HILL PUBLISHING

Engineering Advances, 2024, 4(4), 162-168
https://www.hillpublisher.com/journals/ea/
ISSN Online: 2768-7961

The Role of Sub-natural Materials in Building Fabrication

Yu Li

University College London, London WC1E 6BT, UK.

How to cite this paper: Yu Li. (2024) The Role of Sub-natural Materials in Building Fabrication. *Engineering Advances*, 4(4), 162-168.
DOI: 10.26855/ea.2024.10.002

Received: September 26, 2024
Accepted: October 23, 2024
Published: November 19, 2024

***Corresponding author:** Yu Li, University College London, London WC1E 6BT, UK.

Abstract

The growing demand for rapid manufacturing has positioned standardized building materials as the dominant choice in contemporary construction. However, the potential of sub-natural materials, such as earth and tree branches, remains underexplored. This paper investigates the historical evolution of sub-natural materials in construction, analyzing the factors contributing to their resurgence in modern manufacturing and their relevance to sustainable practices. This study highlights how sub-natural materials interact with digitization and sustainable production methods by examining projects that incorporate these redundant materials, such as earth-based constructions. The research emphasizes the environmental and cultural significance of returning to these materials, which offer advantages in adaptability, ecological balance, and resource efficiency. The study also discusses how integrating digital tools can enhance the precision and scalability of using sub-natural materials, promoting their broader application in modern architectural contexts. Ultimately, this paper sheds light on the emerging potential of sub-natural materials as viable, sustainable alternatives in contemporary construction.

Keywords

Sub-nature material; Earth building; Digital construction; Vernacular architecture; Sustainable building

1. Introduction

In the modern era, discussions within the architecture domain have increasingly focused on pursuing low-carbon adaptive materials, aligning with the principles of sustainable development and the circular economy. This exploration has emerged as a pivotal topic within the field. According to UNEP's Sustainable Building and Construction, OECD countries' building and construction sector consumes 25%-40% of all energy used [1]. Therefore, architects increasingly focus on the relationship between architecture and the environment, dedicating their efforts to exploring new materials and sustainable resources. Moreover, it's worth noting that utilizing sub-natural materials is also an effective approach to achieving sustainable development.

Based on a series of cases on the use of sub-natural materials in manufacturing design, this paper aims to explore the role and application methods of sub-natural materials in architectural manufacturing within the digital context. The paper primarily argues two points. Firstly, it examines the historical application of semi-natural materials like earth and investigates the evolving reasons behind people's changing attitudes toward these materials. Secondly, it explores the potential application and value of sub-nature materials in the era of digital technology. Through an analysis of the project "3D Printing System for Earth Based Construction" and other cases like the "Wood chip Barn," the paper aims to demonstrate the significant relevance of sub-natural materials in modern manufacturing.

2. About sub-nature substance

2.1 What is a sub-natural substance?

Sub-natures are those forms of nature deemed primitive (mud and dankness), filthy, fearsome, or uncontrollable [2]. Sub-natural substances are typically defined as the untidy, non-mainstream elements existing in the natural world (Figure 1).

Figure 1. Anca Benera & Arnold Estefan: The Visible Manifestations of invisible Forces (detail), 2020. (https://blokmagazine.com/subnature-by-anca-benera-arnold-estefan-at-trafo-gallery/).

Simultaneously, some vernacular architectures primarily constructed from earth have, for a period, been perceived as unsophisticated and dilapidated. Vernacular architecture, undeniably the most direct response to local needs, often faces neglect or criticism for a long time due to its marginalized status as a material.

2.2 The development of the status of sub-natural materials in construction

In the early stages of human development, sub-natural materials were essential for providing shelter and spaces for protection. Earth-based constructions have a history spanning thousands of years. During that era, limitations in construction methods and tools prompted dwellings to prioritize safety measures against potential threats from animals. In such circumstances, earth and stones, which were the most accessible materials, became one of the origins of primitive architecture and were widely utilized in indigenous constructions. At that time, humans developed the earliest form of house: pit houses. (Figure 2) They use available materials without much planning or preparation. For instance, the subterranean dwellings used by the Hohokam for irrigation and habitation have proven highly successful and remained in use for several centuries [3]. Presently, many characteristics of these subterranean dwellings have been rediscovered and are being reengineered and repurposed.

