RESEARCH ARTICLE

# User-Centered Design of Architectural Models Adapted to Monolithic Structure Technology

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## Abstract

Monolithic Structure Technology (MST) is a new construction process patented in Morocco, offering significant advantages in terms of durability, resilience, and energy efficiency. This technology enables the mass production of low-rise green buildings thanks to the design of a monolithic metal formwork with a high reuse rate for the bonding of the structure working mainly in compression. Unlike conventional approaches to construction, the architectural design and load-bearing structure are studied simultaneously from the formwork design phase, as the structure mobilizes its form to guarantee stability. The design of architectural models adapted to MST is therefore of paramount importance if we are to exploit the full potential of this innovative technology. In this context, we developed the most suitable designs for MST based on a user-centered approach by directly involving the presumed future operators through a structured questionnaire to identify their preferences.115 respondents were interviewed, and the results were analyzed and used to design 10 different models. We then complemented the design process with a neuro-architectural approach to optimize design factors (facades, levels and rooms, shape and openings, roof type, interior layout, green spaces, and materials). The 10 designed models were then used for a closed card sorting study, followed by another semi-structured interview. User preferences were synthesized and the optimum design for the Moroccan countryside was selected.

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## 1. Introduction

The advent of monolithic structure technology (MST) prompts innovative thinking about construction methods, offering practical, cost-effective solutions while reducing environmental impact. While reinforced concrete has long dominated the construction sector[1], this one-dimensional approach has often had harmful ecological repercussions[2]. However, promising alternatives are emerging, offering sustainable and economically viable solutions for low-rise buildings[3]. With this in mind, MST paves the way for hybrid solutions that integrate traditional materials with modern construction processes, enabling the production of high-value structures. By exploiting materials such as soil, binders, and fibers, MST can be used with fiber-reinforced concrete, offering an ecological and economical alternative to conventional methods[3].

Historically, roofs were built from wood and materials with low tensile strength, such as stone and brick masonry, using shapes such as arches, vaults, and domes to limit shear forces and bending moments.[4][5]. However, these techniques have been abandoned in favor of more modern methods based on reinforced concrete, despite their ecological drawbacks and their limited lifespan due to reinforcement that corrodes over time as a result of carbonation[6]. MST reconciles the advantages of traditional construction, such as ecology and resilience.[7], with the advantages of modern construction processes, such as lower production costs and faster construction rates. This innovative approach paves the way for more sustainable structures while facilitating access to housing for a large low-income population[6].

The present study focuses on the exploration and analysis of different user-oriented design methods and approaches for monolithic structures, with particular emphasis on vaults and domes. We examine how these architectural models can be adapted and optimized to meet the specific requirements of MST while promoting harmonious integration with the needs and preferences of end-users.

In this article, we will describe the methods used for model selection, starting with a series of preliminary questions aimed at understanding basic user preferences. We then turn to the design of architectural models, taking into account both the requirements of monolithic structure technology (MST) and the preferences expressed by users. To refine our design choices, we will implement a card-sorting technique and semi-structured interviews. Finally, we will analyze the results obtained through a qualitative approach and select the final model based on user preferences as well as technical and economic constraints. This model will then be validated to ensure that it complies with MST requirements and meets user expectations.

The article is organized as follows: in the first chapter we'll talk about monolithic architecture and its history, then in the second chapter we'll present the Technology of Monolithic Structures, and finally, in the third chapter we'll develop all the steps involved in designing architectural models suitable for MST.

## 2. An overview of monolithic constructions

Monolithic architecture is architecture made from a single piece. Very few materials allow for this: stone if you take the time to carve the cliff. Other materials may also be suitable (earth in some cases). In stone, there are many spectacular examples: the temples of Abou-Simbel, the temples of Mahäbalipuram, the temples of Kailâsanâtha, and many others[8].

- The Abu Simbel temples (figure 1) are two ancient Egyptian rock-cut temples located near Abu Simbel in southern Egypt[9].

