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EFFECT OF HEIGHT-TO-DIAMETER RATIO ON BIN STABILITY AND COST

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Abstract
Storage bins are essential for industrial and agricultural applications, particularly for storing bulk materials such as grains, cement, and coal. The structural efficiency, material usage, and economic feasibility of such bins are heavily influenced by their geometric proportions. This study aims to compare the structural behavior and cost-effectiveness of shallow and deep bins with the same storage capacity under identical loading conditions using ETABS software. Six different models (three deep bins and three shallow bins) were analyzed, focusing on displacement, forces, bending moments, and material stresses. The study found that deep bins exhibit lower displacement and better structural stability, making them preferable in terms of space optimization and material efficiency. The research concludes that deep bins are more cost-effective than shallow bins due to their reduced surface area and material requirements.

Keywords: ETABS, Finite Element Method, Structural Analysis, Storage Bins, Seismic Load, Wind Load, Cost Optimization, IS Codes.

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1. Introduction

Storage bins, including silos and hoppers, are widely used to store granular materials in industries. The choice between deep and shallow bins is often dictated by space constraints, material requirements, and economic factors. Structural stability and cost efficiency are critical considerations, especially in seismic-prone regions. The objective of this research is to compare the performance of shallow and deep bins with equal storage volume under the same loading conditions using ETABS software.

Storage bins are subject to lateral and vertical forces, including wind, seismic activity, and material weight. Different geometries affect how these forces are distributed. Deep bins tend to have better vertical load distribution, while shallow bins experience higher lateral forces. This study helps in understanding these behaviors for optimized design.

2. Methodology

This study employs Finite Element Analysis (FEA) in ETABS to model and evaluate six different bin configurations. The models include:

2.1 Model Configurations:

- **Deep Bins:**
  - Diameter: 8m, Height: 13.5m
  - Diameter: 7m, Height: 17.6m
  - Diameter: 6m, Height: 24m
- **Shallow Bins:**
  - Diameter: 12m, Height: 6m
  - Diameter: 11m, Height: 7.15m
  - Diameter: 10m, Height: 8.64m

2.2 Load Considerations:

- **Dead Load & Live Load:** As per IS 875 (Part 1)
- **Seismic Load:** As per IS 1893-2002 for Zone III
- **Wind Load:** As per IS 875 (Part 3)

2.3 Material Properties:

Property	Value
Concrete Grade	M30
Steel Grade	Fe500
Unit Weight of Concrete	25 kN/m^3
Unit Weight of Steel	78.5 kN/m^3

The software was used to simulate stress distribution, displacement behavior, and force interactions under various load combinations.

3. Results and Discussion

3.1 Displacement Analysis

Deep bins showed lower displacement values compared to shallow bins, with maximum displacement values as shown below:

Bin Type	Diameter (m)	Height (m)	Max Displacement (mm)
Deep Bin(D1)	8	13.5	9.95
Deep Bin(D2)	7	17.6	10.68
Deep Bin(D3)	6	24	13.25

Shallow Bin(S1)	12	6	10.34
Shallow Bin(S2)	11	7.15	9.78
Shallow Bin(S3)	10	8.64	9.32

The increased displacement in shallow bins is attributed to their lower height-to-diameter ratio, leading to a higher lateral pressure impact.

