Optimizing Lightweight and Cost-effective **Load Bearing Precast** Building Envelope

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Introduction

Problem Statement

The construction industry encounters challenges with the **weight** of load bearing precast building envelope components and the **substantial expenses associated with customization**. Stakeholders, including **users**, **manufacturers**, and **contractors**, seek lightweight precast elements and affordable customization alternatives.

Constraints

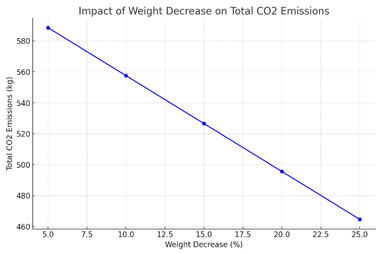
Constraint Category	Details
Structural Integrity	**Limitation in Reducing Weight**: Ensuring strength and stability while reducing weight of precast elements.
Material Availability and Cost	**Cost Implications**: Balancing benefits of lightweight aggregates/advanced admixtures with their impact on budget.
Production Processes	**Quality Control**: Maintaining consistency in products to ensure structural performance amid changes.
Regulatory Compliance	**Building Codes and Standards**: Adherence to local and international regulations may limit weight reduction.
Technological Limitations	**Current State of Technology**: Application of new materials/methods limited by industry capabilities and knowledge.
Load Bearing Design	Main source of customer pain due to heavy weight, compared to alternatives for non-load bearing panels.

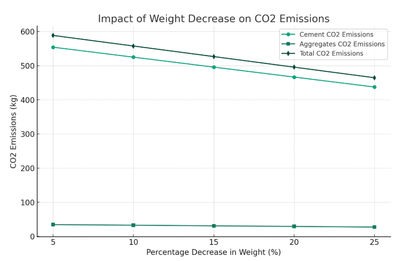
Target Specifications

Specification	Details
Aggregate Standards	**ASTM C330**
Strength Requirement	**Not less than 30 MPa** for structural elements as per Saudi Building Code
Fire Resistance Rating	**2 hours** for structural precast elements
Water/Cement Ratio and Cement Content	**Maximum w/c of 0.5** for severe exposure, **0.6 for moderate exposure**, with a minimum cement content of 350 kg/m³
Dimensional Tolerances	As per SASO standards, including tolerances for length, width, thickness (ranging from **+/- 3mm to +/- 8mm**), and hole locations and sizes (**+/- 5mm**)
Concrete Cover Thickness	**Minimum of 40mm**, in accordance with SBC Section 6.3 and relevant SASO standards

Project Impact

Sensitivity Analysis





Decrease	Cement CO2 (kg)	Aggregates CO2 (kg)	Total CO2 (kg)
5%	554.04	34.47	588.51
10%	524.88	32.66	557.54
15%	495.72	30.84	526.56
20%	466.56	29.03	495.59
25%	437.40	27.22	464.62

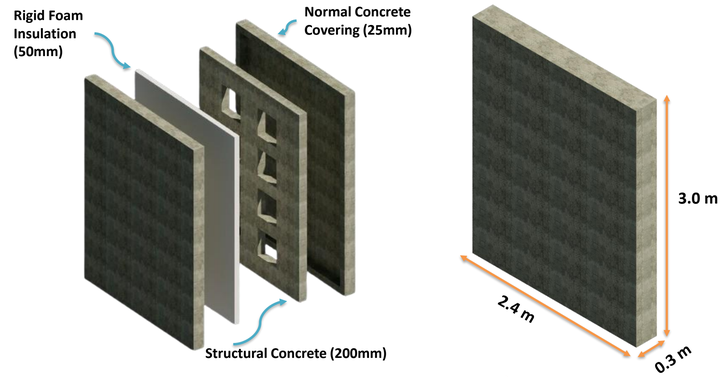
Prototype Design

Design Parameters

- **Compressive strength** 30 MPa
- **Water to cement ratio** 0.4
- **Yield strength (Fy) of the steel** 420 MPa
- **Concrete density** 2400 Kg/m3

Design Values

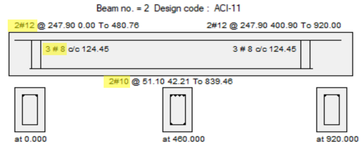
- **Dead Load:** Self weight + 13.69 KN/m (Assuming hollow core slab flooring).
- **Live Load:** 50.75 KN/m (Maximum capacity of the hollow core slab).