**Figure 1.** *The Abu Simbel temples in the 19th century*[9]. **Alt Text:** Illustration of the famous Abu Simbel temple, with its four colossal statues of Ramses II carved in rock. The statues are partially buried under sand, suggesting a scene of exploration or archaeological excavation. Several people are visible around the site, some observing the statues, others climbing onto the structure. The landscape is desert-like, with sand dunes and rock formations in the background, accentuating the temple's isolation in this historic desert setting.

- Mahabalipuram (figure 2) is a UNESCO World Heritage archaeological site located 50 km south of Chennai. Hindu temples and wall reliefs were carved in Charnockite Precambrian rock during the reign of the Pallava dynasty in the 7th-8th centuries. A few stone masonry temples add to the variety of surviving constructions[10].

**Figure 2.** *The temples of Mahābalipuram*[10]. **Alt Text:** There are several chariot-shaped temples and animal statues, including a lion and an elephant. The temples are carved from granite blocks, decorated with intricate patterns and carvings. The site is bathed in natural light, with little vegetation in the background, creating a serene and historic atmosphere.

- The Kailâsanâtha Temple (figure 3) is part of a group of monasteries and temples located in Ellorâ, Maharashtra, India. It is a complex of buildings covering more than 2 km², carved into the face of a high basalt cliff. Of the 34 monasteries and temples, Kailasa, which occupies cave no. 16, is the best known for its size, architecture, and decoration. It was built by excavating and digging into the cliff. It is a significant example of monolithic architecture

**Figure 3.** *The temples of Kailâsanâtha*[11]. **Alt Text**: A complex carved entirely out of the cliff and featuring several levels of detailed architecture, with columns, sculptures and complex reliefs. The buildings are set into a large rock formation, with imposing walls surrounding the site. In the center, a temple tower rises with ornamental carvings.

Monolithic architecture covers buildings carved, cast or hollowed out of a single piece of material, in historic rock forms. The most basic form of monolithic architecture is a building carved out of rock, such as the monolithic churches of Ethiopia built by the Zagwe dynasty[12], or the Pancha Rathas in India[13]. These are cut from solid rock, to which they remain attached at the base[12][13]. In most cases, this is evident from the remaining surrounding rock, but sometimes a building is cut from an outcrop, as in the Shore Temple in southern India, and only close inspection reveals that the building is monolithic[14].

Buildings with a structural material that is poured in place, most often with concrete, can also be described as monolithic. Extreme examples are monolithic domes, where the material is sprayed inside a form to produce a solid structure. An early example of a monolithic dome is that of Theodoric's mausoleum in Ravenna, Italy, whose roof is a single stone[15].

In concrete, the question is perhaps more delicate, insofar as many constructions are made of superimposed layers of concrete held together by steel reinforcements and generally completed by numerous devices (windows, etc.). Nevertheless, there are a few buildings that contain no materials other than reinforced concrete (or not), with a few almost negligible additions such as a door... For example, Zumthor's Bruder Klaus Field Chapel, a large number of bunkers...[8].

Despite the aesthetics and integration with the environment of traditional monolithic constructions, this type of construction has been abandoned in favor of modern reinforced concrete construction methods, which can meet service and safety requirements at an affordable cost but with a negative impact on the environment[2]. Based on the concept of hybrid construction and to take advantage of modern building methods, Belabid et al[16] have developed an invention called Monolithic Structure Technology, inspired by ancient monolithic structures but incorporating the benefits of modern construction methods.

## 3. Monolithic structure technology: a new construction process

The emergence of monolithic structure technology (MST) represents a major evolution in construction, offering a new building paradigm characterized by its integrated and continuous approach. This section will explore in depth the fundamental principles of MST and its implications for the construction industry[6].

It introduces a new construction technology called "monolithic structures", which aims to build low-rise buildings with low environmental impact and low cost. The technology relies on the use of local low-tensile strength materials, such as earth, lime/cement, and fibers, to create fiber-reinforced concrete. It uses arched frames and vaults to provide structural stability without the need for steel reinforcement (figure 4) Prefabricated monolithic formwork enables rapid construction and multiple reuse[6].