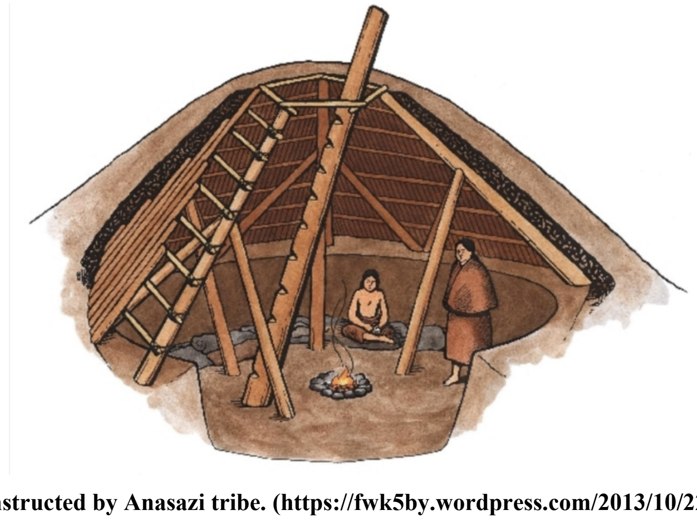

Figure 2. The pit house constructed by Anasazi tribe. (https://fwk5by.wordpress.com/2013/10/22/the-pit-house-assignment-three-draft/)

With advancements in manufacturing technology, the scope of construction materials has expanded beyond local resources. At the same time, the significance of architecture during this era transcends mere " living space." As civilization progresses, the demand for more efficient and rapid construction techniques has spurred the emergence of mudbrick (Figure 3). In comparison to the earth, mudbrick offers heightened construction efficiency due to its shorter molding period.

Figure 3. Choqa Zanbil is a 13th-century BC Iranian gilded pagoda made of mud bricks and burnt bricks. (Roman Ghirshman, La ziggourat de Tchoga-Zanbil (Susiane), Comptes rendus des séances de l'Académie des Inscriptions et Belles-Lettres, vol. 98 lien Issue 2, pp. 233-238, 1954)

Between the early 1900s and the era encompassing World War II, there was a decrease in the utilization of earth-based construction methods. In comparison to most other building materials (such as concrete, steel, and wood), the general adaptability of building earth compositions is not easily standardized due to their inherent natural variability (Figure 4). Undoubtedly, this natural variability has contributed to the widespread decline of earth-based architecture in Europe since the early 20th century [4] Earthen construction is often marginalized and seen as a symbol of poverty or tradition. This marginalization leads to misconceptions about its value.

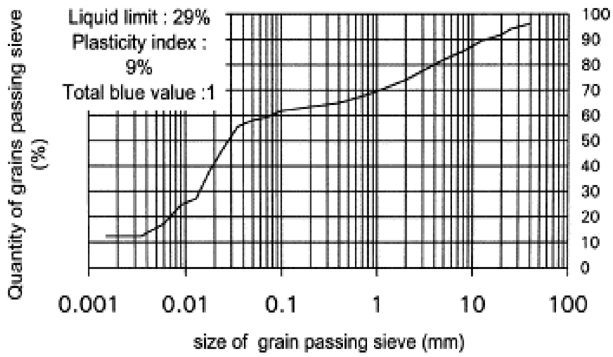

Figure 4. Soil geotechnical characteristics. (J.C. Morel, A. Mesbah, M. Oggero, P. Walker. “Building houses with local materials: means to drastically reduce the environmental impact of construction” Building and environment 36, no.10(2001): 1119-1126.)

