



Design And Development Of Sustainable Portable Homes Powered By Solar Energy And Resistant To Earthquake

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Abstract

The growing intensity of earthquakes and floods, coupled with rapid urbanization, climate change, and increasing energy demands, has highlighted the need for housing systems that are resilient, sustainable, and rapidly deployable. This study presents the design and performance evaluation of a modular, lightweight portable housing system based on prefabricated steel framing, selected for its high strength to weight ratio, ductility, durability, and recyclability. The modular construction approach enables rapid fabrication, transportation, and on site assembly while ensuring structural reliability and adaptability to diverse environmental conditions. Seismic resistance is enhanced through base isolation techniques that reduce force transmission to the superstructure, while flood resilience is achieved using a hydraulic jack based elevation mechanism that safeguards habitable spaces during inundation. Energy sustainability is addressed through the integration of rooftop solar photovoltaic systems, enabling off-grid operation and reduced dependence on conventional energy sources. The incorporation of lightweight sandwich panels further improves thermal performance and reduces dead load, while additional features such as rainwater harvesting enhance resource efficiency. The proposed system demonstrates a practical and sustainable housing solution suitable for disaster prone regions, emergency shelters, and long-term resilient infrastructure development.

Keywords: Portable housing, Steel frame structure, Disaster resilient design, Solar photovoltaic system

1.Introduction

The increasing impacts of climate change, rapid population growth, and unplanned urbanization have intensified the vulnerability of communities to natural disasters such as earthquakes and floods, particularly in developing and disaster prone regions where conventional housing systems remain resource intensive, time consuming, and structurally inadequate. In response, this study proposes the design and development of a sustainable, portable housing system that integrates disaster resilience, renewable energy utilization, and efficient resource management. The proposed housing unit is a modular, lightweight, and

transportable steel framed structure, selected for its high strength to weight ratio, ductility, durability, and suitability for prefabrication, making it effective under seismic loading conditions. Lightweight sandwich panels are employed for walls to reduce dead load while enhancing thermal and acoustic performance and overall energy efficiency. Earthquake resistance is achieved through a cost effective tire based base isolation system, with each tire resting on a separate isolated foundation to dissipate seismic energy and reduce force transmission to the superstructure. Flood resilience is ensured by a hydraulic jack based lifting mechanism that elevates the structure above anticipated flood levels, protecting habitable spaces and critical components. Energy sustainability is addressed through rooftop solar photovoltaic panels that enable off-grid operation and ensure uninterrupted power supply during emergencies. Water sustainability is enhanced through rainwater harvesting, roof based filtration, and grey water recycling systems, while an integrated waste management system promotes environmentally responsible waste handling. Additionally, a GPS based monitoring system supports emergency coordination and disaster response. Overall, the proposed portable housing system offers a eco-friendly, and disaster resilient solution suitable for emergency shelters, temporary settlements, and long-term housing in earthquake and flood prone regions.

