

# Thin Vaulted Tile Structure as a Sustainable Slab

Pradipta Kumar Brahma, Mukesh Pandey, Sohit Agarwal, Farhan Rahman

**Abstract:** The concept of sustainability for roof structure becomes most effective because slab consumes the highest amount of cement and steel in the building. This increases carbon footprint, which is a measure of the impact caused by the utilization of natural resources, eventually affecting the earth, and it becomes a subject of higher cost also. The objective of the paper is to find a safe, economical and sustainable roofing structure suitable for suburban and rural settlements. The literature survey carried out deeply and the potential is observed in tile vaulted structures. The core reasons behind adopting a vaulted structure are, it avoids using steel and concrete materials in construction, utilizes local labour, and low-cost local materials for construction. This predominantly becomes the primary factor in deciding the construction of an economical roofing structure for multiple dwelling units in rural and suburban settlements to provide a safe, sustainable and maintenance-free roofing system using tile vaulted structure.

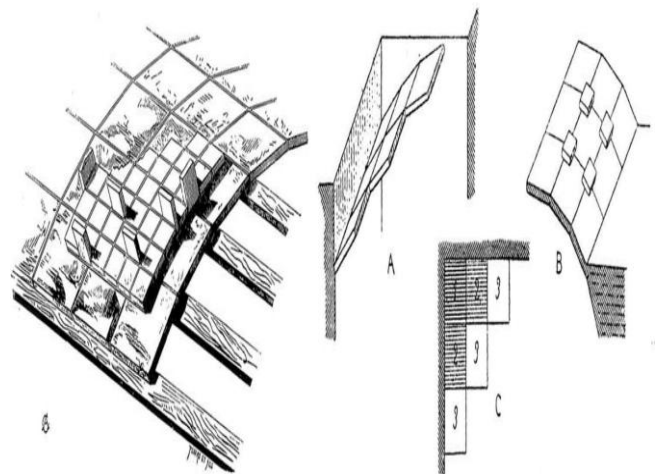
**Keywords:** Carbon footprint, Economical, Slab, Sustainability, Tile vaulted structure.

## I. INTRODUCTION

Progress is inevitable in the 21<sup>st</sup> century due to access to all the research data, and as seen the infrastructure industry is rising at tremendous rates. But with all the cement tones and edible metal, we are leaving the carbon footprint, a measure of the impact that natural resources have on the environment, ultimately affecting the world. It may be difficult for a person to access these types of engineering in any other form of construction, but we can develop methods that are not only environmentally friendly but something that will reduce the cost of building both financially and economically. In 1891, Rafael Guastavino Moreno (Guastavino Sr., 1842-1908) patented the

American barrel tile as a permanent layer of certain layers of brick or concrete as shown in Figure 1 and Figure 2 [1]. At this point, it is quite suitable to introduce vaulted structures, a primitive building technology used by man a long time ago [2]. The proposed tile vaulting construction technique uses an unreinforced masonry construction method, a 600 years old tradition from the Mediterranean region. Also known as the timber vaulting, this age-old construction technology uses thin bricks to create

lightweight and durable roofing systems. The structural principle on which tile vaulting is based is form-finding [3]. These thin unreinforced masonry shells act in pure compression. Traditional timber vaulting, using local tiles or bricks, can be built without extensive formwork. This merging of novel structural geometry with the traditional craft has resulted in an extremely efficient and low-cost roofing solution [1] [2].



**Fig.1 Roman technique to build vaults. (Left) with wooden planks as centering (Choisy 1873); (right) "in space" (Choisy 1899) [3]**



**Fig.2 tile vaults with filling material. (left) descriptive drawings by choisy (1873); (right) guastavino rib and dome system [3].**

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## II. MATERIALS USED

### a) Burnt Bricks

Burnt bricks of non-modular size were used for the construction of the brick walls. These brick walls were acting as edge beams for the vaulted structure. The dimensions of the bricks were 230 mm × 110 mm × 70 mm. The bricks were soaked in water for about an hour before being used for masonry work.