**Figure 4.** *Perspective of a monolithic arched portico building* [6]. **Alt Text:** 3D architectural model of a building with barrel vaults. The building is rectangular in shape, with several continuous arches forming the roof. The walls and vaults are made of earth, giving a traditional appearance. The building is simple, with several arched windows along the sides, and an arched main entrance at the front. The sky in the background is partly cloudy, with soft light streaming through the clouds.

The benefits of this technology include reduced construction costs thanks to material efficiency and formwork reuse, increased building life by eliminating steel corrosion problems, good thermal insulation and fire resistance, and the promotion of sustainable construction with local materials[6].

Limitations of the technology include the fact that it is mainly suitable for low-rise buildings due to structural limitations, that it requires good soil conditions to avoid settlement cracks, and that architectural creativity can be limited by the use of prefabricated formwork and partition walls[6].

Overall, monolithic structures offer a promising approach to low-cost, environmentally-friendly building construction in regions where soil conditions are suitable and the emphasis is on local materials[6].

## 4. Design of architectural models adapted to MST

### 4.1. Preliminary questionnaire: method and results

The questionnaire approach is a systematic method of collecting data from a target group to understand their opinions, behaviors, attitudes, or characteristics[17]. This technique is widely used in social science research, marketing, public health, and many other fields[18].

We designed a detailed questionnaire to gather participants' preferences and opinions[18] regarding desired features for buildings using monolithic structure technology. The questionnaire included questions on aspects such as academic level, budget allocated to the building project, architectural design preferences, preferred roof types, preferred building materials, and other relevant considerations.

The questionnaire was distributed electronically to 115 participants from the Moroccan countryside of Agadir, including students, graduates, and experienced construction professionals. An in-depth analysis of the responses obtained from the questionnaire was carried out to identify trends, majority preferences, and important conclusions on the choice of architectural model suitable for MST. These data were crucial in guiding our study and formulating relevant recommendations for the design and implementation of MST buildings. Table 1 aims to concisely present the main findings of our study, highlighting the dominant trends, majority preferences, and key insights that emerge from the data collected. This information is essential to guide future decisions on the design and construction of MST buildings, proactively addressing the needs and expectations of end-users.

**Table 1.** *Summary of the Preliminary Questionnaire*

| Criteria | Category/Preference | Percentage (%) |
| --- | --- | --- |
| Academic level | Students | 38.6 |
| | Experienced professionals | 28.1 |
| | Graduates | 22 |
| Budget for the construction project | Greater than 300 000 DH | 42.7 |
| | Enter 200 000 and 300 000 DH | 36.5 |
| Design preferences | Building with two visible facades | 57.4 |
| | T4 apartment (4 main rooms) | 47 |
| | T3 apartment | 30.4 |
| | T5 apartment | 20 |
| | Flexible over area | 77 |
| Building shape | Rectangular | 50 |
| | Square | 41 |
| Number of levels | Ground floor+1 | 80 |
| | Simple Ground Floor | 20 |
| Preferred roof types | Mixed vaulted/wood roofs | 34 |
| | Dome roofs | 22.6 |
| | Mixed vault/dome roofs | 21.7 |
| | Mixed vault/wood roofs | 21.7 |
| Preferred building materials | Fiber-reinforced Portland cement concrete | 56.5 |
| | Fiber-reinforced earth concrete | 35.7 |
| Interior design preferences | Homes with patios, green spaces, and large windows | 94 |
| | Rooms with ample space | 78 |
| Preferred partitioning materials | Clay bricks | 39 |
| | Agglos and adobe / compressed earth brick | 19 |
| Environmental concerns | Ready to invest more to minimize environmental impact | 93 |
| | Investment between 0 and 10% of the initial amount | 54 |
| | Investment between 10 and 20% of the initial amount | 35 |