2.Methodology

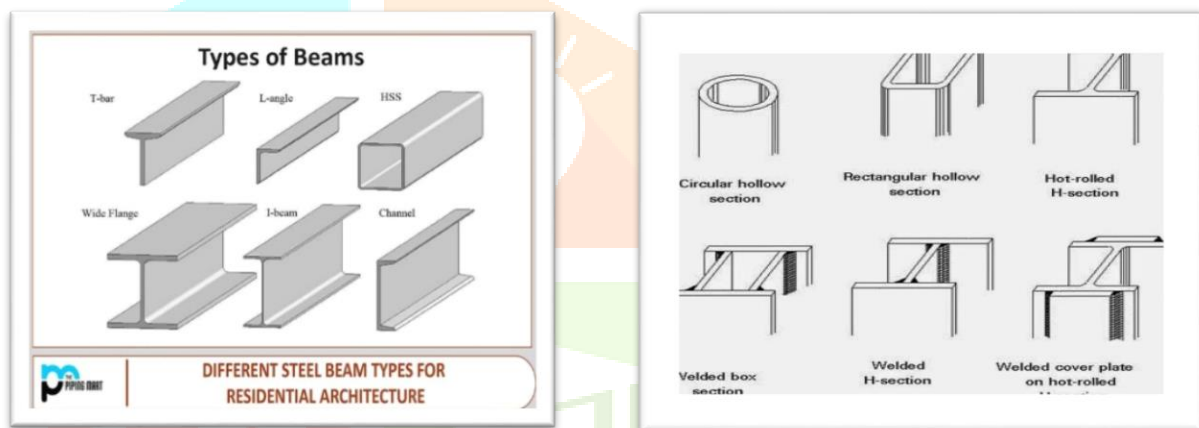
The methodology adopted for the project titled “Design and Development of Sustainable Portable Homes Powered by Solar Energy and Resistant to Earthquake and Flood” follows a systematic and multidisciplinary approach integrating structural engineering, sustainability, and disaster resilience principles. It begins with a comprehensive literature review and problem identification phase, where existing studies on disaster-resilient housing, portable structures, seismic resistance techniques, flood mitigation systems, and renewable energy integration are analyzed to identify suitable materials, technologies, and research gaps, thereby defining clear project objectives. Based on these findings, a conceptual design is developed for a lightweight steel-framed portable house that ensures improved seismic performance, ease of transportation, and rapid installation, while incorporating essential systems such as foundation design, solar energy generation, rainwater harvesting, and waste management. The structural design focuses on steel components like beams, columns, and bracing systems due to their high strength-to-weight ratio and ductility, enhancing earthquake resistance. Additionally, a base isolation system using rubber tyres is introduced, where tyres placed in concrete footings act as flexible isolators to absorb and dissipate seismic energy, reducing vibration transfer to the structure. Flood resilience is achieved through an adaptive foundation equipped with hydraulic jacks that elevate the structure during rising water levels, preventing flood damage. Sustainability is further ensured by integrating rooftop solar panels with possible battery storage for continuous power supply, along with a rainwater harvesting system that collects, stores, and filters water for domestic use, and an eco-friendly waste management system incorporating segregation and composting. Following the design stage, fabrication and assembly of the prototype are carried out, including installation of all structural and functional components. The developed model is then subjected to testing and performance evaluation to assess structural stability, earthquake resistance, flood protection capability, and efficiency of sustainable systems. Finally, the results are analyzed and documented to evaluate feasibility, identify advantages and limitations, and suggest potential improvements, thereby validating the effectiveness of the proposed sustainable portable housing solution.

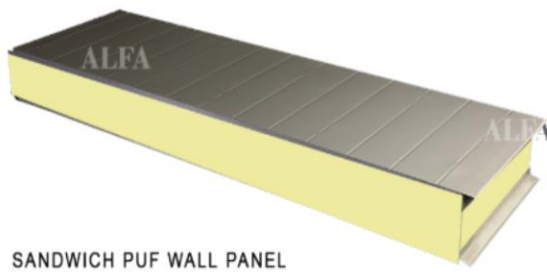
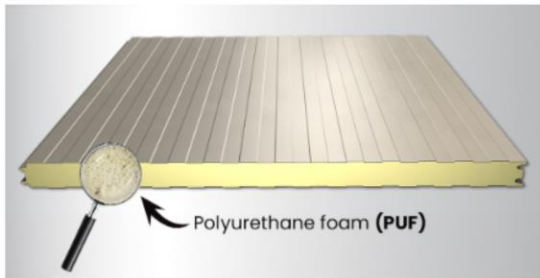
2.1.Materials

The proposed sustainable portable housing system utilizes a high strength structural steel framework to achieve durability, rapid construction, and superior disaster resistance. Steel columns in I, H, box, and circular hollow sections (CHS) are adopted to provide high load-carrying capacity and enhanced seismic performance; I and H sections effectively resist combined axial and bending forces, box sections improve torsional rigidity, and CHS sections offer uniform stress distribution that reduces stress concentration during earthquake loading. Steel beams, including I sections, tapered beams, built-up sections, and truss configurations, are incorporated to ensure efficient load transfer while minimizing structural weight,

thereby reducing seismic forces. Lightweight roofing materials such as GI sheets, color coated sheets, sandwich panels, and aluminum sheets are selected to decrease dead load and enhance overall earthquake resistance. Flooring systems consist of steel decking, composite slabs, and chequered plates to provide strength, speed of installation, and structural integrity.