Figure 5. The Gourna Village resettlement. (https://www.wmf.org/project/new-gourna-village)

After World War II, architects began reevaluating the intrinsic value of mudbrick construction. A pivotal event occurred against the post-colonial backdrop of Egypt, where architect Hassan Fathy opposed the imposition of concrete, steel, and glass architectural languages in the country. Fathy's notable work includes the Gourna Village resettlement (Figure 5) and New Baris Village, showcasing mud-brick construction and communal living, promoting sustainable, affordable housing.

3. The use of sub-nature materials in construction in recent years

The need for urban expansion during the Industrial Revolution led to the creation of building materials such as reinforced concrete. Years later, as environmental issues increasingly worsened, architects and artists began contemplating how to reduce architecture's impact on the environment.

3.1 The influence of the art movement

The development of Architecture and art mutually influence and propel each other, with profound shifts in the understanding and appreciation of art consistently accompanying significant transformations in urbanism and architecture. The burgeoning artistic movements of the modern era emphasize natural aesthetics, sustainability, and equality, prompting a renewed focus on long-overlooked building materials.

During the 19th-century avant-garde art movement, artists endeavored to transcend the limitations of realism from a philosophical standpoint, advocating for the disruption of existing norms through innovation and experimentation. For example, Marcel Duchamp's iconic work "Fountain" is a ceramic urinal (Figure 6); this blurs the concepts of "high" and "low" within art, thereby mitigating, to some extent, the misconception of the earth as a "dirty," "low" substance.

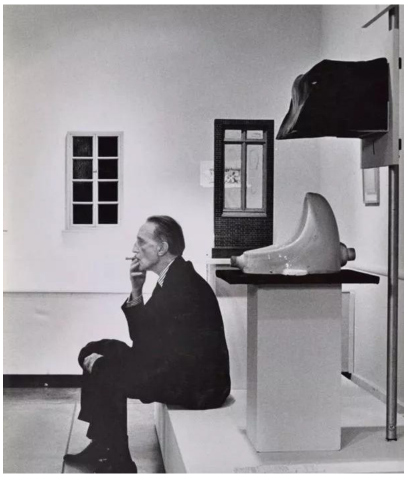

Figure 6. Marcel Duchamp and "Fountain". (http://www.art-ba-ba.com/main/main.art?threadId=190247&forumId=8)

Additionally, during the late 1960s to early 1970s, the Earth Art movement saw artists employing land, earth, and natural materials to create artworks that reflected the concerns of environmental issues, sustainability, and the relationship between humans and nature. For instance, Robert Smithson's work "Spiral Jetty" (Figure 7). These art movements inspired architects to consider environmental concerns and incorporate natural materials into architecture.

Figure 7. Spiral Jetty on the page in Art & Place. (https://www.phaidon.com/agenda/art/articles/2013/november/18/explaining-smithsons-spiral-jetty/)

3.2 A renewed interest in vernacular architecture

Lately, contemporary architects have increasingly focused on vernacular and traditional architecture, driven by escalating energy expenses. These cultural building practices not only offer cost-effective solutions but also prioritize energy efficiency and sustainability. For instance, the “School in Gando” project utilizes local materials such as mud bricks and thatch, effectively harnessing natural resources [5] (Figure 8). This project exemplifies contemporary sustainable architecture utilizing earth-based materials.

Figure 8. School in Gando, 2001. (Diebedo Francis, Kere. "School in Gando, Burkina Faso." Architectural design 82, no. 6(2012):66-71.)

A ubiquitous substance in nature, earth has undergone a transformation in its presence within construction manufacturing, evolving from raw clay to adobe bricks and concrete and back to its original form. The status of the Earth in architecture has traversed a trajectory from being highly regarded to being disregarded and then revalued. The shift in architects' attitudes towards clay reflects the gradual refinement in the development of architecture and construction and signifies a process of increasing recognition of the intrinsic value of sub-natural materials.