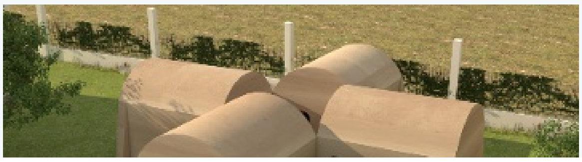
The building chosen on the basis of these criteria would probably be a T4 apartment (4 main rooms) with two visible facades, rectangular in shape, comprising a first floor plus one storey (GF+1). It would mainly use fiber-reinforced Portland cement-based concrete for the construction and clay bricks for the partitioning. The interior design would favor homes with patios, green spaces, and large windows, with a strong focus on environmental impact, indicating a willingness to invest further in sustainable solutions.

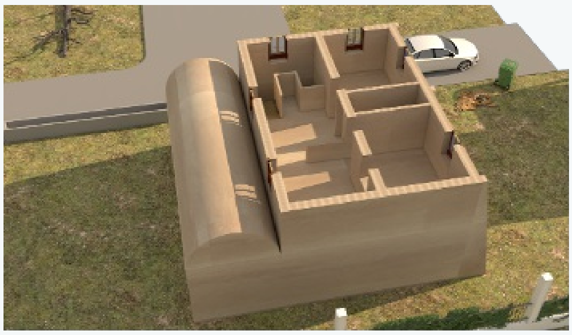
## 4.2. Architectural model designs based on MST requirements and user preferences:

Based on the synthesis of this preliminary questionnaire, taking into account the specific technical requirements of MST and the preferences of the end-users, we proceeded to design 10 architectural models that meet these different criteria.

The majority of preferences identified were incorporated into the designs. For example, the preference for buildings with two visible facades and T4 dwellings influenced the design choices.

**Table 2.** *Illustration of different designs*

| Number | Exterior design | Interior design |
| --- | --- | --- |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| |  |  |

| | | |
|---|---|---|
| 4 |  |  |
| 5 |  |   |
| 6 |  |   |

| | | |
|---|---|---|
| 7 |  |   |
| 8 |  |  |
| 9 |  |  |
| | | |

| | | |
|---|---|---|
| 10 |  |  |

The creation of these ten architectural models (Table 2) reflects a methodical, integrative approach, taking into account both the rigorous technical requirements of MST and the nuanced preferences of users. Each model is designed to offer a unique and tailored solution, meeting the varied needs of users while respecting standards of sustainability, energy efficiency, and regulatory compliance. By integrating user feedback through qualitative and quantitative methods, we have been able to develop architectural models that are aesthetically pleasing, functional, and sustainable.

The design phase of architectural models cannot be limited to the mechanical application of technical requirements and collected preferences. To gain a more nuanced and in-depth understanding of users' needs, and to refine designs in line with their expectations, we used complementary statistical approaches[19], including card sorting and semi-structured interviews[20].

### 4.3. Choice optimization by card-sorting technique and semi-structured interviews

#### a) Card-sorting: results and discussion

The card sorting technique is a method used mainly in UX (user experience) research, and information architecture to understand how people perceive, organize, and categorize information[21]. This qualitative method is also used to explore how users perceive and categorize different aspects of architectural design[22]. This technique is particularly useful for understanding users' preferences, priorities, and mental associations regarding various design elements[21].

There are various kinds of card-sorting methods. First, there is open card-sorting, in which players group the cards into logical categories and assign names to each group. This shows how people identify and understand informational categories. Next is the closed card-sorting, in which participants arrange cards into predetermined groups that the researchers have already established. This is helpful for confirming an existing information structure. The last method is hybrid card-sorting, which combines the two methods. Participants can make their own custom categories if needed, but established categories are also available[21]. We employed the closed card-sorting method for our investigation.