For flood resilience, the housing unit is supported on a hydraulic jack system above the foundation, enabling elevation during high water levels and protecting the structure from inundation damage. Renewable energy integration is achieved through rooftop solar photovoltaic panels mounted on steel frames, complemented by battery storage and inverter systems to ensure uninterrupted off-grid power supply. Sustainable water management is addressed through a rainwater harvesting system comprising roof collection surfaces, filtration units, and storage tanks. Additionally, GPS modules and climate sensors are integrated for real time monitoring, early warning, and environmental data collection. The use of recyclable, corrosion resistant, and modular materials enhances durability, portability, and environmental sustainability. Overall, the integrated structural, energy, and monitoring systems result in a compact housing solution that is earthquake resistant, flood resistant, and energy efficient, making it suitable for disaster prone regions.





3.Design model and Calculation

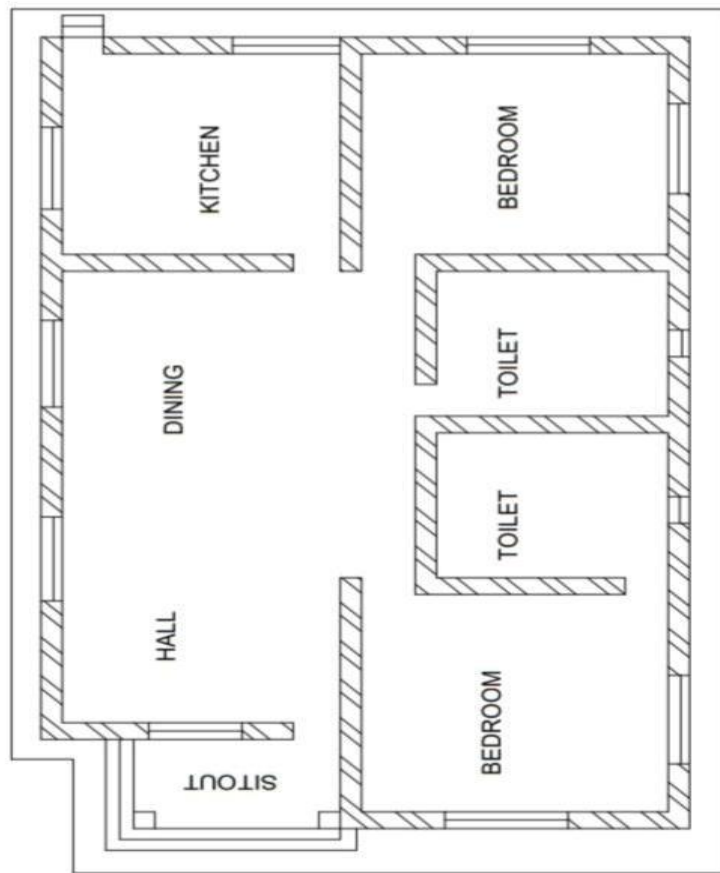


Fig.3.1 Plan of our structure

LOAD CALCULATION

Total built-up area = 700 sq. ft

$$= 700 \times 0.0929$$

$$= 65.03$$

$$= 65.0 \text{ m}^2$$

Dead Load Calculations

→ Roof Load

Sandwich Panels are used for roofing.

Self weight of Sandwich Panels = 8 to 20 kg/m².

$$\text{Roof load} = 65 \times 8 = 520 \text{ kg}$$

→ Floor Load

Checker plates are used for flooring.

Self weight of Checker plate = 40 to 50 kg/m².

Floor load = 65 x 40 = 2600 kg

→ Steel Framing (Beams, Columns, Bracing)

For light single- storey steel buildings, 40-60 kg/m² is commonly assumed.

