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Approximation to the Environmental Impact of the House of Gongora, Cehegín (Murcia, Spain): an LCA Perspective

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Abstract

This paper deals with an approximation to the environmental impacts of constructing the historic House of Góngora in Cehegín (Murcia), originally built in the 16th century using traditional earth architecture. By analyzing historical construction methods, materials, and energy use, the study approximates the environmental footprint of the house during its original construction. It then compares this with the estimated impacts of building an equivalent structure today, which would imply changes in techniques, methods and regulations. The comparison considers key environmental indicators such as carbon emissions, resource extraction, obtained using the Environmental Footprint LCA methodology. The paper highlights the sustainability inherent in traditional earth architecture and contrasts it with the challenges and benefits of contemporary construction practices. The findings question the idea of sustainability as a contemporary issue and reveal insights into the ecological trade-offs between historical and modern construction methods, emphasizing the potential for re-integrating sustainable practices from the past into modern architecture. This study contributes to ongoing discussions on sustainable construction and the relevance of traditional methods in reducing environmental impact.

Keywords: *rammed earth; life cycle assessment; house of Gongora; Cehegín; sustainable construction*

1. Introduction

In the 21st century, characterized by climate change and resource over-exploitation, the construction industry has consolidated as one of the primary contributors to carbon emissions and environmental degradation (IPCC, 2023).

In response to this crisis, the pursuit of sustainable materials has led to a renewed interest in ancestral techniques, namely rammed earth and locally sourced stone construction.

Vernacular architecture, characterized by the use of natural and locally sourced materials, has historically served as a model of environmental efficiency (Merino Pérez, 2022). However, with the process of industrialization during the 18th and 19th centuries and, specially, during the 20th century, new construction systems emerged, prioritizing speed and mass production over locally sourced materials, addressing the rising housing demand driven by exponential population growth (Sandrine Dixson-Declève et al., 2022).

Sustainable materials such as rammed earth are re-emerging as a viable alternative to reducing the environmental impact of the construction sector (Dethier, 2019). In this regard, prior to industrialization, there were remarkable architecture works built using this technique, including a variety of examples developed worldwide such as the Forbidden City in China, the Taroudant Fortress in Morocco, and the city walls of Seville and Granada in Spain. All these structures have withstood the test of time with minimal environmental impact.

At the national level, within the residential sector, the house of Góngora in Cehegín, Murcia, stands as a key case study for analyzing the evolution of this technique and its viability in the contemporary context. From this perspective, this research aims to determine the environmental impacts of residential rammed earth construction using 16th-century techniques and how they compare to those of the same technique when implemented with contemporary methods.

The study evaluates the environmental footprint of the historic house of Góngora, which relied on traditional earthen architecture techniques, and compares its ecological implications with those of modern constructions that employ rammed earth enhanced by technological innovations.

2. Methodology

This study is carried out by mixing three different methodologies. The first one, a case study, the House of Góngora in Cehegín. This house allows for a comparison in the way rammed earth construction has changed over the years. Then, the next methodology is an inventory analysis of the possible processes that took place during the different life cycle stages of the house and compare it with the way in which such a house would be built today. Lastly, a comparison of the impacts through bibliographical analysis.

Fig. 1 – *South view of the tower* (Peñalver, 2004).

Fig. 2 – *Ground floor plan. Current state of the house of Góngora* (edited from the original drawing of arq. Juan Antonio Durán Blázquez).

2.1. The house of Gongora

The house of Alonso de Góngora, also known as the Boticarians' house of the last people who used the building, the Ortega sisters, is a historic building located in the heart of Cehegín, Murcia. It forms a single historical complex alongside the Placeta de los Carros' tower.

These interconnected structures represent distinct yet complementary architectural periods and functions. The tower (Fig. 1), originally built between the 12th and 13th centuries as part of the town's fortifications, served a defensive role before being repurposed for residential and storage use. Its construction evolved over time, with a solid lower section of irregular stone blocks bonded with lime mortar, walls up to 4 meters thick, and interior openings appearing on the second level. The third section, added in the 16th century, transitions to rammed earth reinforced with gravel and lime, while the final level, dating from the same period as the House of Góngora, features a sloped roof that structurally integrates both buildings.

Primarily built in the 16th century, the House of Góngora (Fig. 2) follows a style layout centered around a courtyard. Its original walls, constructed from rammed earth, contrast with later masonry additions from the 18th and 19th centuries. Some sections still incorporate medieval masonry from the 12th and 13th centuries, illustrating its continuous transformation alongside the Placeta de los Carros' tower and the surrounding fortifications. The ground level features subterranean cisterns with reinforced herringbone-patterned brick walls, while the roofing system consists of wooden beams, a cane framework, and a compacted earth mixture known as "*alcatifa*", which enhances insulation.Over the centuries, the tower became an integral part of the House of Góngora, with structural modifications facilitating its incorporation into the residence. Notably, sections of the tower's northeast wall were removed to create a seamless connection between the two structures.