We created cards representing the different designs, numbered from 1 to 10, and presented them to a representative group of users for feedback to determine which design was most appreciated. The 30 card-sorting participants were selected from the respondents to the preliminary questionnaire, ensuring that a diversity of profiles (students, experienced professionals, graduates) was included. During the sorting sessions, each participant was asked to place the cards in the "Likes", "Dislikes" and "Neutral" categories.

Table 3 shows participants' opinions on ten architectural models, based on exterior and interior design. Participants were asked to express whether they liked, disliked, or were neutral towards each design. Here's a summary of the results for each model.

**Table 3.** *Card sorting results*

| Design number | Exterior design | | | Interior design | | |
|---|---|---|---|---|---|---|
| | Like | Dislikes | Neutral | Like | Dislikes | Neutral |
| **1** | 26 | 1 | 3 | 27 | 2 | 1 |
| **2** | 23 | 3 | 4 | 23 | 5 | 2 |
| **3** | 18 | 5 | 7 | 20 | 4 | 6 |
| **4** | 8 | 18 | 4 | 9 | 13 | 8 |
| **5** | 22 | 6 | 2 | 23 | 3 | 4 |
| **6** | 12 | 12 | 6 | 23 | 3 | 4 |
| **7** | 27 | 2 | 1 | 24 | 2 | 4 |
| **8** | 14 | 9 | 7 | 15 | 7 | 8 |
| **9** | 10 | 12 | 8 | 15 | 9 | 6 |
| **10** | 26 | 2 | 2 | 19 | 8 | 3 |

The ten architectural models show variations in terms of popularity and acceptance among participants. Designs 1, 7, and 10 stand out as the most popular overall, while other designs, such as 4, 6, and 9, show more divided opinions. This summary helps us to understand which aspects of the models are the most successful, and which require improvement to better meet user preferences. The optimum design for a ground floor structure is design 1, but if another additional storey is required, design 7 is chosen.

## b) Semi-structured interview: results and discussion

A semi-structured interview is a qualitative data collection method that combines a series of pre-prepared questions with the flexibility to explore topics in depth depending on the participant's responses[23]. This approach allows the interviewer to guide the conversation while leaving room for improvisation and exploration of emerging themes[24]. In a semi-structured interview, the interviewer is given an interview guide containing a list of questions or topics to be addressed. However, the interviewer is also free to ask additional questions or pursue unexpected lines of inquiry. This makes it possible to gather richer, more nuanced data than would be possible in a structured interview.

Tables 4 and 5 shows the different questionnaires submitted to the participants and the responses obtained.

**Table 4.** *Answers on exterior design*

| Question | Answers |
| --- | --- |
| **1. Which of the ten proposals do you prefer most? (1 to 10)** | 5, 1, 7, 1, 2, 2, 7, 10, 10, 1, 7, 7, 7, 7, 1, 10, 3, 10, 7, 1, 1, 1, 7, 2, 7, 1, 7, 10, 10, 6 |
| **Why?** | Design, form, chic, simple, aesthetic, innovative, elegant |
| **2. Which exterior design elements do you consider most important? (Check all that apply)** | Aesthetics: 26<br>General form: 10<br>Textures: 3<br>Facades: 19<br>Roofs: 4<br>Integration with the environment: 12 |
| **3. What architectural styles do you prefer for exterior design? (Check all that apply)** | Modern: 24<br>Classic: 21<br>Minimalist: 4<br>Rustic: 2<br>Industrial: 1 |
| **4. Which facade features do you find most attractive? (Check all that apply)** | Natural materials: 22<br>Bright colors: 4<br>Neutral colors: 18<br>Varied textures: 8 |
| **5. What exterior features (balconies, terraces, windows) do you consider essential?** | Balconies: 6<br>Terraces: 26<br>Windows: 26 |
| **6. What elements or aspects of the exterior design do you find most problematic?** | Form, Openings, Design, door, stability, terrace, street window |
| **7. Do you have any suggestions for improving the exterior design of buildings?** | Simplicity, water entering windows when it rains, more rectilinear shape |
| **8. Which of the ten proposals do you like least? (1 to 10)** | 4, 4, 4, 4, 6, 9, 9, 5, 9, 9, 4, 3, 4, 6, 9, 8, 4, 6, 9, 4, 4, 9, 8, 4, 6, 9, 4, 9, 4, 2 |
| **Why?** | Form, simplistic, facade, circular shape |

