hand was possible for MEBs combined with EM and EAM in stretcher bond. This was impossible for those combinations in the header bond due to the increased block-mortar interface surface area. Wrenching using a quick-release clamp was effective for MEB-EM in the header bond, but a metal clamp was more effective for the wall with EAM in the stretcher bond. Punching using a rubber hammer was also a suitable technique for these combinations, although insufficient for MEB-EAM in header bond, where chipping with a cold chisel was needed. Chipping using a bolster chisel also seemed effective for MEB-EM in both types of bonds. Logically, wetting the mortar layers using a pressure spray would irrevocably damage the MEBs since they are not water-resistant.
The CEB-EM combination was preferred to punch by hand or rubber hammer in stretcher bond, wrench using a quick release clamp, or chip using a cold chisel in shiner bond. Halfway through the

deconstruction process, these two sample walls were wetted to test the effect of a pressurised water jet on the hardened earth mortar layer. The earth mortar immediately started to crumble and dissolve, allowing the blocks to be wrenched or punched by hand in a few seconds. Some caution had to be taken not to spray the wall for too long, as the collateral damage of the water jet could cause minor damage to the blocks. CEBs combined with EAM were most effectively deconstructed by punching with a plastic hammer or chipping with a bolster chisel for both types of masonry bonds. However, punching the blocks in shiner bond caused some of the blocks to break in half, indicating a weakness that may be due to the manufacturing process. Lastly, while it was possible to deconstruct the two CEB-BME sample walls using manual tools (bolster or cold chisel), the CEB-BME prototype could only be deconstructed using powered tools (hammer drill). Since the prototype contains larger CEBs, it can be attributed to the larger contact area between the mortar and the blocks, increasing the net bond strength.

Table 5. Summary of most effective deconstruction techniques applicable to each wall type.

		Techniques →	Wrenching			Punching			Chipping			Wetting
		Tools →	Hand	Clamp		Hand	Hammer		Chisel		Drill	Spray
Block	Mortar	Bond										
MEB	EM	Stretcher	✓				✓	✓	✓			
		Header		✓			✓		✓			
	EAM	Stretcher	✓		✓		✓					
		Header								✓		
CEB	EM	Stretcher				✓	✓					✓
		Shiner		✓						✓		✓
	EAM	Stretcher						✓	✓			
		Shiner						✓	✓			
	BME	Stretcher								✓	✓	
		Shiner								✓	✓	
CEB	BME	Stretcher									✓	

Like the deconstruction process, the earth blocks were cleaned by breaking the bonds at the block-mortar interface and removing residual mortar. The applied cleaning techniques are chipping using a bolster chisel or a hammer drill, scraping using a stripper knife, and brushing using a steel brush. **Table 6** presents the preferred cleaning techniques that were frequently used during the workshop. Chipping using a bolster chisel was the most preferred technique, followed by eventual scraping and brushing. For CEB-EM, chipping was not needed as large chunks of mortar quickly came off by scraping the smooth surface of the CEBs. For CEB-BME, the hammer drill proved helpful due to the labour intensity.

Table 6. Summary of most effective cleaning techniques applicable to each wall type.

		Techniques →	Chipping		Scraping	Brushing
		Tools →	Chisel	Drill	Stripper knife	Steel brush
Block	Mortar	Bond				
MEB	EM	Stretcher	✓			
		Header	✓		✓	✓
	EAM	Stretcher	✓		✓	✓
		Header	✓			✓
CEB	EM	Stretcher			✓	
		Shiner	✓		✓	✓
	EAM	Stretcher	✓		✓	
		Shiner	✓		✓	✓
	BME	Stretcher	✓	✓		
		Shiner	✓	✓		
CEB	BME	Stretcher	✓	✓		