The use of traditional materials, such as rammed earth and locally sourced stone blocks, reflects the evolution of construction techniques and the changing needs of its occupants over time (Peñalver, 2004). As a result, the house serves as a living palimpsest of Cehegín's architectural history and transformation.

2.2. Sustainability in historical context

The methodology used to carry out the sustainability evaluation consists of an inventory analysis combined with an impact determination based on bibliographic analysis. The bibliographic analysis was developed by contrasting modern day technologies with the techniques used at the time of the construction. This analysis is done stage by stage incorporating information from the EN15804+A2 (*Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products*). The stages of this norm structure the results of this study, which are presented in the next section divided into 4 parts, which coincide with the four stages of the life cycle of buildings: Stage A, product stage and construction process, Stage B, use stage, Stage C, end of life, and Stage D, benefits and loads beyond the system boundary.

The Life Cycle Inventory (LCI) has been developed using the software Simapro v9, the most commonly used commercial software for LCA studies. The database of the contemporary solution has been Ecoinvent v3. Ecoinvent is the most comprehensive database for environmental studies. It includes industry data and its reliability is achieved through a careful peer review process prior to the incorporation of any process into the system (ecoinvent, 2020). The study of the LCI of the traditional construction has been made through a bibliographical analysis.

3. Results

As it is indicated in section 2.2, the possible environmental impacts are structured following the structure of the EN 15804.

3.1. Stage A

At the time the building was constructed, at least prior to the part built in the XIX century, raw materials were sourced locally. Rammed earth and the rest of the materials were extracted directly from the site, stones quarried nearby, and gypsum burned in small-scale kilns (Bel-Anzué & Elert, 2021; Wouters et al., 2018). These processes required minimal energy input, relying on manual labor and traditional tools. The embodied carbon of stage A1 (Raw materials supply) could be considered negligible, due to the absence of industrial processing. In the case of Stage A2 (transportation), the impacts were insignificant since materials were carried by hand or with the assistance of animal labor (Bel-Anzué & Elert, 2021).

In contrast, if the same building were constructed today, even while using the same materials, the environmental burden would vary significantly. When it comes to stage A1, industrial processing methods for gypsum and stone require substantial energy input, often relying on fossil fuels (Pedreño-Rojas et al., 2020; Quintana et al., 2018; Suárez et al., 2016). Stabilizers such as cement are often introduced into the rammed earth to improve durability, but this would substantially raise carbon emissions (Ávila et al., 2022a; Kariyawasam & Jayasinghe, 2016; Toufigh & Kianfar, 2019). However, that's not always the case, as many times lime or other natural materials are used as stabilizers (Ávila et al., 2022b; Gomes et al., 2016).

When talking about A2, modern transportation methods for the building industry use hydrocarbons as fuel, which highly increase carbon emissions. This effect will further increase if materials are not sourced from the immediate vicinity (Hadjiiski et al., 2022).

During the construction phase (A3), historical methods relied solely on manual techniques, with workers compacting rammed earth using wooden or metal formworks. Stone carving was done on-site using hand tools. These methods extended construction time but maintained a low environmental footprint. In contrast, modern construction often employes mechanical tampers for compacting rammed earth walls(Calvetti et al., 2021; Udomiaye et al., 2025). For stone masonry stone-cutting machines are currently widely spread. While these approaches would reduce labor intensity and speed up construction, they would increase energy use. Also, nowadays, these earth walls incorporate a damp proof course to avoid the risk of moisture from the ground rising in a capillary way. That course, typically containing butyl rubber or hot bitumen also increases the environmental impact of the construction.

Figure 3 shows the carbon emissions of a rammed earth wall built today compared to an approximation of a masonry wall built in the XVIth century.

