DESIGN AND TESTING OF STRUCTURAL STEEL BEAM SUPPORTING SCAFFOLDING IN ELEVATOR MACHINE

Prepared :

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Problem Statement

The Aspire Huai Khwang Project is a 34-storey reinforced concrete building. The elevator machine room of Building A, at +113.30 m (FFL.), has little space and must carry machinery loads. During floor construction, temporary scaffolding carried workers and equipment, and its loads went to structural steel beams that passed them to the main structure.

Leftover steel sections from earlier work on site were still usable, so reusing them for the scaffolding support beams could cut cost and waste. This project designs those beams from the available sections, analysing load transfer from the scaffolding to the beams, to use resources efficiently while keeping workers safe.

Design Objectives

1. To study the design of structural steel beams for supporting scaffolding at the elevator machine room floor.
2. To study the load transfer behavior from imposed loads to the structural steel beams.
3. To utilize available materials within the project for maximum benefit.

Design Specs

1. Design Loads
   a. Dead Load
- Reinforced concrete unit weight = 2,400 kg/m³
- Self-weight of formwork and falsework not less than 50 kg/m²

   b. Live Load not less than 245 kg/m²
- Weight of workers, equipment, and miscellaneous construction tools
- Weight of construction materials and residual concrete debris
- Impact and vibration effects resulting from concrete placement operations

2. Structural Steel Material Properties
   Steel grade: ASTM A36
- Yield Stress, = 2,500 kg/cm²
- Tensile Strength, = 4,000 kg/cm²
- Elastic Modulus, = 2.04 × 10^6 kg/cm²

Design Constraints

Technical Constraints

- Limited working space at the elevator machine room floor
- Structural steel sections had to satisfy strength and deflection requirements
- Construction loads varied depending on construction activities

Non-Technical Constraints

- Limited project budget
- Need to reuse existing materials available on site
- Construction safety requirements for workers and operations

Engineering Standards

Design Method

- AISC-ASD89 Standard (1989)
- Structural Steel Design Standard for Building Structures (B.E. 2540)

Key Courses Used in the Project

- Structural Analysis: reactions
- Steel Design: H150 beams, AISC ASD

On-Site Construction Actual






Design Approach

Load Transfer Calculation

Total design load for the elevator machine room floor:

- Floor slab weight:
  - Slab thickness = 0.25 m
  - Floor width = 2.4 m
  - Floor length = 7.6 m
  - Slab weight = 2,400 × 0.25 × 2.4 × 7.6 = 10.98 tons
- Live load:
  - Live load = 0.245 ton/m²
  - Area = 2.4 × 7.6 m
  - Live load = 0.245 × 2.4 × 7.6 = 4.47 tons
- Formwork (Plank) weight:
  - Plank thickness = 0.02 m, width = 2.4 m, length = 7.625 m
  - Plank weight = 0.5 × 0.02 × 2.4 × 7.625 = 0.183 tons
- Steel box section (upper layer):
  - Size: 50×100 mm, spaced at 200 mm c/c, unit weight = 5.16 kg/m
  - Number of sections = 2.4 / 0.2 = 12 pieces
  - Weight = 12 × 7.625 × 5.16 = 0.472 tons
- Steel box section (lower layer):
  - Size: 50×100 mm, spaced at 200 mm c/c
  - Number of sections = 12 pieces
  - Weight = 12 × 2.4 × 5.16 = 0.149 tons
- Scaffolding weight:

1.9 m scaffolding frames (50 kg/set):

  - 2 layers × 6 bays (longitudinal) × 3 bays (transverse) = 36 legs
  - Weight = (50/4) × 36 = 0.450 tons

1.2 m scaffolding frames (36 kg/set):

  - 1 layer × 6 bays × 3 bays = 18 legs
  - Weight = (50/4) × 18 = 0.162 tons
  - Total scaffolding weight = 0.450 + 0.162 = 0.612 tons
- Total design load = 10.98 + 0.183 + 0.472 + 0.149 + 0.612 + 4.47 = 16.416 tons

The design employs 6 primary steel beams to support the temporary floor system.