3.3. Labour intensity and time consumption

To gain insights into the labour intensity of earth block reclamation, participating students filled out a form prompting the time and effort needed for the deconstruction and cleaning processes. Since different participants deconstructed each wall, the parameters were evaluated qualitatively. **Figure 5** presents the participants' perceived effort to deconstruct their assigned wall and clean the blocks, while **Figure 6** shows the perceived time. It must be noted that every bar in the charts results from three to five respondents, as this was the number of students who reclaimed the blocks for each wall type.
The sample walls with MEB-EM and CEB-EM laid in stretcher bond are perceived to require the least amount of effort in the deconstruction process. Indeed, wrenching or punching by hand, punching with a rubber or plastic hammer or wetting using a pressurised spray demanded relatively little energy for those combinations. Slightly more effort was perceived for MEB-EM in the header bond, probably due to the larger contact area between the blocks and the mortar. The EAM is perceived as slightly more difficult to deconstruct with CEBs than with MEBs, although it still requires little effort. This may be due to the different surface texture of the blocks, inducing a stronger bond with CEBs. Another explanation lies in the larger dimension variations and irregularity of moulded blocks, making the locally thicker mortar layer easier to chip through. Notably, the CEB-BME combination is the hardest to deconstruct. Chipping using a cold chisel requires more work in a stretcher than in a shiner bond because of the larger block-mortar interface. Indeed, an even larger contact surface in the prototype wall made it impossible to deconstruct it using manual tools and demanded much effort using a hammer drill.
Cleaning was more intensive than deconstruction, especially for EAM, which sticks harder to the surface of the blocks. The difference in intensity between the stretcher and the header bond can be attributed to almost double the amount of mortar to remove. Thoroughly scraping or brushing the EAM remnants also produced more dust than blocks with EM or BME. Cleaning CEBs with BME was perceived as even more intensive than the deconstruction process. Remarkably, minimum effort was needed when cleaning CEBs with EM. Indeed, the mortar could often be removed by one strike of the stripper knife.

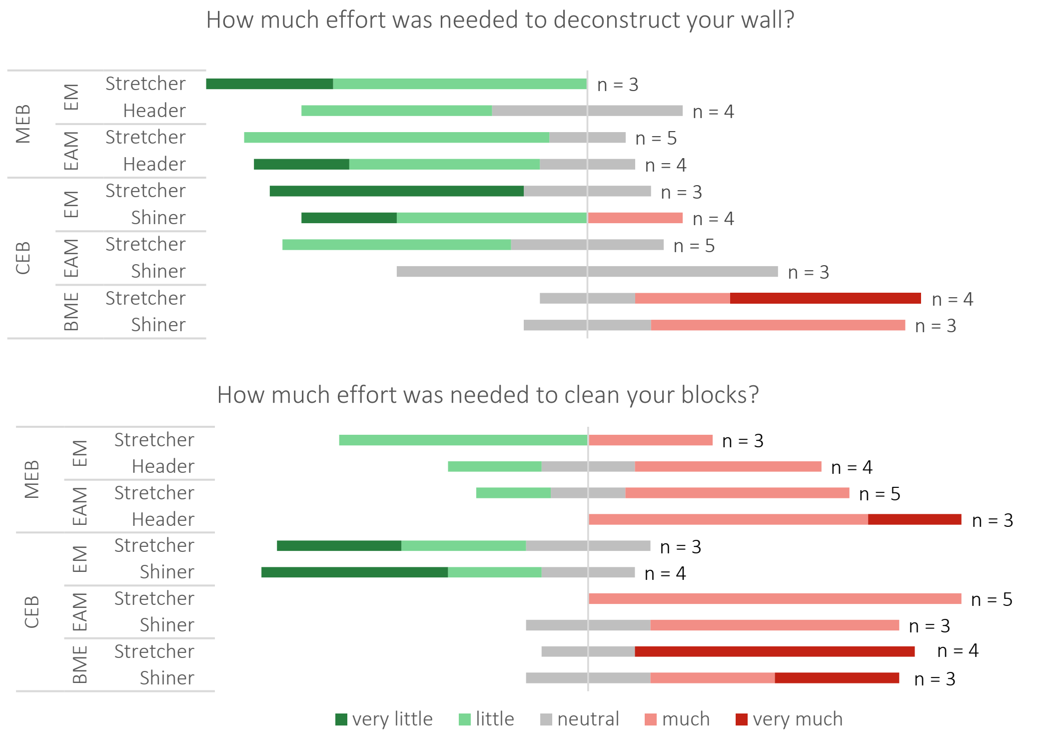

Figure 5. Perceived effort for deconstruction and cleaning per wall type.

