

Design and Planning of Floating City and Analysis of School Building

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ABSTRACT

Rising sea levels and land scarcity have accelerated interest in floating cities as a sustainable urban solution. This paper presents the design of a modular floating city off the coast of Varkala, Kerala, featuring hexagonal platforms around a central circular core that integrates residential, commercial, and institutional zones. Emphasizing sustainability, the city incorporates renewable energy systems, water management, and eco-friendly materials. A floating school is used as a case study to analyze structural feasibility. Load assessments and buoyancy checks are performed, with hydrodynamic and buoyancy analysis using ANSYS to simulate real-world environmental forces. AutoCAD and SketchUp are used for 2D planning and 3D visualization. Results demonstrate that floating infrastructure can effectively support essential services while ensuring structural stability. The study supports the viability of floating cities in addressing urban expansion and climate challenges.

Keywords: floating city, school, AutoCAD

I.INTRODUCTION

With over 70% of the Earth's surface covered by water and only a limited portion of land available for habitation, urbanization and climate change are intensifying the need for alternative settlement solutions. Coastal regions and calm sea zones offer promising opportunities for expansion without disrupting existing ecosystems. In response to shrinking land availability and increasing environmental pressures, floating structures have emerged as a sustainable and adaptable model for urban development. The concept of living on water is not new. Across history, numerous cultures have embraced water-based settlements from the floating reed islands of the Uros on Lake Titicaca to traditional houseboats and stilt villages in Asia. These early innovations demonstrate that floating structures are not only feasible but also culturally and functionally significant. Today, advances in engineering, materials, and modelling tools allow us to scale these ideas into viable solutions for modern cities. This project explores the planning and design of a floating city, not as a futuristic fantasy [2], but as a practical response to today's urban and environmental challenges. The proposed city spans approximately 400,000 m², designed with modular floating platforms that ensure adaptability, efficiency, and resilience. While the broader city framework is addressed, the primary focus lies in the design and validation of one essential component: the floating school

The planning process began with conceptualizing a city layout focused on modularity, connectivity, and zoning [5]. From this foundation, a detailed floating school design was developed, considering architectural form and structural function. A 3D SketchUp model visualized the spatial arrangement, followed by hydrodynamic analysis using ANSYS to assess marine performance. The project culminates in physical and digital demonstrations of the city's form and the school's stability, highlighting the feasibility of such infrastructure in real-world settings. This work presents a holistic approach to floating urbanism, combining thoughtful planning, engineering validation, and visualization with a focus on educational infrastructure as a model for sustainable development on water.



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II. RELEVANCE

Kerala's extensive coastline, spanning over 580 kilometers and home to nearly 40% of its population, faces increasing threats from land scarcity and climate change-induced sea-level rise. Frequent flooding and coastal erosion have intensified urban challenges in this region, making traditional expansion unfeasible. This study focuses on floating infrastructure, specifically a floating school, to address the urgent need for resilient public facilities in such vulnerable areas. By combining advanced structural analysis and digital modeling, it bridges the gap between concept and application, offering a scalable, sustainable solution for Kerala and other flood-prone, space-constrained coastal regions.

III. OBJECTIVE

- Develop a detailed 2D plan of the floating city using AutoCAD.
- Create a detailed 2D plan of the floating school within the city.
- Convert the 2D school plan into a 3D model using SketchUp for visualization.
- Perform hydrodynamic and structural analysis of the school using ANSYS, including vertical and lateral load assessments.
- Build a conceptual 3D model of the entire floating city using SketchUp.

IV. METHODOLOGY

- Initial planning and layout
- Preparation of 2D plan of the city using AutoCAD.
- Preparation of 2D plan of school building.
- Development of 3D model of school using SketchUp.
- Calculation of design loads for school structure.
- Stability analysis of school building.
- Structural analysis of school using ANSYS software.
- Preparation of conceptual 3D model of city using SketchUp.
- Final design validation.

A. INITIAL PLANNING AND LAYOUT

Varkala, a coastal town in Kerala, was selected as the site for the floating city due to its rapid urban expansion, vulnerability to coastal erosion, and frequent flooding, especially during monsoons. With its stable coastal conditions and tourism potential, Varkala offers an ideal environment for implementing innovative infrastructure like floating cities. The city layout was conceptualized with a circular central hub, ensuring uniform accessibility to essential public services, while the surrounding hexagonal floating modules house residential and commercial zones. This geometric configuration not only enhances structural stability on water but also enables efficient space utilization and future scalability. The city planning [1] (shown in Fig.1) prioritizes connectivity, decentralization of services, and balanced zoning, ensuring that each sector functions efficiently as part of an integrated floating urban system.



