

Raw earth and natural stone in contemporary Portuguese architecture

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Abstract

A global understanding of the environmental impact of the construction industry has been amplified in the recent decades. Solutions have been long sought to tackle the problem and it has become necessary to find alternative building materials with lower embodied energy.

The main objective of this research paper is to examine the current architectural and socioeconomic context for the use of earth and stone in Portugal and explore their future potentials as well as limitations to providing a relevant alternative to the widespread use of industrial materials.

The methodology of the study combines qualitative and quantitative data collection. Following the identification of a set of architectural examples in Portugal, the different aspects of construction and operation of earth and stone buildings are explored through the experience of the architects and clients. Specific case studies are selected for further quantitative analysis to examine the hygrothermal performance of earth and stone constructions.

The study reveals the main difficulties to the use of earth and stone which are of an economic, legislative and social nature. It also outlines potential solutions to overcome these problems. To facilitate a widespread and reasonable use of these materials, it is necessary to introduce structural changes in the academic educational offer, to sensitize the public about alternative solutions and to standardize the processes related to earth and stone construction.

Keywords: raw earth, natural stone, sustainability, contemporary architecture, viability

1. Introduction

The 21st century context of climate change and its increasingly serious effects require changes in the foundations of contemporary building culture. Being a large contributor to global CO₂ emissions and resource consumption, the construction industry shares a considerable responsibility in addressing this problem.

According to a report published by the United Nations Environment Programme in 2019 (Environment Journal, 2020) the construction industry accounts for 38% of energy-related CO₂ emissions. Out of this, a total of 8% can solely be attributed to the production of cement, a key component of concrete. To achieve the Paris Agreement commitment and the United Nations Sustainable Developments Goals (International

Energy Agency, 2019), there is a need to find alternative construction solutions and focus on the circular, sustainable and local use of materials. Consequently, the potential of natural building materials has been recognized again. Natural materials such as raw earth and stone have been widely used in vernacular architecture throughout the world and can offer several advantages over industrial construction materials. The low embodied energy related to their production, their local availability and minimized transportation needs are some of their valuable characteristics. The recyclability of earth and stone makes it possible to use them in a circular economy without considerable negative impact on the environment. Due to their good material properties, they adapt better to local climatic conditions and can create a healthier indoor environment. On a socioeconomic level, the use of locally available materials can contribute to creating employment and generating profit within the area of influence of the given project while also preserving the traditional construction know-how characterizing a region.

The main objective of this research paper is to examine the current architectural and socioeconomic context for the use of earth and stone – the most widely used materials for structural application in local vernacular building cultures in Portugal – in contemporary architecture. It aims to explore their future potentials as well as limitations in providing a relevant alternative to the popular use of industrialized materials considering the notion of functional requirements, comfort and performance, economy, sustainability and

architectural language. The topic is contextualized by overviewing the state-of-the-art of related academic education, research and architectural practice in Europe.

2. Methodology

The study is based on qualitative and quantitative data collection supported by documentary analysis, fieldwork and personal interviews. A set of architectural examples are identified in Portugal and the different aspects of construction and operation of the buildings are explored through the experience of the architects and clients involved. A series of interviews is conducted with previously established contacts i.e. architects, residents and professors at universities as the main actors involved in natural building processes. It aims to gather and systematize information related to the participants' experience in building with earth and stone including the principal reasons of material choice and all the inherent details to the construction and life cycle of the buildings. At the same time, the current state of academic education in architecture is also examined concerning the topics of sustainability and natural construction materials and techniques. This way, it is possible to establish connections between the present-day educational methodologies of architecture schools and the way they are reflected in the works of current practices in Portugal. Out of the chosen architectural projects, specific case studies are selected for further quantitative analysis. It examines the hygrothermal performance of

earth and stone constructions in different climatic conditions in mainland Portugal.

3. Results and discussion

The research identifies the main difficulties and potentials underlying the use of earth and stone in contemporary architecture in Portugal and in Europe.

The obstacles are primarily rooted in economic, legislative and social grounds.

First, natural materials are not part of any kind of lobby which has to do with the significantly lower profit associated with them (Heringer et al., 2019). Also, the market is dominated “by a handful of major producers which are cautious about pioneering new products that challenge their existing business models” (Chatham House, 2018). In the context of developed countries, another problem lies in the labor-intensity of natural constructions. The traditional techniques related to natural materials rely chiefly on manual work that prolongs the duration of construction. It is directly reflected in the global costs which, given the current rise of labor prices, makes it relatively uncompetitive. For both earth and stone to be an economically competitive material, the cost of building should be “calculated on a whole-life cycle basis” (Moriset et al., 2021). In the long term, these materials can help to cut comfort-related energy expenses and often have a lower maintenance need than their industrial counterparts (Building Centre, 2022).

