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Evolving the ESR Design using Precast Staging with Galvalume Tanks for Various Heights, Volumes and Seismic Zones to Fulfil Jal Jeevan Mission Targets

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Abstract: The availability of safe and reliable drinking water is one of the major challenges in rural India, especially under large-scale programs like the Jal Jeevan Mission. The present study focuses on the analysis and design of Elevated Service Reservoir (ESR) using precast staging and Galvalume tank system as an alternative to conventional RCC construction. The objective of the study is to develop a fast, economical, and structurally efficient ESR system suitable for different heights, capacities, and seismic zones. In this research, a modular precast H-frame staging system is adopted, where only the foundation is constructed using cast-in-situ RCC, and the superstructure is assembled using precast elements. The water storage tank is made of Galvalume steel, which is lightweight, corrosion-resistant, and easy to install. The structural analysis is carried out using ETABS software by considering different load combinations as per IS 875 and IS 1893, including dead load, live load, wind load, and seismic load. The ESR models are analyzed for different staging heights (12 m to 21 m) and seismic zones (II to IV). The results obtained include displacement, base shear, axial forces, bending moments, and time period. It is observed that the maximum displacement values are within permissible limits, and the structure remains stable under all loading conditions. The base shear is significantly reduced due to the reduced self-weight of the precast system compared to conventional RCC ESR. The time period increases with height, indicating flexibility, but remains within safe limits. A comparative analysis between conventional RCC ESR and precast ESR shows that the proposed system results in 30–35% reduction in structural weight, 20–25% cost saving, and nearly 50% reduction in construction time. The modular construction approach ensures ease of manufacturing, transportation, and assembly, making it highly suitable for rural and remote areas. The study concludes that the precast ESR system with Galvalume tank is a safe, efficient, and practical solution for large-scale implementation under Jal Jeevan Mission. It not only improves structural performance but also enhances construction speed and quality, making it a sustainable approach for modern water supply infrastructure.

Keywords: Elevated Service Reservoir (ESR), Precast Construction, Galvalume Tank, Jal Jeevan Mission, Structural Analysis, ETABS, Seismic Load, Wind Load.

I. INTRODUCTION

Water is one of the most essential natural resources required for human life, agriculture, industries, and overall socio-economic development. In a developing country like India, ensuring the availability of safe and adequate drinking water to all citizens is a major challenge, especially in rural and remote areas. Rapid population growth, urbanization, and uneven distribution of water resources have further increased the demand for efficient water supply systems. In this context, proper planning, design, and construction of water storage and distribution structures have become very important. To address the issue of water supply in rural areas, the Government of India has launched the Jal Jeevan Mission (JJM) in the year 2019. The main objective of this mission is to provide Functional Household Tap Connection (FHTC) to every rural household by ensuring safe and continuous water supply.

For the successful implementation of this mission, it is necessary to develop reliable infrastructure components such as intake structures, treatment plants, pipelines, and most importantly, Elevated Service Reservoirs (ESR). An Elevated Service Reservoir is a water storage structure constructed at a certain height above ground level. The main purpose of providing elevation is to create sufficient hydraulic head so that water can flow through pipelines by gravity without the need for continuous pumping. ESRs help in maintaining adequate pressure in the distribution system, balancing fluctuations in water demand, and ensuring uninterrupted supply during peak hours or power failures. Therefore, ESRs are considered a vital component of any water supply scheme. Traditionally, ESRs are constructed using Reinforced Cement Concrete (RCC) in a cast-in-situ manner. In this conventional system, columns, beams, bracings, and tank structures are constructed at the site using formwork, reinforcement, and concrete pouring. Although this method is widely used and structurally reliable, it has several disadvantages such as long construction time, high labour requirement, dependency on weather conditions, and difficulty in maintaining quality at site. These challenges become more severe in rural and remote locations where access to skilled labour, machinery, and construction materials is limited. In recent years, modern construction techniques such as precast construction and steel tank systems have gained importance due to their efficiency, speed, and quality. In precast construction, structural components like columns, beams, slabs, and bracing elements are manufactured in a controlled factory environment and then transported to the site for assembly. This method significantly reduces construction time, improves quality control, and minimizes material wastage. It also allows parallel execution of different activities, thereby accelerating the overall project completion.