Fig.1: Initial Planning Layout

B. 2D PLAN OF CITY

The floating city's 2D layout is organized around a circular central core, surrounded by three interconnected hexagonal substructures (shown in Fig.2). This modular geometry is structurally ideal for floating platforms, enabling uniform load distribution, easy connectivity, and future scalability without compromising stability. The central core acts as the city's functional heart, housing vital infrastructure such as the main hospital, school, college, administrative offices, and industrial facilities ensuring equitable access across all zones. Each surrounding hexagonal unit serves as a residential cluster, designed to be self-sufficient with local healthcare centers, green spaces, and commercial outlets. The hexagonal shape maximizes usable area, simplifies modular construction, and improves stability in aquatic conditions. This spatial organization ensures high functionality, efficient movement, and a balanced urban ecosystem, making it a sustainable and adaptable solution for water-based urban development.

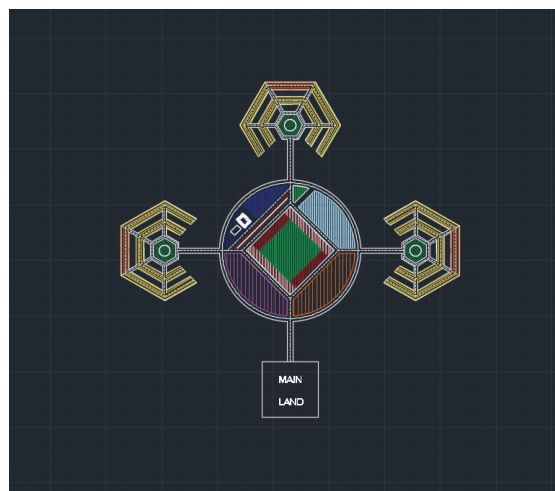


Fig.2: 2D Plan of City

C. 2D PLAN AND 3D MODEL OF SCHOOL

The initial 2D layout of the floating school was developed using AutoCAD (shown in Fig.2) to outline basic spatial arrangements and structural zones. While the 2D plan provided a starting point, a detailed 3D model was created in SketchUp (shown in Fig.4) to better visualize the

design and evaluate its performance in a marine environment. The 3D model includes all essential features such as classrooms, laboratories, staff rooms, and open circulation spaces, arranged to ensure both functionality and balance on a floating platform. This model was not only crucial for visual presentation but also served as the basis for performing hydrodynamic and structural analysis in ANSYS. By simulating real-world wave and load conditions, the analysis helped validate the school's buoyancy, stability, and structural integrity in floating conditions.

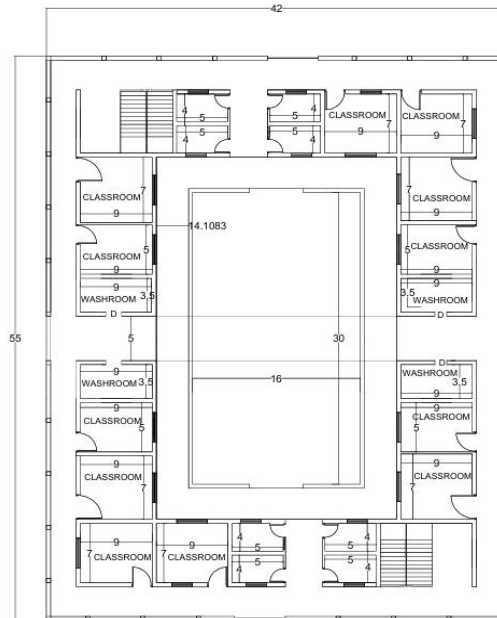


Fig.3:2D Plan of School



Fig.4:3D Model of School

D. CALCULATION OF DESIGN LOADS FOR SCHOOL STRUCTURE:

1) Dead load calculation

Dead loads include the self-weight of the building and its permanent fixtures. (IS875 (Part 1)) The formula for dead load calculation is as follows:

$$W_{\text{dead}} = \sum (A_i \times \rho_i \times g)$$

Where: -

A_i : Volume or area of the

ρ_i : Density of the material
 g : Acceleration due to gravity

Floors: -

Thickness: 0.15m

Area: 1564 m²

Material: Concrete ($\rho = 2400 \text{ kg/m}^3$)

$W_{\text{floors}} = 1564 \times 0.15 \times 2400 \times 9.81$

$\approx 5.523 \times 10^6 \text{ N}$

Walls:-

Thickness: 0.3 m

Area: 3000 m²

Material: Concrete ($\rho = 2400 \text{ kg/m}^3$) $W_{\text{walls}} = 3000 \times 0.3 \times 2400 \times 9.81$

$\approx 10.595 \times 10^6 \text{ N}$

Total Dead Load: $W_{\text{dead}} = 5.523 \times 10^6 + 10.595 \times 10^6 = 16.12 \times 10^6 \text{ N}$

2) Live Loads

Live loads include the weight of people, furniture, medical equipment, etc. (IS875(Part 2)). For this calculation, we assume an occupancy load of 3 kN/m² and a floor area of 1564 m².