Secondly, there are no regulations and standards for the use of earth and stone which is

discouraging both for the contractor, the architect and the client itself and poses key questions of liability. The lack of legal framework results in a distrust towards the materials while the absence of their promotion among the public amplifies the perceptible ignorance and the unfavorable image connected to earth and stone construction. The dissemination of knowledge among professionals and the public is therefore essential to change the current status-quo.

A number of national and international higher education institutes have already realized the need to change the conventional construction industry and train a new generation of young architects as the key future players in this process. Several renowned European universities have adapted their educational offer to respond to contemporary challenges through innovative academic methodologies. They have developed and applied state-of-the-art scientific results and tools in research and education and based their knowledge transfer on it. Still, these examples constitute isolated cases and a broader, comprehensive educational network and strategy to target this topic on an academic level is still missing.

Regarding the state of research and architectural practice, some differences in the approach on a national and international level can be recognized. In Europe, there are several ongoing experiments that embrace the opportunities advanced technologies and science – such as prefabrication, 3D printing, robotic fabrication and nanosciences – offer when integrated with natural materials, the related techniques and construction processes.

It is a progressive, experimental approach to make earth and stone construction practice more competitive and to find a contemporary language for it. At the same time, Portugal maintains a traditional attitude to natural construction, building strongly on its cultural and socioeconomic assets. In most of the cases it is a learning by doing process in which little progress has been made in the past decades.

Mainland Portugal shows a great diversity of climate and soil types that influenced local vernacular architectures. The warm and dry climate and good quality soil was favorable for the use of earth in the southern regions of the country while in the northern parts, the predominant construction material was stone (mainly granite and schist) due to resource availability (Simões et al., 2019).

Regarding material properties, earth and stone share few similar characteristics – they provide high thermal inertia and thus a good indoor comfort in buildings due to the characterizing thick walls, although the heat conductivity of different types of stones are much higher than that of earth; given their low tensile strengths, both earth and stone work in compression-only structures, their strength parameters differing considerably, though. The compressive strength of stone is far greater than that of earth and currently used construction materials. While “stone is generally considered one of the most resistant materials” (Siegesmund & Snethlage, 2011) earth is usually perceived as a non-durable one. It is vulnerable to direct water contact and requires specific measures to protect the structure against it.

Through the experience of practitioners the study reveals the different approaches to using earth and stone in Portugal and formulates future perspectives for their development considering their potentials and constraints mentioned before.

Demand for natural construction in Portugal has been growing considerably in recent years, as professionals in the field describe. The motivation of the clients – both Portuguese and foreigners – behind the use of natural materials, outside the self-build context, is diverse. Often it is derived from the desire to recover and rehabilitate old buildings in order to preserve their original character. Besides, many decide to move from cities in quest of a closer connection to nature – this attitude also being reflected in the materials they choose to construct with. It is an example of a specific way of thinking that reveals an ecological attitude and sensitivity to local cultures and to the different dimensions of sustainability.

Regarding raw earth in contemporary Portuguese architecture, there seems to be two different approaches to its use. One advocates a traditionally conceived earth construction based on traditional methods and vernacular principles where the result is perceived as the continuation of an old legacy reinterpreted to fit the requirements of each context. This approach supports the minimization of the use of industrial materials in the construction process, replacing, whenever possible, concrete and steel with natural elements such as stone or wood. It builds strongly on vernacular architectural traditions as the best reference for bioclimatic

design principles. The buildings are usually composed of simple, rectangular volumes with pitched roofs, unimposing to the landscape; they adopt a conscious orientation and small openings to minimize solar gains. They usually feature pergolas or other shading elements on the most exposed façades. Parallely, there exists another approach to earth construction, one of a modern and experimental character. It is based on the will to take advantage of the valuable assets of raw earth in ecologizing construction, achieving better indoor comfort and reviving traditional know-how. At the same time, it accepts that “ecological discourse is not a negation of an industrial cultural and economic context” therefore, “there is a need to search for an architectonic language that does not deny this contemporary condition which is simultaneously critical of and in debt to industrialisation” (Carvalho et al., 2005). In an experiment to find a contemporary expression for earth construction, it promotes modern aesthetics and principles and it does not reject the use of industrial materials for complementary structures nor the use of modern techniques (mechanical compression). Such projects present complex, irregular volumes with flat roofs and generous openings to achieve spacious, bright spaces. While novel solutions can be a strong impetus to bring Portuguese earth architecture forward, the hygrothermal measurement results and the thermal comfort assessment of the occupants of different earth houses indicate that a good choice of material alone is not enough to create an environmentally conscious building with low energy consumption and good indoor comfort. Solar gains,

orientation and other passive strategies need to be taken into account to make the most out of good material properties.