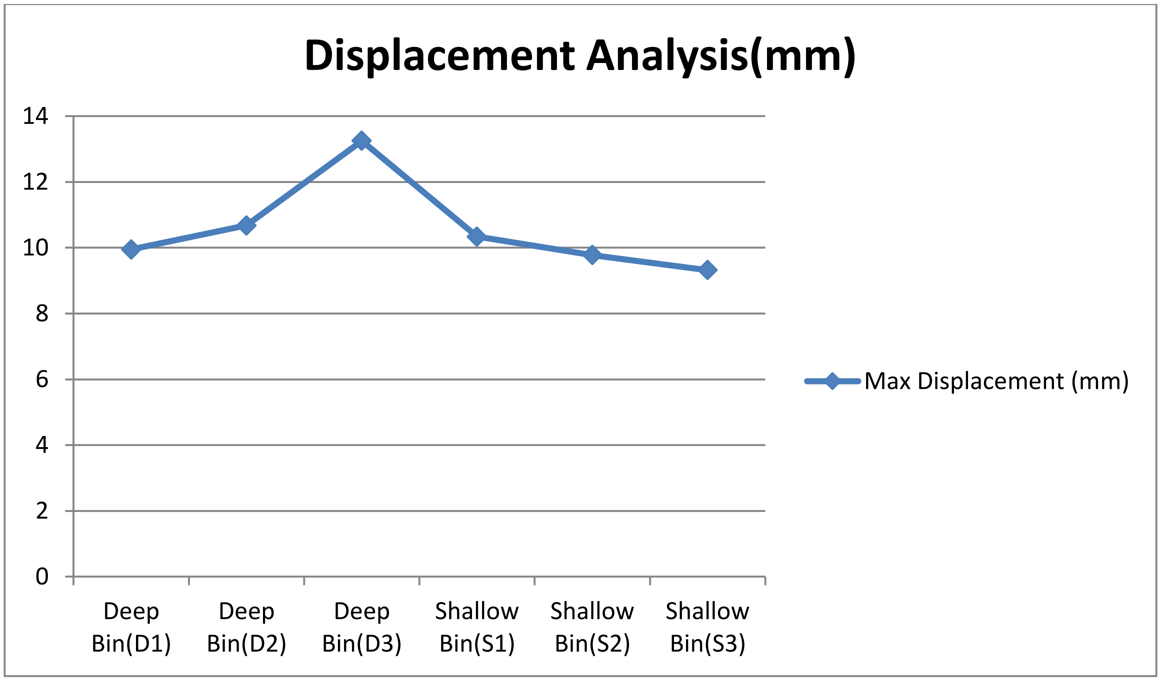

Fig. 1 Displacement Analysis

3.2 Stress and Force Analysis

Bin Type	Diameter (m)	Height (m)	Max Bending Moment (kNm)	Max Shear Force (kN)
Deep Bin(D1)	8	13.5	450	120
Deep Bin(D2)	7	17.6	520	135
Deep Bin(D3)	6	24	610	150

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Shallow Bin(S1)	12	6	700	180
Shallow Bin(S2)	11	7.15	680	170
Shallow Bin(S3)	10	8.64	650	160