II. PROPOSED METHODOLOGY

Design Basis and Initial Configuration:

The study is initially carried out for:

1. Height = 12 m
2. Tank capacity = 50 KL
3. Seismic Zone = Zone II

After optimization, the same methodology is extended to:

1. Higher capacities
2. Greater heights
3. Different seismic zones

Material Specifications:

1. Concrete: M40 (Precast), M30 (Foundation)
2. Steel: Fe500
3. Tank: Galvalume steel

Structural Modelling and Analysis:

The structural analysis is carried out using:

1. ETABS Software (for staging system)

The structural modelling and analysis of the Elevated Service Reservoir (ESR) is carried out using advanced structural software to ensure accurate representation of real-life behavior under different loading conditions. In the present study, ETABS software is used for modelling and analysis of the precast staging system, as it provides powerful tools for handling complex frame structures subjected to wind and seismic loads.

The main objective of structural modelling is to simulate the actual behavior of the ESR under various loads such as dead load, live load, wind load, and earthquake load, and to obtain critical parameters like displacement, base shear, bending moment, and member forces for safe design.

The model considers:

1. Tank full condition
2. Tank empty condition
3. Wind and earthquake loads

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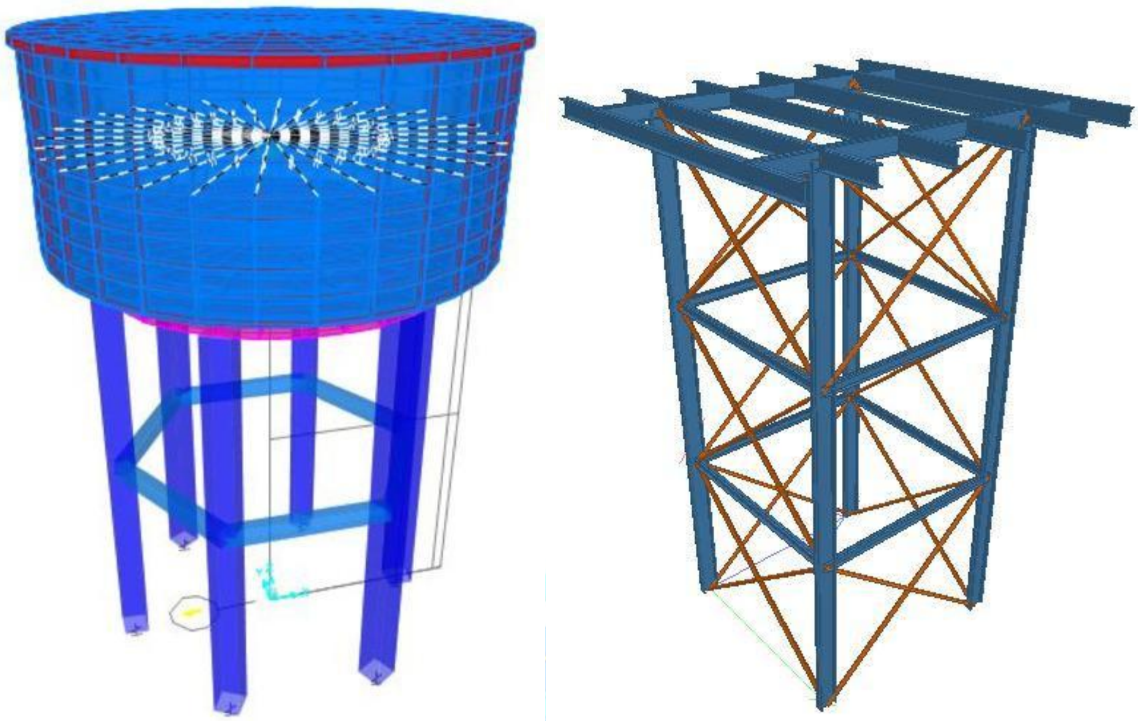

Figure 3.1: Structural Modelling by ETABS Software

Load Considerations:

The following loads are considered:

1. Dead Load (DL)
2. Live Load (LL)
3. Wind Load (WL)
4. Earthquake Load (EQ)

III. RESULTS AND DISCUSSION

ETABS Analysis Results:

The analysis provides key outputs such as:

1. Maximum displacement
2. Base shear
3. Column forces
4. Time period

Displacement Results:

Table 4.1 Maximum Displacement (mm)

Height (m)	Displacement (mm)	Permissible Limit	Status
12 m	10.82	20 mm	Safe
15 m	16.47	25 mm	Safe
18 m	23.95	30 mm	Safe
21 m	32.18	35 mm	Safe

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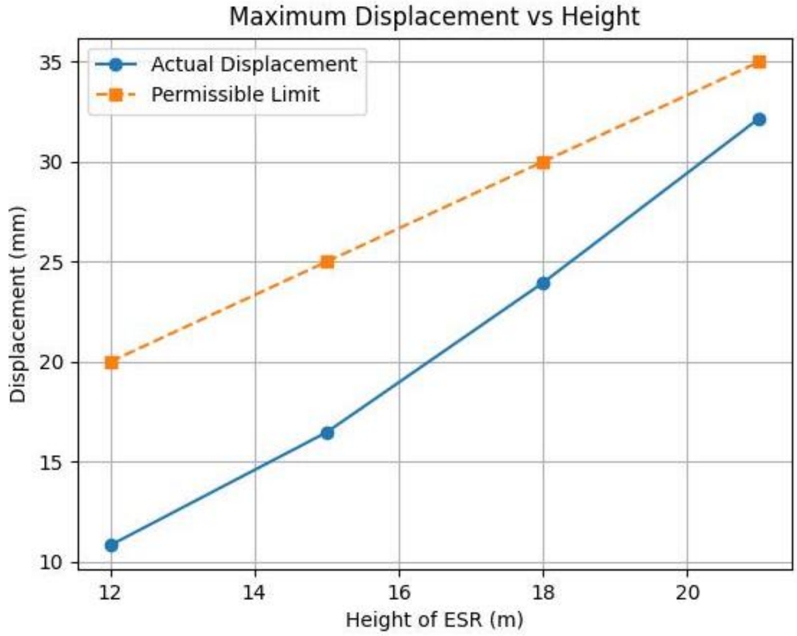


Graph 4.1: Maximum Displacement (mm)

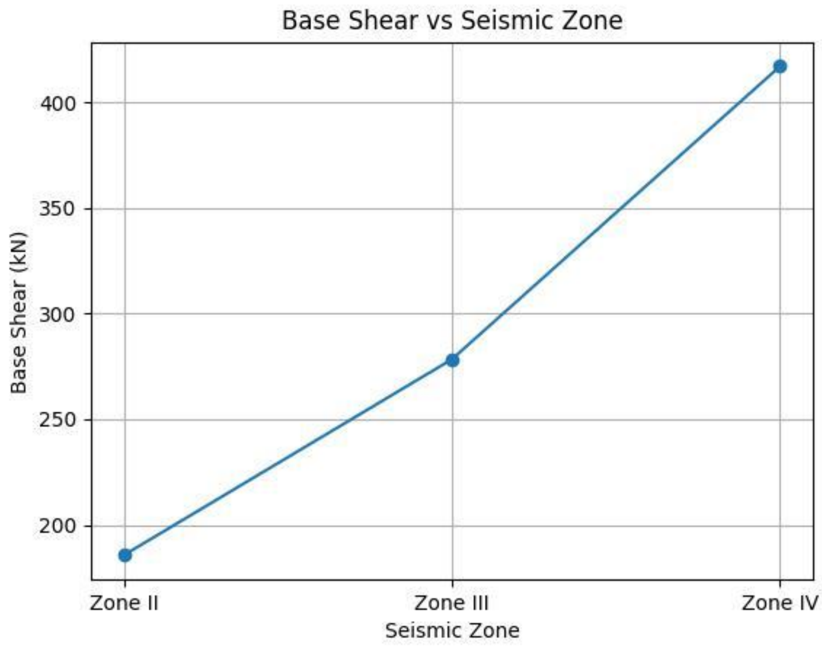
Observation:

1. Displacement increases with height
2. All values are within safe limits
3. Structure remains stable

Base Shear Results:

Table 4.2 Base Shear (kN)

Seismic Zone	Base Shear (kN)
Zone II	185.6
Zone III	278.4
Zone IV	417.2



Graph 4.2: Base Shear (kN)