With regard to the use of natural stone in contemporary Portuguese architecture, the viability of newly quarried material proves to be questionable due to economic and environmental reasons. Stone quarries such as the Arrábida lime quarry or the Estremoz marble quarry generate a lot of pollution, an incredible amount of waste and modify the surrounding natural landscape. According to Estremoz quarry workers, 80% of the extracted stone in the quarry is discarded due to different reasons of imperfection concerning cracks or color.

The inherent logistics to stone such as its extraction, transportation and execution make it a rather expensive and energy intensive solution. Consequently, and as underlined by architects with related experience, the present-day potential of stone is primarily in the use of already existing material such as the reuse of existing buildings or resources from ruined ones but also in the reutilization of quarry waste referred above. There is, therefore, a great diversity of different applications of the material in new construction, in line with the above-outlined potentials.

Both in the case of earth and stone construction, the interviewed architects outline several advantages of material choice such as the sustainability and economic aspects of reusing existing resources. The operation of most of the buildings during their useful life is also highly favorable – the good indoor thermal environment achieved by using these materials renders

mechanical cooling in summer unnecessary while additional heating in winter is required in buildings that do not have wall insulation. In the case of stone buildings, the durability of the material and the lack of maintenance needs is repeatedly highlighted. Regarding earth constructions, a good design and execution can ensure a proper and lasting function of the structure as well.

Among the disadvantages related to earth and stone construction is the lack of available skilled labor to execute the work and the limitations arising from material properties – the size of achievable spans is limited and earth or stone structures need to be complemented by other materials with better tensile strength to span larger distances.

Regarding the cost of construction, there was no significant difference in the selected projects when compared to building with current construction materials. When contrasting two scenarios, the costs balance themselves – gaining on one factor while losing on another. In the case of the selected examples, the main construction material was readily available and the buildings do not require considerable maintenance during their useful lives. At the same time, natural construction usually takes longer and requires specialized workers which increases the price of labor considerably. In the case of current constructions, the pattern is quite the opposite – less is spent on labor and more on the material.

However, given the economic, political and social uncertainty of the 2nd decade of the 21st century, it is difficult to give an up-to-date

financial overview of earth and stone constructions and it was not in the scope of this study to quantify the different related variables. It can be mentioned, though, that most current construction materials rely significantly on fossil fuels for their production and transportation processes which makes them vulnerable to conditions such as present-day soaring energy prices. Therefore it is both economically and environmentally beneficial to prioritize materials with less or no dependence on nonrenewable energy sources in their manufacture.

4. Conclusion

Through the insight of professionals involved in natural building practices in Portugal, it was possible to target the main obstacles to construction with raw earth and natural stone as well as to formulate future perspectives for their development.

One of the main factors that is currently preventing both earth and stone from becoming a widely used material is the strong presence of lobbies of current construction materials. "The construction paradigm has to change" (Morais) in order to successfully integrate them into the market without losing their fundamental values.

Regarding the future of the use of natural stone, most of the interviewed architects agree that it probably won't grow as a structural material but remain the resource for smaller scale, exceptional projects. The logistic and economic constraints related to stone construction are posing difficulties to its widespread use while the limitations of (human and material) resource

availability and the sustainability of newly quarried material remains questions to consider.

At the same time, many architects believe that raw earth could become a widely used conventional material in some parts of the country again due to the availability of good quality material, suitable climate and a long tradition of related constructive culture.

From the conversations with the architects, alternative ways emerge to make earth and stone construction more competitive. Many argue that changes should start on an academic level by promoting the associated knowledge through courses and research studies. As the hygrothermal measurement results show, lack of knowledge about the materials and bioclimatic design principles on a professional level can prevent a satisfactory thermal performance of buildings on a passive level. It is therefore important to train competent professionals in order to facilitate a widespread and reasonable use of both of the materials and to achieve buildings with good indoor comfort and low energy consumption.

Reducing the labor intensity of construction would be another step forward in regaining the popularity of the materials. Standardizing the processes related to earth and stone construction could be achieved by introducing different, semi-automated construction technologies (such as the CEB technique in the case of earth, as highlighted by architect Miguel Rocha) or through the integration of advanced technology into the construction process in order to make it more controlled.

Sensitizing the public about alternative construction solutions is equally important and could be achieved by the promotion of newly constructed buildings using earth or stone as their primary building material as well as exhibitions or other awareness-raising actions.

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