

Earthship

The reuse of waste materials in construction

¹Asita Datla, ²Vempati Sai Pujitha, ³Gaurab Das Mahapatra

^{1,2}Post-graduate Student in Master of Architecture (Sustainable), ³Assistant Professor.

^{1,2,3}School of Architecture,

^{1,2,3}GITAM (deemed to be) University, Visakhapatnam, India

Abstract : This paper aims to study the concept Earthships and emphasizes on the usage of recycled materials in its construction. An Earthship is a type of passive solar house which is made of recycled can, bottles and reused car tires. It gives an overview of its meaning and its principles as well as a perspective on how Recycled materials are used in its constructed. There is a rising burden of carbon emissions from the construction industry, with 40% of the worldwide energy usage coming from it. The main objective of this paper is to identify the use of recycled materials in construction of Earthships. This paper concludes that through a wareness and understanding of the use of recyclable and reusable materials in the field of architecture as a substitute for conventional brick by the architects can aid in reduction the amount of inorganic materials that end-up in landfills while reducing CO₂ emissions and manufacturing costs.

IndexTerms - Earthship, Recycled material, Construction, Sustainable habitats.

I. INTRODUCTION

Environmental deterioration has captured the world's attention and has been one of the most discussed subjects locally, nationally and globally (Bentivegna V., 2002). The construction industry contributes to 40% of energy consumption in the world. In 2011, 336 million tons of cement was produced in the country. It was found that 1 ton of cement emitted about 0.719 tons of carbon dioxide. This contributes to 7% of India's total man-made carbon dioxide emissions (Mishra). If there isn't any change in the consumption of the construction materials around the world then by the year 2050 the production of the cement in the world could reach 3.5 billion metric tons. The methodology process of this paper is given in Fig.1.1.

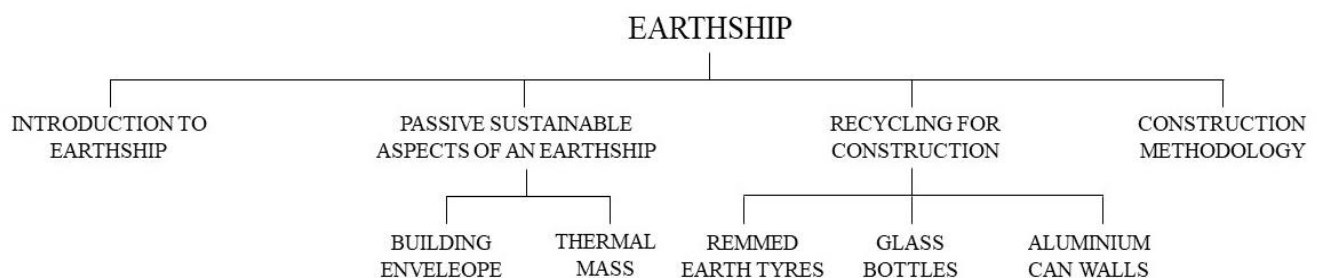


Figure 1.1: Methodology of Earthship: Reuse of waste materials in construction.

1.1 Earthship

Earth ship is a type of passive solar house made of natural and recycled or up-cycled materials. The concept of Earthship was created by Michael Reynolds, an architect, in the early 1970s. As he said in his book Earthship is “a self-contained vessel capable of sustaining an environment for human habitat on its own, through its own interfacing with natural phenomena” (Reynolds, 1990). These homes are primarily constructed to work as autonomous buildings and are generally made of earth-filled tires, using thermal mass construction to naturally regulate indoor temperature. Earthships are usually off-the-grid homes that are constructed in a way that they make optimum usage of local and naturally available resources such as solar energy and cross ventilation creating comfortable dwellings through passive techniques.

1.2 Off-grid Housing

The term off-the-grid refers to self-sufficient way of living which in the context of housing refers to a dwelling that doesn't rely on any public utilities or services such as municipal water, electricity from the power grid and other such services. In other terms a dwelling that is able to provide itself with electricity, water and other utilities with help of natural sources such as rainwater harvesting and solar power.