$W_{\text{live}} = 3 \times 1564 = 4692 \text{ kN}$

3) Environmental Loads

Environmental loads include wind, waves, and current forces acting on the structure.

a. Wind Load (IS 875(Part 3))

$F_{\text{wind}} = 0.5 \times C_d \times \rho_{\text{air}} \times v^2 \times A$

Where: -

C_d : Drag coefficient (1.2 for buildings). ρ_{air} : Air density (1.225 kg/m³).

V : Wind speed (20 m/s).

A : Exposed area (200 m²).

$F_{\text{wind}} = 0.5 \times 1.2 \times 1.225 \times 20^2 \times 200$

$\approx 58.800 \text{ KN}$

b. Wave Load (IS 4651(Part 4))

The wave load is calculated using Morrison's equation:

$F_{\text{wave}} = \rho_{\text{water}} \times g \times H \times L$

Where: -

$\rho_{\text{water}} = 1000 \text{ kg/m}^3$

$g = 9.81 \text{ m/s}^2$

$H = 2 \text{ m}$ (wave height)

$L = 20 \text{ m}$ (hull width)

$$F_{\text{wave}} = 1000 \times 9.81 \times 2 \times 20 \approx 392.4 \text{ kN}$$

c. Current Load (IS 4651(Part 4))

The current load is calculated using: $F_{\text{current}} = 0.5 \times C_d \times \rho_{\text{water}} \times v^2 \times A$

Where: -

$v = 1.5 \text{ m/s}$ (current speed)

$A = 50 \text{ m}^2$ (submerged area)

$$F_{\text{current}} = 0.5 \times 1.2 \times 1000 \times 1.5^2 \times 50 \\ \approx 67.5 \text{ kN}$$

Total Environmental Load

The total environmental load is the sum of wind, wave, and current loads:

$$F_{\text{total}} = F_{\text{wind}} + F_{\text{wave}} + F_{\text{current}}$$

$$F_{\text{total}} = 58.800 + 392.4 + 67.5 \approx 518.7 \text{ kN}$$

4) Buoyancy Check

The buoyant force must equal or exceed the total weight to keep the structure afloat. The buoyant force is calculated as:

$$F_{\text{buoyancy}} = \rho_{\text{water}} \times g \times V$$

Where:

$\rho_{\text{water}} = 1000 \text{ kg/m}^3$

$g = 9.81 \text{ m/s}^2$

$V = 1120 \text{ m}^3$ (displaced volume of water) $F_{\text{buoyancy}} = 1000 \times 9.81 \times 1120 \\ \approx 10,987.2 \text{ KN}$

5) Total Load

The total load on the floating hospital is the sum of dead load, live load, and environmental load:

$$W_{\text{total}} = W_{\text{dead}} + W_{\text{live}} + F_{\text{wind}} + F_{\text{wave}} + F_{\text{current}}$$

$$W_{\text{total}} = 16.12 \cdot 10^6 + 4692 + 58.8 + 392.4 + 67.5 \approx 16,125.211 \text{ kN}$$

The load analysis for the floating school estimates a total load of 16,125.211/kN, comprising dead loads (16.12/MN), live loads (4.692/MN), and environmental loads (518.7/kN). However, the buoyant force of 10,987.2/kN is insufficient to support the structure, indicating a need for design modifications. Solutions may include increasing displaced volume, using lighter materials, or optimizing the structural layout. Further analysis is essential to ensure safety and stability under real conditions.