Steel framing load = 65 x 40 = 2600 kg

→ Hydraulic Jack

Self weight = 4 to 9.5 kg / Jack

Assume 8 Jack (typical course + intermediate support).

Load = 8 x 4 = 32 kg

→ Solar Panel

Self weight = 18 to 25 kg

Assume 4 panels.

Load = 4 x 18 = 72 kg

→ Miscellaneous Dead Load

(Fasteners, connections, wiring, plumbing, coatings)

5% of Total dead load

Total Dead Load

Roof - 520 kg

Floor - 2600 kg

Steel frame - 2600 kg

Hydraulic Jack - 30 kg

Solar panel - 72 kg

Total Load = 5824 kg

Miscellaneous = 5% of Total Dead Load.

$$= 5/100 \times 5824$$

$$= 291.2$$

$$\approx 291 \text{ kg}$$

Total Dead Load = 5824 + 291 = 6115 kg

$$= 615 \div 1000 = 6.115 \text{ tons}$$

$$= 6.1 \text{ ton}$$

Live Load

As per AS 875 (part2) for residential Buildings

$$\text{Live Load} = 2.0 \text{ KN/m}^2$$

$$= 200 \text{ kg/m}^2$$

$$\text{Live Load} = 65 \times 200$$

$$= 13000 \text{ kg}$$

Total Design Load

$$\text{Service Load} = \text{DL} + \text{LL}$$

$$= 6115 + 13000$$

$$= 19115 \text{ kg}$$

$$= 19.1 \text{ tons}$$

Load Per Hydraulic Jack

Assume 6 Jacks

$$\text{Load} = 19.1 / 6 = 2.4 \text{ tons}$$

$$\text{Total structural weight} = 6.1 \text{ tons}$$

$$\text{Design load including live load} = 19.1 \text{ tons.}$$

Steel Grade.

From the load calculations the steel grade used for flood resistant and earthquake resistant housing unit is ASTM A572 Grade 50.

STIFFNESS OF TYRE

$$\text{- Total structural load (DL)} = 6.1 \text{ tons}$$

$$\text{- Total design load (DL+LL)} = 19.1 \text{ tons}$$

$$W = 19.1 \times 1000 \times 9.81$$

$$= 187371 \text{ N} = 187.371 \text{ KN}$$

$$\approx 187 \text{ KN}$$

$$M = W/g = 187371/9.81 = 19100 \text{ kg}$$

Target Fundamental Period (Base- Isolated)

For effective seismic isolation :-

- Fixed base steel structure $\rightarrow T = 0.3 - 0.5 \text{ s}$

- Base-isolated structure $\rightarrow T = 2.0 \text{ to } 3.0 \text{ s}$

K is adopt,

$$T = 2.5 \text{ s}$$

Required Total Lateral Stiffness of Isolation System

$$k = 4\pi^2 \times m / T^2$$

$$k = 4\pi^2 \times 19100 / 2.5^2$$

$$= 120646.0442 \text{ N/m}$$

$$= 121 \text{ KN/m}$$

This is the combined lateral stiffness of all types.