II. PASSIVE SUSTAINABLE ASPECTS OF AN EARTHSHIP

2.1 Building Orientation

The orientation of the building to be made from North to South direction for the Indian condition and this orientation is done for the reason that the rays of the sun from east falls inclined on the building and then it comes to the upright position and then descend to the west. (Blue Rock Station, 2019) So, this provides the complete light to the building until the daylight ends. This helps in power saving in the daylight hours and the solar panels can be installed to absorb the solar energy for heating and lighting process in the building.

2.2 Thermal Mass

India is considered to have the climatic condition for all sorts of agricultural, industrial and economic growth. The average temperature in India is about 38 degree Celsius. (Blue Rock Station, 2019) The rammed earth tyres that are used for major stretch of the walls act as thermal mass and help in achieving comfortable indoor temperatures.

III. RECYCLED MATERIALS IN AN EARTHSHIP

One of the greatest advantages of Earthship construction is the use of recycled materials. The main materials used in construction of an Earthship are tires, bottles and cans. The foundation of an Earthship is laid with old vehicle tyres that are filled with dirt or soil. The soil is compressed into the tyre in a way that it acts as a strong solid and dense brick. Three of the facades of a typical Earthship are comprised of these rammed earth tyre walls which not only act as support for the home roofing system but also act as thermal mass of the structure. Interior and decorative walls are often built using bottles and cans instead of the typical brick materials. This integrated matrix of concrete and recycled materials reduces the total amount of mortar that is needed and can also provide a great decorative element.

3.1 Rammed-Earth Tyres

Rammed earth tyre walls are used in the Earthship. The combination of tyre walls and the earth compacted in them soak up heat during the day and radiate heat at night acting as thermal mass, ensuring comfortable indoor temperatures naturally throughout the year. Thus reducing the need for heating or cooling devices, which contribute in CO₂ emissions.



Figure 3.1: Construction using Rammed Earth Tyres (Earthship Karuna, 2007)

3.2 Aluminum cans and Glass bottles

The construction of the earth ship walls can be done with the old aluminium tins and by mixing along with cement or mud. The mud a mixture of sifted clay, sand and a bit straw and water. Then a few bits of plaster lathe is nailed to the wood frame to help anchoring the can wall. A layer of mud is laid and the aluminium cans are pressed into it. This process is repeated filling mud between and above the aluminium cans. A small dimple is made in the middle of the can, so it is no longer perfectly round, so that the can cannot be popped out of the dried wall. At the appropriate level, the lathe is pressed into the mud anchoring the wall. Only a few courses can be done before it begins to feel a bit unstable, at this point the wall is left to dry before continuing. After the wall is built and it is dried out, the exterior finish is begun.



Figure 3.2: Construction of wall using Plastic Bottles (Earthship Karuna, 2007)

IV. ADVANTAGES AND DISADVANTAGES OF AN EARTHSHIP

4.1 Potential Advantages

It is very beneficial to have an earth-bermed home which is having windows facing sun where the heat gain is required. The rainwater will be collected from the roofs which will reduce the runoff impact of the building. By using the plant beds for runoff water, grey water, and black water will help in reducing the environmental impact of the building. By using the rubber tires we can avoid landfills and also to prevent them from being burnt illegally. The structure can be modified to different aesthetical tastes.

4.2 Potential Disadvantages

The sloped glazing may be difficult to keep watertight where as in warm climates it will allow excessive solar gain in summer. Where as in colder climates, the glazing with poor insulation may tend to heat loss in winter. Rubber-tire walls may lead to lack structural stiffness and it may require perpendicular stiffening ribs. Ramming dirt and mud inside the tire will require more labor.

V. CASE STUDY OF A RELATED PROJECT: EARTHSHIP KARUNA

5.1 Introduction

Earthship Karuna is a luxury home with an extremely low carbon footprint for the build process and an even lower environmental impact over the decades of the life of the building. The purpose behind making of this Earthship is to demonstrate the possibility of creating an aesthetically pleasing home which can be green and sustainable in all aspects. (Earthship Karuna, 2007) While there are many sustainable aspects that can be plugged into a conventional built, an Earthship is considered to be a complete approach towards sustainable living.