4. Application of sub-nature materials in the digital era

4.1 Significance

The extent of issues arising from the reduction in the availability of natural resources depends on several factors, such as consumption rates, resource substitutability, recyclability, and the regeneration time of renewable resources. Sub-natural materials, once deemed surplus to mainstream usage, are now re-emerging in manufacturing, representing an improved utilization of natural resources in the industrial sector. Taking the use of timber as an example, many years ago, designers would redesign forest structures based on the demand for timber; they engaged in the design of the forest or set the direction for changes in the forest [6]. We might consider nature as a more dynamic source of materials, exploring methods to utilize "redundant matter" (e.g., irregular branches, dirt, etc.) beyond standardized materials (Figures 9 and 10).

Figure 9. Irregular trees in the forest. (https://www.offset.com/search/overgrown)

For example, the “FIELD STATION” project by AA school shows the potential of using branches as a fabricating material. They utilize an innovative robotic application to transform small-diameter roundwood (50-90mm, typically a by-product of timber harvesting) into the main structural element for a 100m² roof system at a field station in Hooke Park, Dorset, UK [7]. Furthermore, the utilization of sub-natural materials can contribute to sustainability by reducing carbon emissions. In the "3D Printing System for Earth-Based Construction" project, the research team focuses on cob, a traditional, locally sourced building material considered relatively crude by modern standards [8]. Compared to modern construction materials like concrete, COB made primarily from sub-natural materials such as clay, straw, etc., tends to be more biodegradable and emits lower carbon dioxide levels [9], thus presenting a more environmentally friendly option.

Figure 10. "WoodChipBarn" project in which the designers used irregular tree branches for the construction. (Self-Martin, and Vercruysse Emmanuel, “Infinite variations, radical strategies,” In Fabricate: Rethinking Design and Construction,30-35. London: UCL Press, 2017.)

4.2 Methods of application

In contrast to engineered production materials, sub-natural materials are characterized by their dispersed, irregular, and non-standardized nature. Hence, integrating such substances into industrial-scale production poses certain challenges. When discussing the use of sub-natural materials in manufacturing, emphasis should be placed on non-standardized manufacturing processes and methodologies. Architects can derive ample inspiration from traditional rural architecture that incorporates sub-natural materials. Traditional rural architecture is typically crafted by skilled artisans based on their experience. Digital technology, on the other hand, aims to capture the implicit elements of the production process—the skill, experience, and intuition inherent in technical actions—and quantify these as digital records. The goal is to replace implicit knowledge with explicit, repeatable rules.

In the "3D Printing System for Earth-Based Construction" project. Compared to traditional COB construction, which relies primarily on manual labor, robot-assisted construction represents a digitized method that emulates the manual building process. It translates the conventional craftsmanship-based "construction techniques" into digitized methods using computer technology, enhancing construction efficiency.

The primary advantage of parametric methods is achieving complex solutions through simple systems [10]. Introducing parametric design systems enables architects to address intricate design issues using a unified language. In the COB project, researchers extensively investigated the characteristics of three extrusion systems using mechatronic and pneumatic methods (Figure 11), ultimately developing a novel custom dual extruder. With the introduction of extrusion systems and their associated computer control systems, these non-solid materials can be precisely used in construction processes. Undoubtedly, digital technology serves as a simple, standardized, and precise language, significantly reducing the production complexity of sub-natural materials.

Another common approach is to convert sub-nature materials into digital information, completing the construction through design. A related example is the "Wild Wood Gridshells" project, where researchers first used 3D scanning equipment to convert tree forks into digital models. After simulating and designing with Grasshopper, mixed reality (MR) technology was used for manufacturing. Using a mixed-reality app on a smartphone, the researchers visualized the location of individual wildwood joints in real time and used a pen to mark cutting lines directly on the wood [11].

Similarly, many studies are exploring innovative methods for manufacturing building components using bio-based materials. These methods focus on leveraging the natural properties of organic substances to create sustainable and efficient construction techniques. For example, the BioKnit pavilion is a structure that is either grown directly on-site or cultivated in a controlled growing chamber, resulting in a single [12], cohesive piece that eliminates the need for traditional assembly methods. In a related vein, the "Upscaling Mycelium-Based Composites" project delves into the potential of combining wood chips with mycelium—a fungal material that acts as a natural binder—to fabricate robust and environmentally friendly partition walls [13].