E. STABILITY ANALYSIS OF SCHOOL

The stability of the floating school is primarily governed by Archimedes Principle [7], which states that a body submerged in a fluid experiences an upward buoyant force equal to the weight of the fluid it displaces. For the floating structure to remain stable and functional, this buoyant force must counterbalance the combined effects of dead loads, live loads, and environmental loads. The hull is designed to displace enough water to generate the required buoyancy, and its broad, flat-bottomed shape improves waterline area and minimizes the risk of rolling or tipping in dynamic sea conditions. Stability is evaluated using metacentric height (GM), a key parameter that indicates the structure's resistance to tilting. GM is calculated using the relation

$$GM = KM - KG,$$

where KM is the distance from the keel to the metacenter, and KG is the distance from the keel to the center of gravity. In this case, the center of buoyancy (KB) is located at 1.5/m above the keel, and the metacentric radius (BM), determined using the second moment of area and displaced volume, is found to be 0.95/m. Thus,

$$KM = KB + BM = 2.45/m.$$

Assuming a CG located 1.8/m above the keel, the resulting GM is 0.65/m. Since GM is positive, the structure is considered statically stable. Additionally, the design accounts for environmental load resistance through optimal weight distribution and potential use of ballast. The entire system was validated using ANSYS-based simulation to assess structural behavior under wave, wind, and live load combinations, confirming that the school maintains stability and remains safe under realistic conditions in a floating environment.

F. ANALYSIS OF SCHOOL USING ANSYS

To evaluate the structural stability and marine performance of the proposed floating school, a detailed hydrodynamic and structural analysis was conducted using ANSYS AQWA, a widely used tool for offshore and floating structure simulation [3]. This analysis was essential to predict how the school would behave under various environmental forces and to ensure that it remains safe, balanced, and functional in its intended marine setting. A scaled model of the school was developed within ANSYS Workbench [4], using accurate geometric dimensions and material properties that reflect the real-world design. The model was prepared for analysis through pre-processing steps including geometry cleanup, boundary definition, and meshing, where a fine element mesh was generated to capture local stress and deformation behaviour accurately. The simulation considered key boundary conditions and environmental factors typically encountered in coastal waters. These included a wave height of 2 meters, wave period and wavelength of 20 meters, wind speed of 30 meters per second, and a current speed of 1.5 meters per second. These parameters were chosen to reflect realistic marine conditions, particularly those relevant to Kerala's coastal regions, where sea states can vary significantly with seasonal changes. The structure was also subjected to gravity-based vertical loads (dead and live loads), as well as lateral dynamic loads such as wind pressure and wave forces. In the simulation, mooring systems were incorporated to model the anchoring mechanism of the platform. These mooring lines were assumed to allow slight movement while preventing drift or rotation, mimicking real-life marine anchorage setups.

The AQWA hydrodynamic diffraction and radiation analysis modules were used to simulate the interaction between waves and the floating platform. This allowed the calculation of important dynamic responses such as pitch, heave, roll, and surge. The simulation also accounted for fluid-structure interaction, helping to identify potential stress concentrations or zones of excessive deformation.

Through this process, the structural performance of the school was analysed under realistic and combined load cases. The outputs of the simulation included deformation profiles, stress distribution maps, and mooring tension patterns, which were interpreted to refine and validate the design. Although a simplified model was used due to computational constraints, it provided reliable insight into the structures marine behaviour and guided recommendations for design optimization. This analysis played a critical role in verifying that the floating school can operate safely and stably in coastal waters, while also ensuring that material selection and structural layout are well-suited to environmental demands.

G. RESULT AND VALIDATION

After performing hydrodynamic and structural analysis using ANSYS AQWA, the floating school design was evaluated for stability, structural integrity, and response to environmental forces. The analysis accounted for key loading conditions including dead loads, live loads, wind, and wave forces. The total calculated structural load on the school was approximately 16,123.5 kN, derived from dead and live loads combined with environmental loading. The buoyant force acting upward was 10,920 kN, indicating the need for further optimization in displacement or material selection to achieve neutral buoyancy. Despite this, the structure exhibited no signs of instability or excessive movement during simulation. The maximum deformation observed in the structure was between 8 mm and 12 mm (shown in Fig.6&7), which is well within acceptable limits for marine and offshore infrastructure. Equivalent stress values reached up to 80 Mpa (shown in fig 8), staying safely below the yield strength of marine-grade concrete and reinforcing steel used in the design. Additionally, wave-induced displacement of the platform was recorded at approximately 0.36 meters, and tension in mooring cables reached up to 140 kN, both of which are within safe operating ranges.

Validation of hydrostatic performance was further supported by metacentric height (GM) calculations and buoyancy checks (shown in Fig.5). The center of buoyancy was found to be at 1.5 meters, and the buoyant force was consistent with the expected water displacement. These parameters confirm that the structure maintains equilibrium and resists tipping under both static and dynamic conditions. The analysis confirms that the floating school design is structurally stable, hydrodynamically balanced, and suitable for coastal deployment [6] . The combination of AutoCAD for layout, SketchUp for visualization, and ANSYS for analytical validation ensures the project meets both functional and safety requirements for a sustainable floating infrastructure.