**Table 5.** *Interior design answers*

| Question | Answers |
|---|---|
| **1. Which of the ten proposals do you prefer most?** | 1, 1, 1, 7, 3, 2, 10, 7, 4, 7, 1, 5, 7, 8, 5, 7, 10, 7, 1, 2, 7, 10, 1, 1, 10, 7, 1, 10, 2, 5 |
| **Why?** | Realistic, spacious, layout, functionality, location of rooms, interior layout, modern, simplistic |
| **2. What interior design elements do you consider most important? (Check all that apply)** | Aesthetics: 18<br>Functionality: 12<br>Comfort: 19<br>Ergonomics: 3 |
| **3. What interior design styles do you prefer? (Check all that apply)** | Modern: 17<br>Classic: 15<br>Minimalist: 7<br>Rustic: 2<br>Industrial: 2 |
| **4. Which interior design features do you find most attractive? (Check all that apply)** | Natural materials: 19<br>Modern materials: 5<br>Bright colors: 7<br>Neutral colors: 11<br>Varied textures: 3<br>Natural lighting: 20 |
| **5. Which interior design features are most important for your comfort?** | Thermal insulation: 16<br>Acoustic insulation: 5<br>Light: 16<br>Ventilation: 10 |
| **6. Are there any specific elements that you find problematic in the interiors of these structures?** | Distribution of spaces, restricted spaces, open spaces, complexity, space, wall circular part, posts, beams, fallout |
| **7. Do you have any suggestions for improving the interior design?** | Minimize the number of walls, natural colors |
| **8. Which of the ten proposals do you like least? (1 to 10)** | 4, 2, 4, 9, 6, 9, 2, 4, 4, 2, 6, 4, 9, 6, 2, 10, 4, 9, 8, 2, 4, 9, 3, 2, 8, 10, 9, 4, 2, 10 |
| **Why?** | Small spaces, patio, spacing, unattractive, room layout |

An analysis of exterior design preferences reveals marked trends. Proposals 1 and 7 are the most popular, with 8 and 10 votes respectively, due to aesthetic criteria and simplicity. Proposals 10 and 2 are also popular. Aesthetics (26) and facades (19) are the most valued elements, while modern and classic styles dominate preferences. Natural materials are highly prized (22), as are neutral versus bright colors. Terraces and windows are considered essential by all respondents

(26 each), with balconies also important (6). The main problems identified include shape, openings, design, stability, terraces, and street-facing windows. Suggestions for improvement focus on simplicity, watertightness of windows, and more rectilinear shapes. Proposal 4 is the least appreciated (11 times), followed by proposals 9 and 6 (9 and 6 times respectively), due to problems with shape, simplicity, and the circular facade.

Analysis of the interior design reveals clear preferences and priorities among respondents. Proposals 1 and 7 are the most popular, each receiving 8 votes, mainly due to their clarity, functionality, and modern style. Comfort (19 votes) and aesthetics (18 votes) are the most valued aspects, while functionality, although important, is less of a priority, and ergonomics is given low priority. Modern and classic styles are the most popular, contrasting with the low interest in minimalist, rustic, and industrial styles. Natural lighting (20 votes) and natural materials (19 votes) are highly appreciated, and neutral colors are preferred to bright ones. In terms of comfort, thermal insulation, and luminosity are considered essential, with ventilation also important but less of a priority. The main problems identified concern the distribution of spaces, as well as certain structural elements such as posts and beams. Suggestions for improvement focus on simplifying the space and using natural colors. At the other end of the scale, proposal 4 is the least appreciated (8 votes), followed by proposal 9 (6 votes), mainly due to small spaces, the patio, spacing, and lack of aesthetics.