The perceived time is closely related to the perceived effort of deconstruction and cleaning. As a reference, all the sample walls were deconstructed within two hours by three to five participants, considering some delaying factors such as testing the tools, developing experience and documenting the process. Cleaning the blocks required additional time in some cases, namely for blocks with EAM and BME fragments. Deconstructing MEB-EAM laid in header bond and CEB-EM laid in stretcher bond are experienced as the least time-consuming combinations. In both masonry bonds, cleaning MEB-EM is more neutral regarding time experience. Perceptions of time and effort are similar for CEB-BME, with the stretcher bond being perceived as more time-consuming to deconstruct than the shiner bond. For the sake of comparison, the sample size of 88 earth blocks from the prototype wall was reclaimed in seven hours by two inexperienced researchers documenting the process. Overall, the time needed to clean the blocks was perceived as slightly more consuming than the effort.

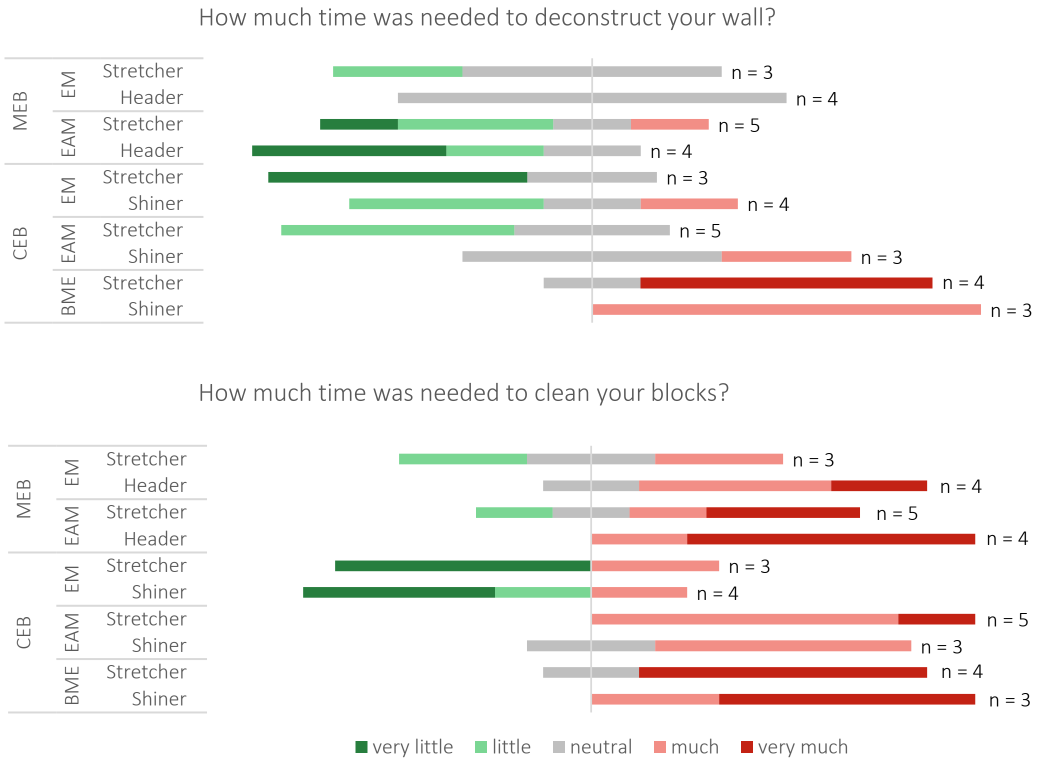

Figure 6. Perceived time for deconstruction and cleaning per wall type.

The survey ended with two open-ended questions on how the deconstruction and cleaning process could be made more efficient. The 47 relevant responses can be grouped into five main themes: experience (6), workflow (4), workforce (9), tools (17), and technique (11). Skilled workers would indeed know from the start which method works best for which block-mortar combination and an organised workflow between multiple workforces should speed up the process. Three responses proposed deconstructing multiple blocks' wall segments and separating them on the floor, suggesting that working downward is ergonomically less intensive than sideways. This situation unintentionally occurred numerous times during the workshop, especially when wrenching or punching. Five responses underlined the potential of wetting as a very efficient deconstruction technique, although controlling water usage was mentioned as a point of attention. Seventeen responses were related to optimising tools; five suggested using powered tools, and eight suggested using tailored tools. One respondent suggested using a vacuum cleaner in the cleaning process to prevent the blocks from collecting dust. Another respondent commented that the CEB-BME combination is probably not worthwhile reclamation. A final remark was made on the manageability of the blocks: MEBs are easier to handle and stack than CEBs.