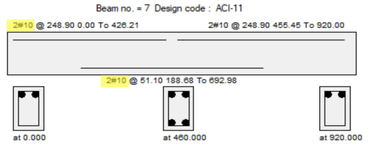
Final Optimized Design

Reinforcement Details:

Top Beam

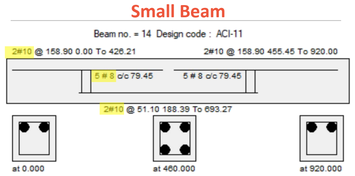


Bottom Beam

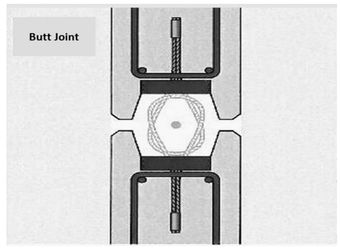


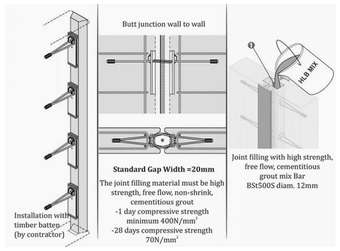
Small Beam

Columns Don't Need Reinforcement.



Types of Connections (wall To side wall)





Advantages

1) Good shear transfer.
2) Rigid connection.
3) Connections protected with grout.

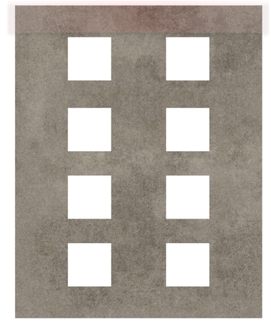
Disadvantages

1) Thermal bridging (thermal insulation discontinuity).

Analysis

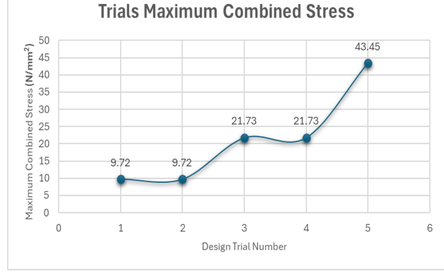
Parameter	Measurement
Assembly total Volume	1.89 m^3
Cross section of Columns	0.2m x 0.5m
Cross section of Top & Bottom Beams	0.2m x 0.3m
Small beams	0.2m x 0.23m
Voids size	0.41m x 0.41m
Maximum combined stress	1.97 N/mm²
Percentage of volume reduction	12.5%
Percentage of Weight reduction	27.3% (Compared to normal precast)
Total Assembly weight	3770 kg
Inner Layer Weight (including Reinforcement)	2700 kg
Concrete Covering Weight	1058 kg
Insulation Board Weight (5cm Thick – 35 kg/m³)	12 kg

Inner Layer Final Layout

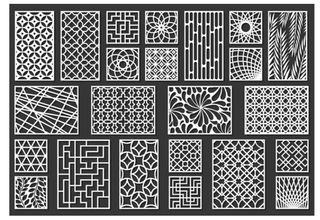


Follow-Up Tests

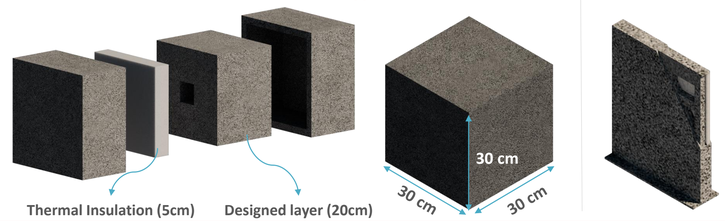
Precast Wall Stress Graph



Aesthetic Elements design



Prototype



Conclusion

In summary, optimizing lightweight and cost-effective load-bearing precast building envelopes offers a compelling solution for enhancing construction efficiency and affordability without compromising structural integrity.

Future Work

Future work may concentrate on durability studies, construction time reduction methods, and sustainable material alternatives to advance lightweight, cost-effective load-bearing precast building envelope systems.

Acknowledgement

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