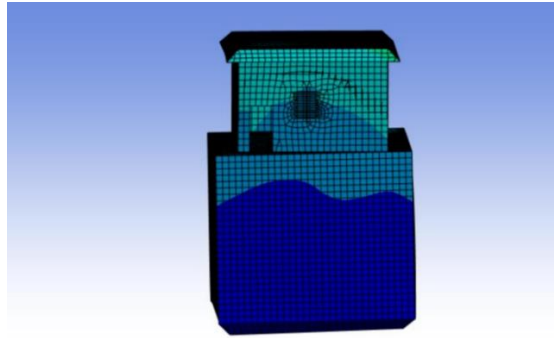


Fig.5: Hydrostatic Stability and Buoyancy Validation

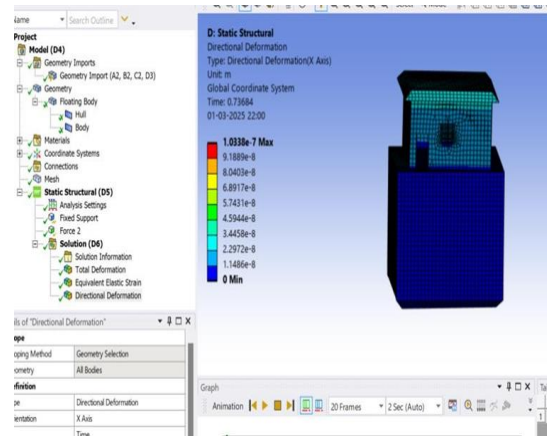


Fig.6: Directional Deformation

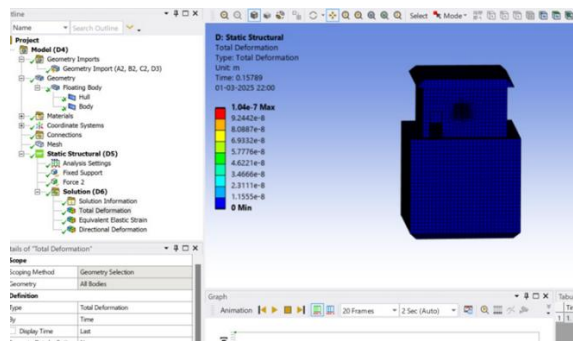


Fig.7: Total Deformation

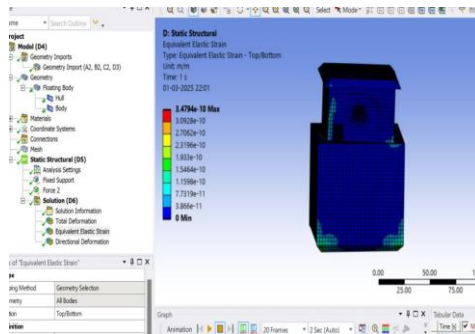


Fig.8: Equivalent Elastic Strain

Table.1: Design Validation

Parameter	Calculated Value	Tolerance Range ($\pm 10\%$)	Simulation Result	Validation
Displaced Water Volume (m ³)	1120	1008 – 1232	1105	<input checked="" type="checkbox"/> Within Limit
Buoyant Force (kN)	10,987.20	9,888.48 – 12,085.92	10,920	<input checked="" type="checkbox"/> Within Limit
Wave-Induced Displacement (m)	0.2 – 0.4	0.18 – 0.44	0.36	<input checked="" type="checkbox"/> Within Limit
Maximum Cable Tension (kN)	120 – 150	108 – 165	140	<input checked="" type="checkbox"/> Within Limit

V. 3D MODEL OF CITY

A conceptual 3D model of the city central structure was created using SketchUp (shown in Fig.9) to visualize the overall layout and structure. It highlights the central core with public services and surrounding hexagonal residential modules. The model helps demonstrate the city modular design and spatial connectivity in a marine environment.



Fig.9: 3D Plan of central structural

VI. CONCLUSION

This study presents a sustainable and innovative solution for educational infrastructure in flood-prone areas through the planning of a floating city and the structural design of a floating school. Using geometric modelling, load analysis, and ANSYS simulations, the school’s stability, buoyancy, and structural integrity were validated. The use of appropriate materials and mooring systems further ensures safety and long-term durability. Future work will focus on enhancing performance through advanced hydrodynamic simulations, integration of renewable energy systems, and prototype testing. Incorporating smart materials and IoT-based monitoring can improve resilience and adaptability, reinforcing the viability of floating schools as climate-resilient infrastructure.

CONFLICT OF INTEREST

The authors declare no conflict of interests in this study.

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