- Load per beam:

W = 16.416 / 6 = 2.736 tons

Tributary area distribution:

- R_1 = (0.625 / 2.4) × W = 0.26W → R_1 = 0.26 × 2.736 = 0.711 tons
- R_2 = (1.15 / 2.4) × W = 0.48W → R_2 = 0.48 × 2.736 = 1.313 tons
- R_3 = (0.625 / 2.4) × W = 0.26W → R_3 = R_1 = 0.711 tons



Free Body Diagrams

- Support reactions (Simply Supported conditions):

Taking moments about A : $\sum M_A = 0$

- R_{by} = [0.711(0.05) + 1.313(1.2) + 0.711(2.35)] / 2.4 = 1.368 tons

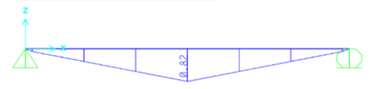
Vertical equilibrium :

- R_{Ay} = 1.368 − (0.711+1.313+0.711) = 1.368 tons

Shear Force Diagrams



Bending Moment Diagrams





Structural Steel Beam Design Calculation

- Step 1: Required Section Modulus ($S_x$required)
  - Allowable bending stress: F_b = 0.66F_y = 0.66 × 2,500 = 1,650 kg/cm²
  - Required section modulus: $S_x$required = M_{max} / F_b = 74,693.06 / 1,650 = 46.27 cm³

→ Select H150×150 section with properties as follows:

Nominal Size	Weight	Sectional Dimension					Sectional Area	Moment of Inertia		Radius of Gyration		Modulus of Section	
		H	B	t1	t2	r		I_x	I_y	R_x	R_y	S_x	S_y
in.	m./in.	in.	in.	in.	in.	in.	in.²/cm.	in.⁴	in.⁴	in.	in.	in.³/cm.	in.³/cm.
150*150	31.5	150	150	7	10	11	40.14	1640	563	6.4	3.75	219	75

- Step 2: Actual Bending Stress
  - f_b = M_{max} / S_x = 74,693.06 / 219 = 341.06 kg/cm²
- Step 3: Section Classification (Compact / Non-Compact)
  - Flange: b_f/ 2t_f = 150 / (2×10) = 7.5 ≤ 10.75 ✓
  - Web: d / t_w = 150 / 7 = 21.43 ≤ 107.99 ✓

→ Section classification: Compact Section

- Step 4: Lateral Bracing Check

L_c = min of:

- 0.444b_f√(E/F_y) = 0.444 × 15 × √(2.04×10^6 / 2,500) = 190.25 cm
- 0.69EA_f / (dF_y) = 0.69 × 2.04×10^6 × (15×1) / (15×2,500) = 593.04 cm

→ Controlling L_c = 190.25 cm

- Since L_b = 240 cm > L_c = 190.25 cm → Lateral bracing is insufficient; allowable bending stress F_b depends on L/r_T.
- L/r_T = 240 / (0.26×10) = 92.31, C_b = 1.0 (unbraced)

→ Check: √(3.517EC_b/F_y) ≤ L/r_T ≤ √(17.586EC_b/F_y) → 53.57 ≤ 92.31 ≤ 119.79 ✓, so the buckling equation governs.

- Lateral-Torsional Buckling (LTB) check: F_{bx} = [2/3 - F_y(L/r_T)² / (52.759EC_b)] F_y = [2/3 - 2,500×92.31² / (52.759×2.04×10^6×1)] × 2,500 = 1,171.84 kg/cm² ≤ 0.60F_y = 1,500 kg/cm²
- Torsion equation check: F_{bx} = 0.414E$C_b$$A_f$ / (Ld) = 0.414×2.04×10^6×1×15 / (240×15) = 2,815.2 kg/cm² > 1,500 → use 1,500

→ Controlling allowable bending stress = 1,171.84 kg/cm²

- Step 5: Bending Stress Verification

→ F_b = 1,171.84 kg/cm² > f_b = 341.06 kg/cm² ✓ PASS

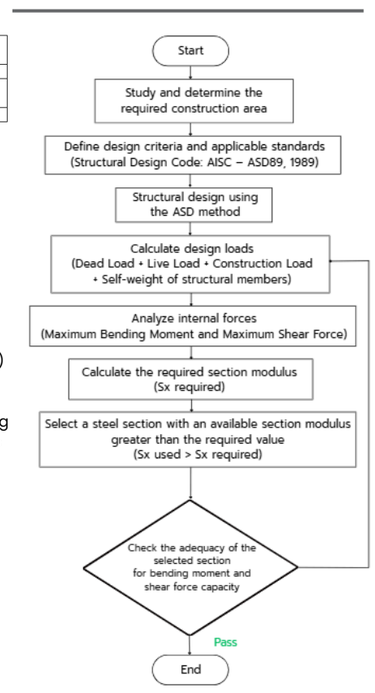
- Step 6: Shear Capacity Check
  - V_{max} = 1,368 kg
  - Actual shear stress: f_v = V / (d × t_w) = 1,368 / (15 × 0.7) = 130.29 kg/cm²
  - Web slenderness: h/t_w= 15/0.7 = 21.48 ≤ √(5E/F_y) = 63.58 ✓
  - Allowable shear stress: F_v = 0.40F_y = 0.40 × 2,500 = 1,000 kg/cm²