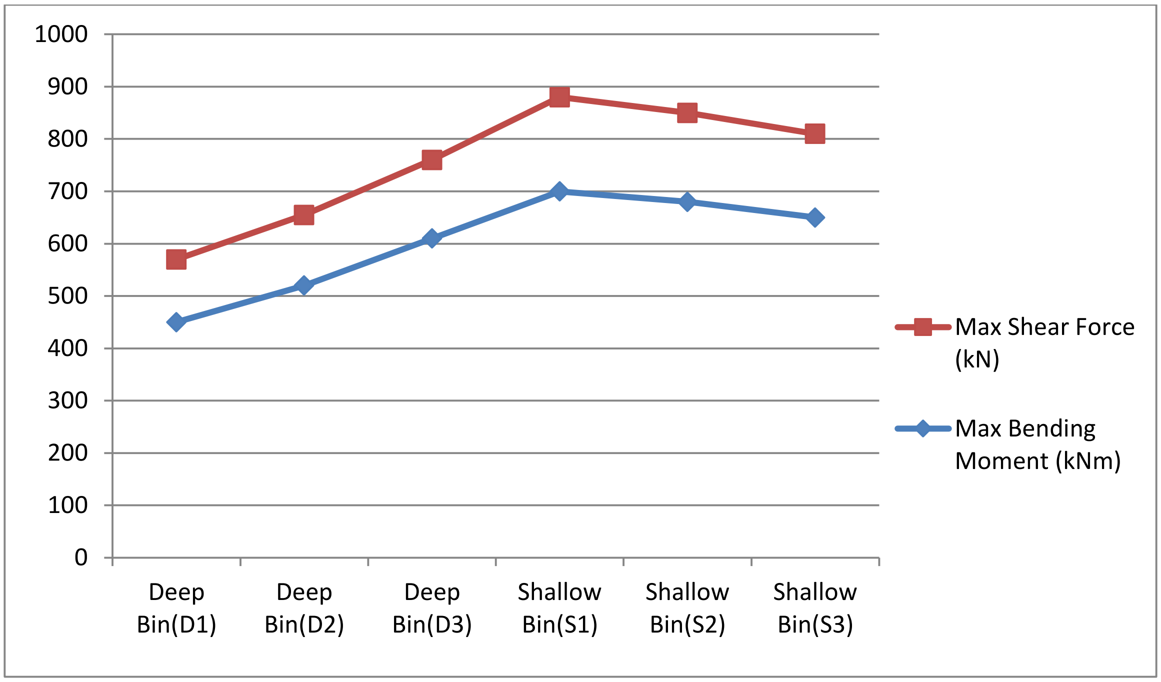
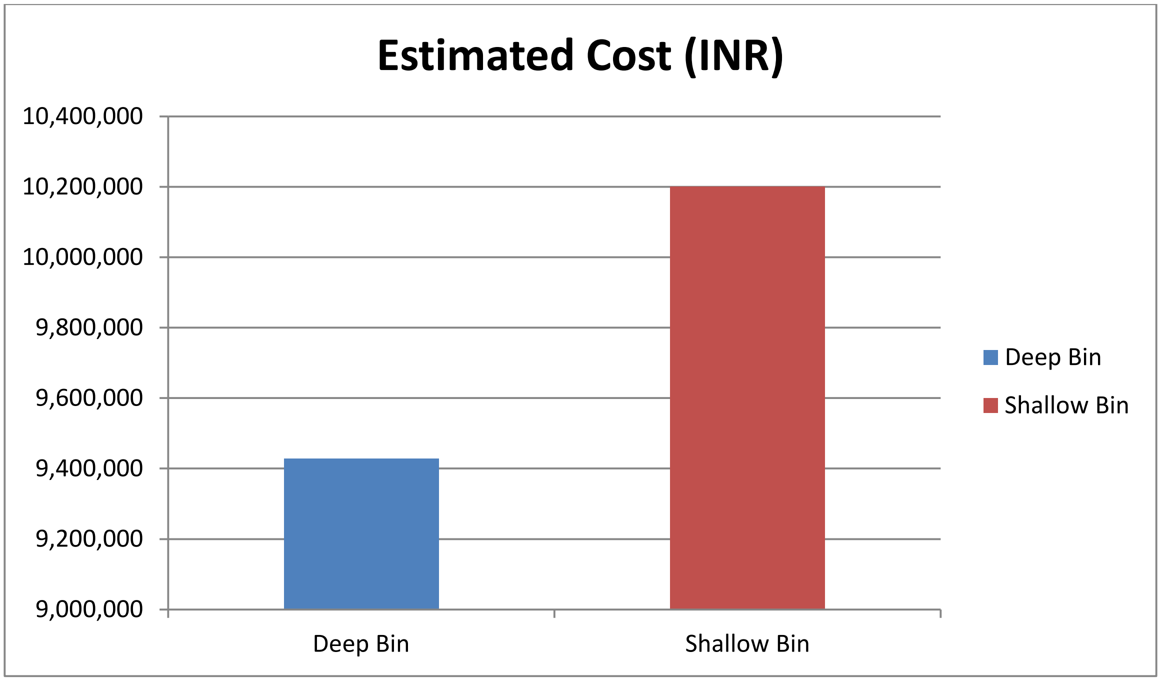


Fig. 2 Max Bending Moment (kNm) and Max Shear Force (kN)

Deep bins distributed vertical loads more efficiently, reducing stress concentrations at the foundation. Shallow bins required additional reinforcement to withstand lateral loads.

3.3 Cost Comparison

Bin Type	Concrete Volume (m^3)	Steel Requirement (kg)	Estimated Cost (INR)
Deep Bin	678.24	81200	9,427,536
Shallow Bin	678.24	90,000	10,200,000



Deep bins required **less reinforcement steel per unit volume** due to better load distribution, making them more cost-effective.

4. Conclusion

This study confirms that deep bins offer better **structural performance and cost-effectiveness** compared to shallow bins. Their **reduced surface area**, **lower displacement**, and **better load distribution** make them the preferred choice for storage applications. Deep bins require **less reinforcement** and provide **higher seismic resistance**, making them more sustainable in the long run. Future research can focus on optimizing reinforcement detailing and incorporating soil-structure interaction for more refined results.

References

1. IS 875 (Part 1 & 3): Indian Standard Code for Structural Load Considerations.
2. IS 1893-2002: Seismic Design Guidelines for Structures.
3. ETABS User Manual for Finite Element Analysis.
4. Various Research Papers on Structural Optimization of Storage Bins.