This semi-structured interview process yielded rich, detailed data, providing an in-depth understanding of participants' interior and exterior design preferences. They expressed a clear preference for simple, functional designs that blend harmoniously into the natural environment. Based on these results, practical recommendations and design guidelines were formulated, including the use of eco-friendly materials, the adaptation of designs to local climatic conditions, and the promotion of construction techniques that minimize the ecological footprint, while meeting the aesthetic and functional needs of future users.

The findings of the preliminary questionnaire show a strong preference for rectangular architectural models and the use of materials such as fiber-reinforced concrete and clay bricks. The results obtained using card-sorting techniques and semi-structured interviews highlight interesting similarities and differences in the understanding of participants' preferences with regard to interior and exterior design. Using card-sorting, it was possible to categorize the design elements according to their perceived importance to the users, giving a global view of the group's priorities. Meanwhile, the semi-structured interviews provided more in-depth and specific information, opening up the possibility of analyzing the motivations and justifications behind the participants' decisions.

Both methods tend to adopt simple and functional designs, however, the semi-structured interviews highlighted additional aspects, such as functionality, aesthetics, architectural style, interior space arrangement, opening characteristics, natural ventilation, thermal and acoustic insulation. The results of the two methods are complementary, which reinforces the soundness of the final recommendations and highlights the importance of combining quantitative and qualitative approaches in order to fully understand users' needs.

## 5. Conclusion

The results of our methodological research show that users prefer rectangular architectural models, mainly made of fiber-reinforced concrete and clay bricks. These materials, combined with appropriate installation techniques, create structures that are aesthetically pleasing, functional, and durable.

The optimum design chosen is Design 1 (Table 2), which favors simple, uncluttered forms that encourage natural ventilation and lighting, while being robust and durable. Adapting designs to local climatic conditions, with appropriate orientation to maximize energy efficiency, is crucial.

In addition, MST stands out for its ability to reduce the ecological footprint of construction, by favoring the use of natural materials and minimizing the need for high-gray-energy materials such as reinforced concrete[2]. Simplifying construction techniques also reduces labor costs and makes these methods accessible to a larger number of people, particularly in rural and semi-urban areas.

This in-depth analysis of the design of architectural models adapted to Monolithic Structure Technology (MST) highlights the crucial importance of the user-centered approach in the design process. We have demonstrated that vaults and domes offer viable and aesthetically appealing architectural solutions for monolithic structures while meeting the criteria of sustainability, structural performance, and contextual integration. MST also offers a viable and sustainable solution for construction, combining the advantages of old techniques with modern requirements, while being environmentally friendly and economically accessible.

## Statements and Declarations

### Funding

None.

### Conflict of Interest

The authors declare no conflict of interest, financial or otherwise.

### Data Availability

The authors confirm that the data supporting the findings of this study are available within the article. Raw data that support the findings of this study are available from the corresponding author, upon reasonable request.