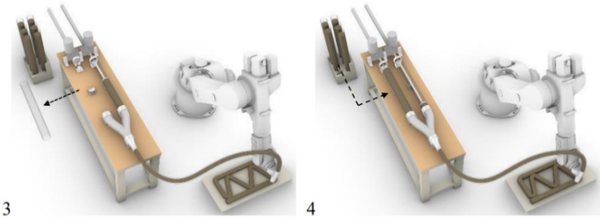

Figure 11. The electromechanical linear ram extruder and its 3D printed outcome. (https://www.sciencedirect.com/science/article/pii/S0926580521000285.)

5. Conclusion

This paper provides an in-depth exploration of the evolutionary trajectory of sub-nature materials as architectural components. It systematically delineates their transition from a position of prominence to being disregarded and subsequently re-embraced while acknowledging the multifaceted influences contributing to this evolution, encompassing historical context and the pace of urban development, among other factors. It is particularly noteworthy that the emergence of modern art movements has altered perceptions regarding materials like soil, once considered "inferior," consequently integrating them into the realm of contemporary architecture. Additionally, the scrutiny of vernacular architecture serves as a reminder of the pivotal role played by sub-natures in sustainable development.

This article further delves into the prospective applications of sub-nature materials within a digital context. As a natural element, sub-nature remains indispensable in contemporary architecture. On the one hand, it effectively utilizes redundant resources, thereby enhancing the efficiency of natural resource utilization. On the other hand, materials like cob reduce carbon emissions, aligning more closely with the trend of sustainable development. In the digital era, sub-nature materials hold vast potential for applications. Digitalization techniques can simulate manual construction logic, introducing systems such as 3D scanning and robotic extrusion, which significantly enhance the resolution of challenges in non-standardized manufacturing more efficiently.

References

[1] Assefa G, et al. Environmental assessment of building properties—Where natural and social sciences meet: The case of EcoEffect. Building and Environment. 2007;42(3):1458-1464.

[2] Gissen D. Subnature: architecture's other environments. Princeton Architectural Press; 2009.

[3] Niroumand H, et al. Earth architecture from ancient until today. Procedia-Social and Behavioral Sciences. 2013;89:222-225.

[4] Morel, Jean-Claude, et al. Building houses with local materials: means to drastically reduce the environmental impact of construction. Building and Environment. 2001;36(10):1119-1126.

[5] Kéré, Diébédo Francis. School in gando, burkina faso. Architectural Design. 2012;82(6):66-71.

[6] Ibañez, Daniel, Jane Hutton, Kiel Moe, eds. Wood urbanism: from the molecular to the territorial. Actar Publishers; 2019.

[7] Vercruysse E, Kate D, Wyatt A. Foraging for a Field Station. Fabricate. 2024(April 4, 2024);14-21.

[8] Gomaa M, et al. 3D printing system for earth-based construction: Case study of cob. Automation in Construction. 2021;124: 103577.

[9] Morel, Jean-Claude, et al. Building houses with local materials: means to drastically reduce the environmental impact of construction. Building and Environment. 2001;36(10):1119-1126.

[10] Scheurer, Fabian. Digital craftsmanship: from thinking to modeling to building. Digital workflows in architecture. 2012;76.

[11] Tim C, et al. Wild Wood Gridshells: Mixed-Reality Construction of Nonstandard Wood. Technology|Architecture + Design 7. 2023 Jul 3;(2):216-31.

[12] Kaiser R, Ben B, Elise E, Jane S. BioKnit: Development of Mycelium Paste for Use with Permanent Textile Formwork. Frontiers in Bioengineering and Biotechnology. 2023 Jul 14;11.

[13] Rossi A, et al. Upscaling Mycelium-Based Composites Strategies for Biofabrication of Sustainable Building Components. Fabricate. 2024 Apr 4;130-137.