4. Discussion

Overall, initial explorations show promising results for specific block-mortar combinations. The results highlight the importance of customising reclamation tactics to different earth block masonry configurations and the significant impact of mortar choice on the recovery rate. Earth mortar (EM) exhibits the highest potential for successful reclamation. Earth adhesive mortar (EAM) demonstrates high recovery rates with moulded earth blocks (MEBs) but to a lesser extent with compressed earth blocks (CEBs), stressing the influence of block type. However, before considering earth block reclamation as a strategy over demolition and recycling, environmental and economic benefits should outweigh the labour-intensive nature of deconstruction and cleaning. The bastard mortar containing earth (BME) yields very few reusable CEBs, demanding excessively effortful reclamation. Full-scale testing reinforces these results, making it more advisable for demolition and recycling.

Additional factors affecting the reclaimable potential include masonry bond, reclamation tools and techniques, experience, workflow, and workforce. Masonry bond moderately affects recovery rates, with the highest differences attributed to CEB-EAM comparing stretcher and shiner bonds. The suitability of tools and techniques is also bond-dependent, as seen in the feasibility of wrenching and punching for MEB-EAM in stretcher bond but not in header bond. Despite EAM having higher initial shear strength than BME, the significantly higher recovery rate with EAM suggests that factors beyond bond strength, such as mortar layer thickness or different material properties, may affect block integrity. Moreover, at least for CEBs, earth plaster finishing does not affect earth block reclamation potential. Finally, although the comparison was not directly assessed, higher block dimensions and weight of CEBs will likely affect labour intensity and thus reclaimable potential.

Despite the reclamation being tested for one block-mortar combination at the scale of a prototype partitioning wall, some results offer insights at a larger scale. Quantitative extrapolation of the recovery rates is deemed precarious at this stage and should be tested. At least for CEB-BME, scaling up from a freestanding sample wall to a full-scale prototype wall enclosed in a concrete frame introduces challenges related to the limited degrees of freedom of the blocks in corners and edges of the wall and the ergonomic hurdles accompanying those locations. Excluding the bordering blocks, it remains uncertain whether the block's position within the wall affects the separation difficulty due to potential local changes in bond strength. These differences may be more sensitive to block-mortar combinations with lower bond strength and may affect the choice of tools and techniques along the wall. The necessity to demolish locked blocks in the edges and corners of an infill wall, such as for the CEB-BME partitioning wall, may not be required for infill walls with EM and EAM. Considering the wetting technique using a pressurised spray, the outer blocks would gain some freedom of movement by the disintegrating mortar layer. Some methods, like wrenching, are impossible for peripheric blocks or blocks in double-layered masonry bonds.

The absence of a standardised methodology for assessing the reclaimable potential of building components limits the comparability of this study with the literature. Future research should aim to establish a robust and universally accepted methodology for evaluating the reclaimable potential of various construction materials. Additionally, the involvement of different students in the reclamation process introduces variability in applied force, skill levels, efficiency, and time. Future research should develop controlled conditions and standardised protocols to mitigate the potential impact on the consistency of results and generalisability of findings. Besides, participating students' qualitative evaluation of perceived time and effort lacks a reference for comparison, emphasising the need for additional research to determine reliable reference masonry configurations. Developing more objective measures or employing other metrics could enhance the reliability of assessments. Future studies may benefit from integrating quantitative tools to provide a more nuanced understanding of labour intensity and time consumption. Characterisation of bond strength would greatly support these tools.