Stiffness of one type

Car tyre - 5-10 KN/m Typical lateral stiffness

Truck / bus tyre -15-25 KN/m Typical lateral stiffness

We assume 20 KN/m

No: of Types Required

$$n = k_{\text{total}} / k_{\text{type}}$$

$$= 121 / 20 = 6.05$$

Adopt higher number

$$n = 8$$

Check: Load per Tyre

$$W_{\text{per tyre}} = 19.1 / 8 = 2.39 \text{ tons}$$

$$= 2.4 \text{ tons}$$

Therefore, Design seismic weight = 19.1 tons

Target collapse period = 2.5 s

Total required stiffness = 121 KN/m

Stiffness of one tyre = 20 KN/m

No of tyres = 8

Load per tyre = 2.4 tons

Analysis of the Structure

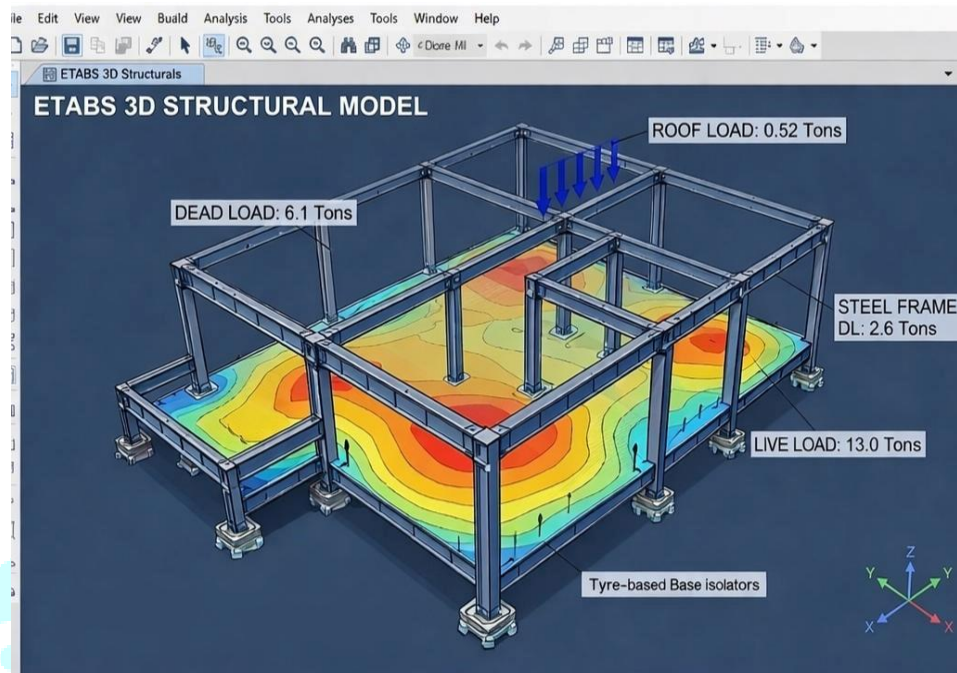


Fig.3.2. Structural model Using etabs

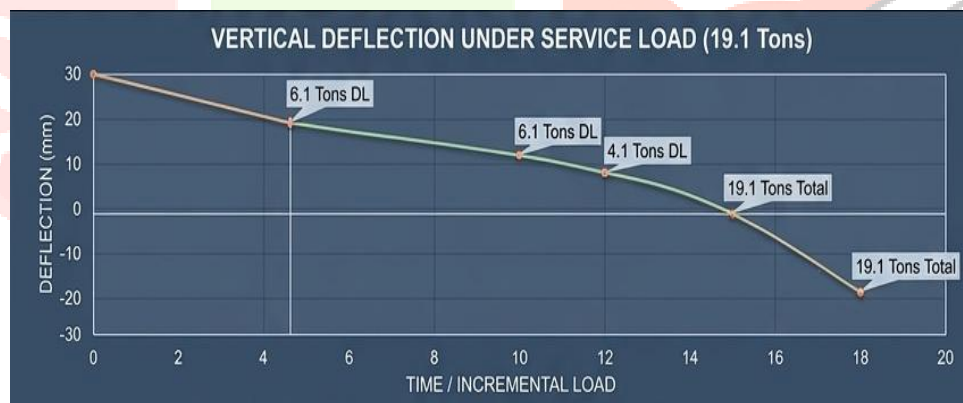


Fig.3.3 deflection graph

SUMMARY OF LOADS AND KEY DEFLECTION RESULTS			
LOAD CASE	DESCRIPTION	LOAD VALUE	MAX DEFLECTION (mm)
CASE 1	Total Dead Load (Structural+Misc)	6,115 kg (6.1 Tons)	12.3
CASE 2	Total Live Load (Residential IS 875)	13,000 kg (13.0 Tons)	29.7
CASE 3	Design Load (DL + LL)	19,115 kg (19.1 Tons)	42.0
LOAD PER TIRE	LOAD PER TIRE (Adopt 8 Tires)	2.4 Tons / Tire	---
MAX SHEAR	Total Design Shear	2.8 kN	---