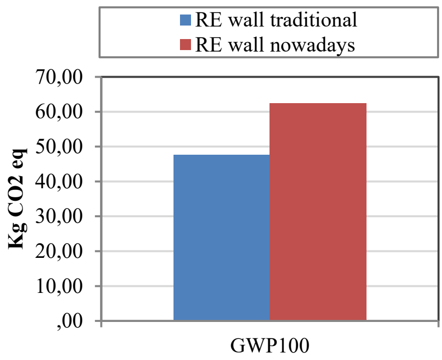

Fig. 3 – *Comparative Life Cycle Assessment of traditional vs contemporary construction of rammed earth walls (Stage A).*

3.2. Stage B

The impacts produced during the use phase of buildings depend solely on the context. In the case of energy consumption (B6), historical buildings were not built with the idea of using modern day HVAC (Heating, ventilation, and air conditioning) techniques to control the inner temperature. However, many of those buildings are now equipped with such systems. Therefore, it only makes sense to compare old and current ways of controlling temperature. While back in the day there was no way of refrigerating buildings, although its morphological conception with patio and gallery allow passive cooling of the house, heating was commonly achieved burning wood, which can be considered a carbon intensive way of heating, comparable to modern day fuels such as natural gas (Punhagui & John, 2022).

In terms of energy efficiency, modern day constructions using earth usually incorporate thermal insulation in the outer layer. That reduces thermal losses while increasing the impacts of Stage A.

Introducing these kinds of external insulation systems also increases the impacts of maintenance (B2-B5), as the insulation layer needs to be replaced after 25 years(Davis et al., 2025). If not for that layer, these kinds of constructions can be considered to be low maintenance (Kariyawasam & Jayasinghe, 2016).

In contrast, modern day stabilized rammed earth would likely require less frequent maintenance than its traditional counterpart, but any necessary repairs might involve industrially processed materials rather than locally available earth.

3.3. Stage C

At the end of its life cycle, the historical building could be deconstructed with minimal environmental impact. Had it reached the end of its lifespan prior to the twentieth century, it would have been dismantled with manual labor, which does not directly have carbon emissions. Tearing down the same old house nowadays would incorporate fuel powered machinery, which does increase carbon emissions. Rammed earth walls could be reintegrated into the soil, while stone and gypsum could be repurposed for new construction. Due to the lack of synthetic materials, waste generation would be minimal, and almost all materials would remain biodegradable or reusable(Arrigoni et al., 2017).

A modern reconstruction, however, would present additional challenges. Stabilized rammed earth containing cement or polymers might not be as easily reintegrated into the soil. Transportation emissions from removing demolition waste would also be higher, and any synthetic insulation systems used in the construction process could introduce non-biodegradable waste (Arrigoni et al., 2017).

3.4. Stage D

Analyzing the stage D of both current and ancient buildings is not an straight forward matter. One way of doing so is from a circular economy perspective. As mentioned in section 3.3, in the case of the original house, materials could be fully reused or naturally degraded without leaving a lasting environmental footprint. Rammed earth could be recycled directly into new walls, and stone elements could be repurposed without significant reprocessing.

The integration of modern techniques in rammed earth construction, however, might reduce the potential for full recyclability. If stabilizers or industrial additives are present, rammed earth might require additional processing before reuse. While modern tools allow for precision-cut stone elements to be reused efficiently, the overall complexity of modern waste management systems increases the environmental burden. Even though some materials could be reintegrated into future projects, the additional energy required for reprocessing would need to be accounted for in the LCA.

4. Conclusions

The article analyzes the environmental impact of rammed earth construction by comparing historical techniques used in the 16th-century House of Góngora in Cehegín, Murcia, with contemporary forms of rammed earth construction, assessing their sustainability through a life cycle analysis structured by the EN 15804 framework.

The 16th century rammed earth construction method shows a significantly lower environmental impact than modern adaptations due mainly to the use of locally sourced materials, manual labor, and carbon-based energy input.

While contemporary techniques enhance time and human labor efficiency through stabilizers and mechanized processes, they also introduce higher embodied carbon and waste. The LCA reveals that historical buildings present more local and naturally sourced materials that may be easier to reintegrate into the environment, whereas modern versions require additional processing, reducing their sustainability potential.

Despite advancements, traditional rammed earth remains a viable low-impact alternative, especially when combined with careful material selection and passive design strategies.

Future studies could expand the comparison between traditional and contemporary rammed earth construction methods and the most used modern techniques, such as reinforced concrete structures and masonry with perforated bricks. This analysis could yield valuable insights, particularly regarding environmental impact, with a focus on carbon emissions.

Historically, buildings like the case study analyzed in this research did not have a definitive end-of-life. The integration of *Placeta de los Carros*' tower into the house and the 19th-century additions highlight an approach that currently is gaining great momentum, such as adaptability and flexibility in building use. During these periods, such adaptations had minimal environmental impact.

As industrialization continues to depend on mechanized, energy-intensive processes and products, and given the ongoing climate crisis and slow decarbonization of our economy, bio-based, local, and traditional methods offer a promising alternative for sustainable construction and building adaptation.

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