Future research directions may delve into the economic and organisational challenges of implementing identified techniques on a larger scale and explore advancements in reclaiming technology for earth blocks in diverse construction contexts. For instance, in- and ex-situ reuse require different logistical approaches that may influence the reclamation strategy. User preferences should also be studied to evaluate the reuse potential. For instance, the reclaimed earth blocks appear different in colour than newly produced blocks, especially for CEBs. While it may be more appealing for users demanding a more robust block than MEBs but aesthetically more alike, others may perceive it as degraded or unclean. Additionally, conducting life cycle (cost) assessments is crucial to verify the ecological benefits of reuse and assess end-of-life scenarios with environmental gains versus financial investments. Finally, it is essential to validate whether reclaimed earth blocks undergo tolerable changes in properties for technically sound reuse, especially considering weathering and decay during their service life.

5. Conclusion

This study contributes valuable insights into the reclamation of earth blocks, laying the groundwork for further research on circular construction practices. The findings shed light on various factors influencing recovery rates, suitable reclamation tools and techniques, and labour intensity of deconstruction and cleaning. The choice of mortar emerges as a pivotal factor in determining the success of reclamation efforts, followed by block type and masonry bond. Earth mortar exhibits the highest potential for successful reclamation, while bastard mortar is discouraged for earth block reuse. In addition, the results unveil the potential of previously unexplored deconstruction techniques, such as wrenching and wetting in salvaging earth blocks. However, the absence of a standardised methodology highlights areas for further research and methodological refinement. Future studies are encouraged to consider earth block reclamation as a legitimate circular strategy for end-of-life scenarios in life cycle (cost) assessments. Post-reclamation research tracks include organisational aspects, user preferences, and technical validation for reusing earth blocks.

6. CRediT author statement

E Pelicaen[1] (1st author, corresponding author): Conceptualisation, Methodology, Formal Analysis, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualisation.

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7. References

[1] Ben-Alon L, Loftness V, Harries K A, Hameen E C and Bridges M 2020 Integrating earthen building materials and methods into mainstream construction *J. Green Build.* **15** 87–106
[2] Heringer A, Howe L B and Rauch M 2019 *Upscaling earth : material, process, catalyst* (gta Verlag)
[3] Fabbri A, Morel J-C, Aubert J-E, Bui Q-B, Gallipoli D and Reddy B V V 2022 *Testing and Characterisation of Earth-based Building Materials and Elements - State-of-the-Art Report of the RILEM TC 274-TCE*
[4] Fernandes J, Peixoto M, Mateus R and Gervásio H 2019 Life cycle analysis of environmental impacts of earthen materials in the Portuguese context: Rammed earth and compressed earth blocks *J. Clean. Prod.* **241**
[5] Minke G 2013 *Building with Earth: Design and Technology of a Sustainable Architecture* (Basel, Switzerland: Birkhaeuser)
[6] Van Damme H and Houben H 2018 Earth concrete. Stabilization revisited *Cem. Concr. Res.* **114** 90–102
[7] Pelé-Peltier A, Charef R and Morel J C 2022 Factors affecting the use of earth material in mainstream construction: a critical review *Build. Res. Inf.* **1** 1–28
[8] Pelicaen E, Novais Passarelli R and Knapen E 2023 Challenges to upscale earth block masonry in Western Europe from a life cycle perspective *IOP Conf. Ser. Earth Environ. Sci.* **1196**
[9] Interreg FCBRE, ROTOR, Bellastock, CSTB, Brussels-Environment and Salvo 2021 *REUSE TOOLKIT - Solid clay brick*
[10] Zhou K, Chen H M, Wang Y, Lam D, Ajayebi A and Hopkinson P 2020 Developing advanced techniques to reclaim existing end of service life (EoSL) bricks – An assessment of reuse technical viability *Dev. Built Environ.* **2** 100006
[11] Gregory R J, Hughes T G and Kwan A S K 2004 Brick recycling and reuse *Proc. Inst. Civ.*

Eng. Eng. Sustain. **157** 155–61
[12] Mulder E, de Jong T P R and Feenstra L 2007 Closed Cycle Construction: An integrated process for the separation and reuse of C&D waste *Waste Manag.* **27** 1408–15
[13] Morton T 2008 *Earth masonry: Design and Construction Guidelines* (Berkshire: IHS BRE Press)
[14] Walker Peter 1999 Bond Characteristics of Earth Block Masonry *J. Mater. Civ. Eng.* **11** 249–56