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## References


1. ^Guillerme A. "Techniques Et Matériaux de construction XIXE-XX siecle, une introduction." Hist Technol. 7 (3–4): 165–178, Jul. 1991. doi:10.1080/07341519108581775.
2. a, b, cJonathan Watts. "Concrete: the most destructive material on Earth." The Guardian.
3. a, bBelabid A, Elminor H, Akhzouz H. "The Concept of Hybrid Construction Technology: State of the Art and Future Prospects." Future Cities and Environment. 8 (1), Dec. 2022. doi:10.5334/fce.159.
4. ^IKO. "Les toitures des cultures anciennes." https://www.iko.com/blog/fr/ancient-roofs/#Importance. Accessed: May 04, 2024.
5. ^Antonelli A, Desodt C, Molinard HH. "Conception et constructions des arcs." ENS de Paris, 2016.
6. a, b, c, d, e, f, g, hBelabid A, Akhzouz H, Elminor H, Elminor H. "Monolithic Structure Technology: A New Construction Process to Enhance Traditional Construction." International Journal of Sustainable Construction Engineering and Technology. 14 (1), Feb. 2023. doi:10.30880/ijscet.2023.14.01.005.
7. ^Schweiker M, et al. "Ten questions concerning the potential of digital production and new technologies for contemporary earthen constructions." Build Environ. 206: 108240, Dec. 2021. doi:10.1016/j.buildenv.2021.108240.
8. a, bBéral R. "Qu'est-ce qu'une architecture monolithique?" Quora. Accessed: May 22, 2024. [Online]. Available: https://fr.quora.com/Quest-ce-quune-architecture-monolithique.
9. a, bÉnel T, Héry F-X. Le secret d'Abou Simbel: Le chef-d'œuvre de Ramsès II décrypté. FeniXX, 1996.
10. a, bKázmér M, Prizomwala S, Gaidzik K. "8th century coastal uplift in Peninsular India – The Shore Temple at Mahabalipuram, Tamil Nadu." Quaternary International. 638–639: 140–147, Nov. 2022. doi:10.1016/j.quaint.2022.02.014.
11. ^Burgess J. "The Temple of Kailâsanâtha." Journal of the Royal Asiatic Society of Great Britain & Ireland. 23 (2): 337–337, Apr. 1891. doi:10.1017/S0035869X00156928.
12. a, bLepage C. "L'église rupestre de Berakit." Annales d'Ethiopie. 9 (1): 147–191, 1972. doi:10.3406/ethio.1972.897.
13. a, bAhmed S. "Pancha rathas, the five stone temples of the Mahabalipuram site." Paranoá: cadernos de arquitetura e urbanismo. (28): 1–27, Sep. 2020. doi:10.18830/issn.1679-0944.n28.2020.07.
14. ^Smith W. "The Visnu Image in the Shore Temple at Mamallapuram." Artibus Asiae. 56 (1/2): 19, 1996. doi:10.2307/3250103.
15. ^Lewis B. "The Antiquities of Ravenna." Archaeological Journal. 32 (1): 417–431, Jan. 1875. doi:10.1080/00665983.1875.10851688.
16. ^Belabid A, Akhzouz H, Elminor H, Elminor H. "Procédé de construction à base de la technologie des structures monolithiques." MA 59020 A1, Jun. 28, 2022. Accessed: Jul. 05, 2024. [Online]. Available: http://patent.ompic.ma/publication-server/pdf-document?PN=MA59020%20MA%2059020&iDocId=20704&iepatch=.pdf.

17. ^*Fowler FJ Jr. Survey research methods. Sage publications, 2013.*
18. a, b*Bryman A. Social research methods. Oxford university press, 2016. Accessed: Jul. 06, 2024. [Online]. Available: https://books.google.co.ma/books?hl=fr&lr=&id=N2zQCgAAQBAJ&oi=fnd&pg=PP1&dq=Bryman,+A.+(2016).+Social+Research+Methods.+Oxford+University+Press.&ots=dqKrEXIbtk&sig=Y6R-w9lWk6xAS2UoJnHOZq5yaHE&redir_esc=y#v=onepage&q=Bryman%2C%20A.%20(2016).%20Social%20Research%20Methods.%20Oxford%20University%20Press.&f=false.*
19. ^*Creswell JW, Creswell JD. Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications, 2017.*
20. ^*Merriam SB, Tisdell EJ. Qualitative research: A guide to design and implementation. John Wiley & Sons, 2015.*
21. a, b, c*Warfel T, Maurer D. "Card sorting: a definitive guide." Boxes and arrows, 2004.*
22. ^*Spencer D. Card sorting: Designing usable categories. Rosenfeld Media, 2009.*
23. ^*Galletta A. Mastering the semi-structured interview and beyond: From research design to analysis and publication. 18. NYU press, 2013.*
24. ^*Seidman I. Interviewing as qualitative research: A guide for researchers in education and the social sciences. Teachers college press, 2006.*