Figure 5.1: View of Earthship Karuna (Earthship Karuna, 2007)

5.2 Construction Method

A circular or U-shaped layout for the outer walls are marked on site. The first layer of tyres are lied side by side along the marked line. The insides of the tyres are filled with earth and rammed with hammers until the tyres are firmly packed with soil and are formed into solid bricks. Attention has to be paid to levelling of all the tyres. Once the first layer is uniformly done a second layer of tyres are laid in a staggered, on top of the first layer. These steps are repeated till the walls have reached the desired height. Voids if any are filled with empty pop cans/ glass bottles and cover the tire walls, inside and out, with mud adobe, cement or stucco to create a smooth finished surface. The roof can be made with log beams or traditional trusses or even domed shaped with rebar that is wired together and covered with chicken wire and cement. In this case study the roof is done with wood and has sky light in the centre. A typical Earthship however has a skylight/vent to the rear side of it for regulating the internal temperatures and in the front has a sloped greenhouse wall built on a low wall and includes a large planter box on the inside. The glazing is done using recycled sliding glass door panels or other similar materials. An entrance door is built at either end of the greenhouse hallway. Any interior walls are constructed of cement and pop can matrix that is covered by an adobe finish. The planter boxes are also built using aluminium cans and cement. The house systems include a rain water catchment cistern, a battery banks, solar panels, power inverter and a composting toilet. The kitchen waste water is filtered via the green house planters which grow fresh vegetables year-round. Finishing touches include tile or flagstone floors, glass bottle accent windows and wood inlays. Two story designs can include spiral staircases and just about any kind of custom design you can imagine.

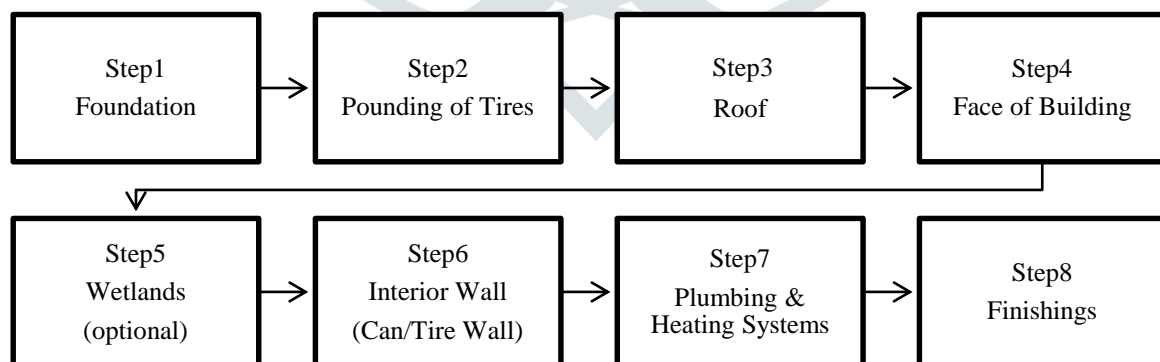


Figure 5.2: Flow Chart showing the Stages of Construction in an Earthship. (Earthship Karuna, 2007)

VI. COMPARISON BETWEEN CONVENTIONAL AND REUSABLE BUILDING MATERIALS

Table 6.1: Difference between conventional reused materials.

Conventional Building Materials	Reusable Building Materials
1) Bricks: Embodied Energy MJ/kg: 3 Carbon Kg CO₂ per Kg: 0.24 Density kg/m³: 1700	1) Aluminium: Embodied Energy MJ/kg: 23.0 Density kg/m³: 2750
2) Cement (1:1.5:3): Embodied Energy MJ/kg: 1.11 Carbon Kg CO₂ per Kg: 0.159 Density kg/m³: 2400	2) Glass: Embodied Energy MJ/kg: 15 Carbon Kg CO₂ per Kg: 0.72 Density kg/m³: 2500

Table 6.1 shows the comparison of embodied energy and densities of both conventional materials and the materials reused in construction of earthships during initial manufacturing of the materials.

VII. CONCLUSION

Earthships are a perfect example of off-grid housing and how a beautiful building can be constructed without the use of conventional materials or construction techniques. It takes almost zero energy for the manufacturing of the construction material as they are mostly local, reused, recycled or up-cycled materials. The construction process requires minimal energy and it also depends on renewable energy sources during occupancy. Hence, Earthships have a low environmental impact throughout its life cycle to that of a conventional building. They also aid in the reduction of inorganic waste being dumped in landfills during its construction and organic waste during occupation.

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