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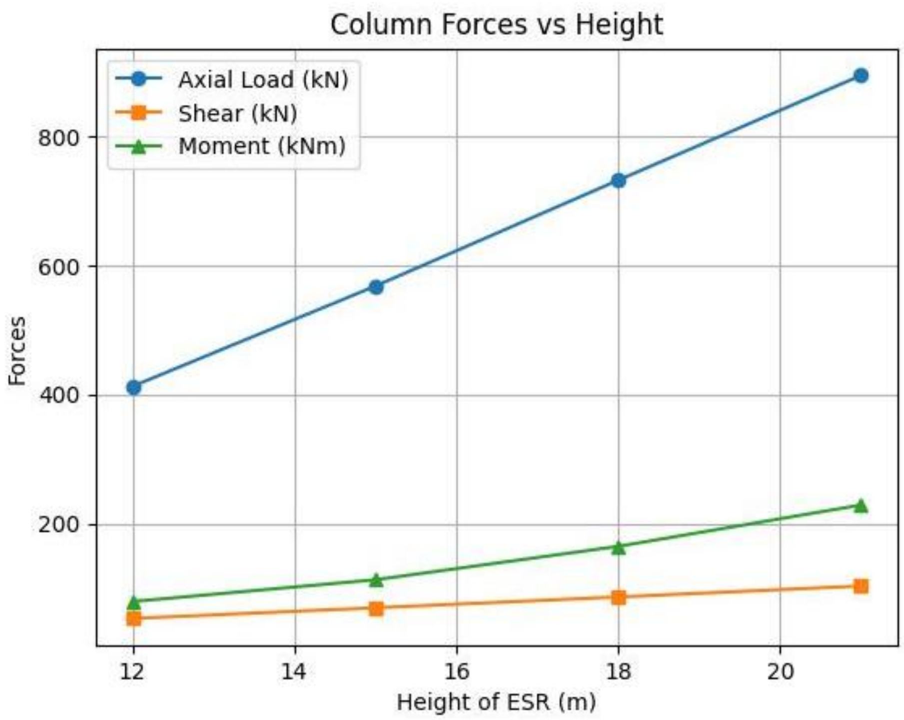
Observation:

1. Base shear increases with seismic zone
2. Precast ESR reduces seismic forces due to lower weight

Column Force Results:

Table 4.3 Column Forces

Height	Axial Load (kN)	Shear (kN)	Moment (kNm)
12 m	412.5	52.3	78.6
15 m	568.2	68.9	112.4
18 m	732.6	85.7	164.2
21 m	895.4	102.8	228.5



Graph 4.3: Column Forces

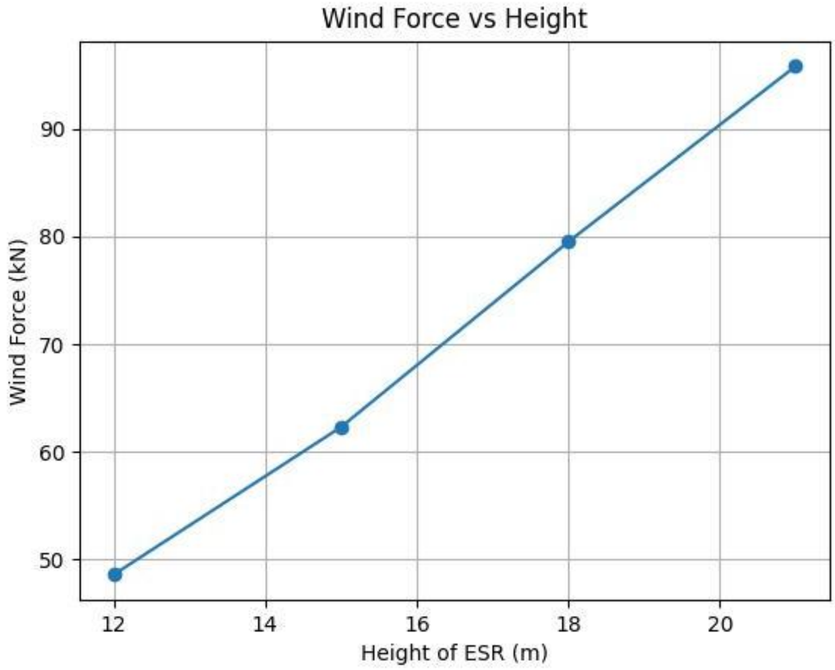
Observation:

1. Forces increase with height
2. All values are within safe design limits

Wind Load Effect:

Table 4.4 Wind Forces

Height	Wind Force (kN)	Governing Condition
12 m	48.6	Moderate
15 m	62.3	Moderate
18 m	79.5	High
21 m	95.8	Critical



Graph 4.4: Wind Forces

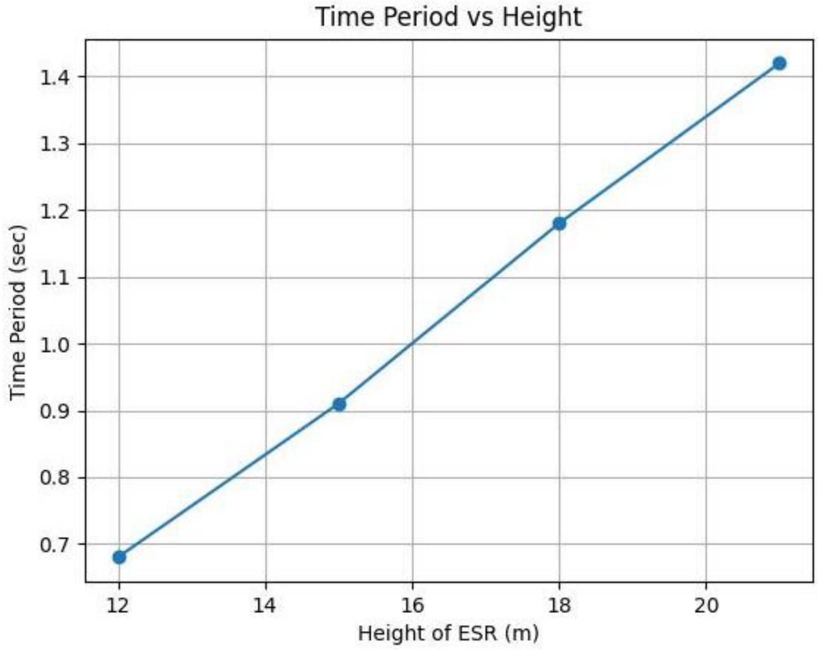
Observation:

- Wind governs design at higher heights
- Windward columns are critical

TIME PERIOD RESULTS:

Table 4.5 Time Period

Height	Time Period (sec)
12 m	0.68
15 m	0.91
18 m	1.18
21 m	1.42



Graph 4.5: Time Period

Observation:

- Time period increases with height
- Indicates flexibility increase

Comparison of RCC and Precast ESR:

Table 4.6 Comparative Analysis

Parameter	RCC ESR	Precast ESR
Self-Weight (kN)	1450	980
Base Shear (kN)	520	417
Displacement (mm)	38.5	32.18
Construction Time	7 months	3 months
Cost (₹ Lakhs)	28.5	21.8

CONCLUSION

Based on the detailed analysis, design, and comparison of the Elevated Service Reservoir (ESR) using precast staging and Galvalume tank system, the following conclusions are drawn:

1. The precast ESR system is found to be structurally safe and stable under all loading conditions including dead load, wind load, and seismic load.
2. The maximum displacement values obtained from analysis are within permissible limits, indicating adequate stiffness of the structure.
3. The base shear values are significantly reduced compared to conventional RCC ESR due to lower self-weight of precast components and Galvalume tank.
4. The use of lightweight Galvalume tank reduces the overall load on staging, resulting in improved seismic performance.
5. The H-frame modular staging system provides efficient load distribution and enhances structural stability.
6. The precast construction method ensures better quality control due to factory production of elements.
7. The total construction time is reduced by approximately 50%, making it suitable for time-bound projects like Jal Jeevan Mission.
8. The system is found to be economical, with cost reduction of about 20–25% compared to conventional RCC construction.

9. The design is highly suitable for rural and remote locations, as precast elements can be easily transported and assembled.
10. The ease of erection using cranes reduces labour dependency and improves safety at site.
11. The proposed system allows standardization of design, which can be used for different tank capacities and heights.
12. Overall, the precast ESR system is a modern, efficient, and practical solution for large-scale water supply infrastructure development under Jal Jeevan Mission.

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