Fig.3.4. Load Analysis and Deflection Results

The ETABS 3D structural model illustrates the load distribution and corresponding deflection behavior of the proposed portable housing system under service conditions. The total dead load of 6.1 tons, including structural and miscellaneous components such as the steel frame (2.6 tons) and roof load (0.52 tons), is comparatively lower than the live load of 13.0 tons, indicating that occupancy and usage govern the structural response. The deflection graph shows a progressive increase in vertical displacement with incremental loading, where the maximum deflection reaches 42.0 mm under the combined design load of 19.1 tons (DL + LL), while individual contributions from dead and live loads result in deflections of 12.3 mm and 29.7 mm respectively. The contour distribution highlights localized deformation zones, suggesting effective load transfer through columns and foundation supports. Despite the increase in deflection, the values remain within acceptable serviceability limits, demonstrating adequate stiffness and structural integrity. This controlled deformation behavior, coupled with relatively low base shear (2.8 kN) and uniform load distribution, indicates that the structure possesses sufficient flexibility and energy dissipation capacity, which are essential for earthquake resistance. Additionally, the elevated structural system and distributed load path reduce the risk of excessive settlement and structural damage under flood conditions, thereby confirming the suitability of the design for disaster resilient, sustainable portable housing application

4.Results & Discussions

The structural analysis performed using ETABS provides detailed insight into the load carrying capacity and deformation characteristics of the proposed sustainable portable housing system, confirming its suitability for disaster prone environments. The structure is subjected to a total design load of 19.1 tons, consisting of 6.1 tons of dead load (including structural components and roofing) and 13.0 tons of live load, indicating that the system is lightweight yet capable of supporting significant occupancy loads. The deflection behavior shows a progressive and controlled increase, with maximum vertical displacement reaching 42.0 mm under combined loading, while individual deflections due to dead and live loads are 12.3 mm and 29.7 mm respectively. These values fall within permissible serviceability limits, demonstrating that the structure maintains adequate stiffness while allowing necessary flexibility. The contour distribution of deflection highlights efficient load transfer through beams, columns, and supports, with no critical concentration of stresses, thereby ensuring structural stability and integrity.

From an earthquake resistance perspective, the relatively low base shear value of 2.8 kN, combined with gradual deformation characteristics, indicates that the structure can effectively respond to seismic forces. The lightweight nature of the system reduces inertia forces during ground motion, while its flexibility enhances energy dissipation, preventing brittle failure and improving overall seismic performance. In terms of flood resistance, the elevated column supported configuration plays a crucial role by keeping the main living space above potential water levels, thereby reducing direct exposure to floodwaters. This

design minimizes risks such as water induced damage, soil erosion, and differential settlement. Additionally, the distributed foundation system ensures better load sharing even under saturated soil conditions. Overall, the results confirm that the structure not only satisfies strength and serviceability requirements but also demonstrates the necessary characteristics such as flexibility, stability, and elevation to resist both earthquake and flood hazards effectively, making it a reliable and sustainable solution for portable housing in vulnerable regions.

5. Conclusion

present study demonstrates that the proposed sustainable portable housing system, analyzed using ETABS, successfully meets the requirements of structural safety, serviceability, and disaster resilience. The analysis confirms that the structure is lightweight yet capable of withstanding the applied dead and live loads, with deflection values remaining within permissible limits, indicating adequate stiffness and stability. The controlled deformation behavior and low base shear highlight the structure's ability to effectively resist seismic forces through improved flexibility and energy dissipation capacity.

furthermore, the elevated and column supported configuration enhances flood resistance by minimizing direct water impact, reducing the risk of damage, and ensuring stability under saturated soil conditions. The integration of these features, along with the use of sustainable materials and solar energy systems, makes the design both environmentally friendly and functionally efficient. Overall, the project concludes that the developed portable housing model is a viable, safe, and sustainable solution for deployment in earthquake and flood prone regions, with strong potential for real world application in disaster mitigation and emergency housing.

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