### b) Cement Mortar

The grade of cement used for cement mortar is M53. Design mix of cement mortar was taken as 1:3, i.e. 3 volumes of cement were mixed with 1 volume of sand. Enough mortar was prepared such that the mortar requirement for construction for the next 30 minutes will be satisfied.

### c) Superplasticizer admixture

Superplasticizer admixture is used in cement mortar primarily to increase the workability of the mix. Along with an increase in workability, Superplasticizer also helps in increasing strength and reduces bleeding and segregation.

### d) Burnt clay tiles

Burnt clay tiles are used for the construction of the vault. The dimensions of the tiles used for construction are 140 mm × 140 mm × 16 mm. These bricks have very low compressive strength (< 5 N/mm<sup>2</sup>). The clay tiles have been obtained from local suppliers proving its availability in the vicinity of construction site.

## III. LITERATURE SURVEY

**Ann Katharine Malkovich et al.** [4] The success of the integrated construction plans developed by the Guastavino Fireproof Construction Company can be measured in a number of ways, from their technical growth to the rigidity of the system to the aesthetics. Collective design has a history of working with materials, capitalizing the complete power of order. After careful study of this tradition, the Guastavinos' began their experiments with various types of mortar and tiles to create a modern integrated building system.

**Catherine De Wolf et al.** [1] This study shows that most of the material is on the roof and floor, not on the walls and columns. Therefore, the first strategy to minimize the impact would be to reduce their material value on the building and under the roof. With the second plan, some learning material is learned. The vaulted composite structures combine both techniques: effective vault space gaps and cohesiveness have lower composite impact than steel and concrete. The results show that the combination of both strategies effectively lowers the structural carbon: the average base and roof range from 440 kg CO<sub>2</sub> e/ m<sup>2</sup> and the tile composition of the tile can be as low as 60 kg CO<sub>2</sub> e/ m<sup>2</sup>.

**Domènech Rodríguez et al.** [2] This paper presents the result of research aimed at understanding the functionality of materials, reconstruction processes and the structural behavior of a traditional method that has provided countless examples of architectural heritage and can in itself be considered a cultural value and heritage to be preserved: Tile repair.

**Mariana Palumbo Fernández et al.** [3] The "Brick-topia" project was established on a consolidation of recent structural analysis and tools to find forms with traditional, low-cost, and efficient construction techniques. It is the result of innovations fighting budget and time. The commencing allocation was around 3000 euros and for seven weeks it was time to look out for sponsors, designing of structure, and plan stages of construction. The whole process of design, decision on resources, analysis done and construction is presented on paper, including exploring new ways to get the project back for researching a new system that works using scarves, cardboard, wire and metal rods and cutting as a primary tool.

**David Lopez et al.** [5] This document reviews different examples of tile plastering that is combined with concrete and / or reinforced in the past, demonstrates their successful results and gives an idea of how their authors deal with the analysis and design of the building.

**Philippe Block et al.** [6] This paper discusses the power of tile systems to provide sustainable and affordable construction in Africa, based on both academic and practical experience. This proposed cooling system has the potential to meet three main objectives: to provide a sound environment-based solution, to bring social cohesion and pride to local communities through traditional means, and to stimulate economic growth by providing local services, while reducing dependency on imported materials.

**Matthias Rippmann et al.** [7] This paper presents research into the design of freeform, multi-vaulting tiles, characterized by a comprehensive process and application of the extended paper interface system. This sophisticated formulation is enabled by the analysis of Thrust Network Anal (TNA) - a three-dimensional novel design tool for testing pleasurable form. These free-form shells present new challenges in typing patterns, structure sequences and in particular structural stability and guide function during construction.

## IV. CONCLUSION

Tile Vaulting is a primitive form of roofing structure used from medieval times. Taking tile vaulted structure and when applied in a real-life scenario, it can be an economical and sustainable replacement of conventional roofing structures in rural and suburban dwelling units [6]. Considering its low cost, use of local materials and labors and maintenance-free characteristics, vaulted structures can be utilized in places such as slums as well as multiple housing units in underdeveloped and developing countries [7].

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