→ F_v = 1,000 > f_v = 130.29 kg/cm² ✓ PASS

- Step 7: Deflection Check
  - Δ_{all} = Δ_1 + Δ_2 = P_{center}·L^3/(48EI) + P_a/(24EI)·(3L^2 - 4a^2) =[1,313×240³/(48×2.04×10^6×1,640)]+ [711×5/(24×2.04×10^6×1,640)×(3×240²-4×5²)] = 0.121 cm
  - Allowable deflection: Δ_{allow} = L/360 = 240/360 = 0.67 cm

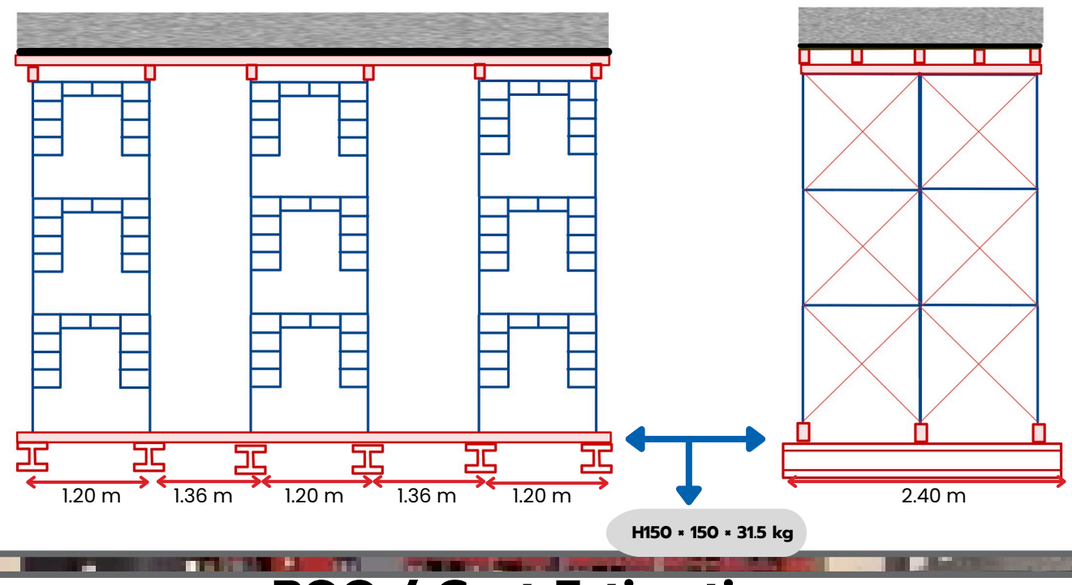
→ Δ_{all} = 0.121 < 0.67 cm ✓ PASS

- Step 8: Web Bearing Check
  - Web Yielding (midspan concentrated load): R / [t_w(N + 5k)] = 1,313 / [0.7×(10 + 5×2)] = 93.79 kg/cm² ≤ 0.66F_y = 1,650 ✓ PASS
  - Web Yielding (end reaction): R / [t_w(N + 2.5k)] = 1,368 / [0.7×(10 + 2.5×2)] = 130.29 kg/cm² ≤ 1,650 ✓ PASS
  - Web Crippling:R = 0.20t_w^2[1 + 3(N/d)(t_w/t_f)^1.5]√(EF_y·t_f/t_w) =0.20×1²×[1+3×(10/15)×(1/0.7)^1.5]× √(2.04×10^6×2,500×0.7/1) = 52,758.06 kg > 1,368 kg ✓ PASS



Result

- H-section steel beam size H150 × 150 × 31.5 kg , quantity: 6 pieces



BOQ / Cost Estimation

BILL OF QUANTITIES

Project: Steel beams supporting scaffolding, elevator machine room, Aspire Huai Khwang Building A

No.	Description	Qty	Unit	Material (THB/unit)	Labour (THB/unit)	Amount (THB)
1	Main steel beams H-beam 150 × 150 × 7 × 10 mm (ASTM A36), 6 beams × 2.40 m	453.60	kg	33.00	10.00	19,504.80
2	Plywood formwork 20 mm (2.40 × 7.625 m)	18.30	m²	380.00	120.00	9,150.00
3	Upper steel box joists 50 × 100 mm (7.625 m long @ 0.20 m)	472.20	kg	34.00	8.00	19,832.40
4	Lower steel box joists 50 × 100 mm (2.40 m long @ 0.20 m)	148.56	kg	34.00	8.00	6,239.52
5	Scaffolding frames 1.9 m (36 legs: 2 tiers × 6 × 3)	9.00	sets	1,200.00	350.00	13,950.00
6	Scaffolding frames 1.2 m (18 legs: 1 tier × 6 × 3)	4.50	sets	850.00	250.00	4,950.00
	Direct cost (materials + labour)					73,626.72
	VAT				7%	5,153.87
	GRAND TOTAL					**78,780.59**

Conclusion and Recommendations

Conclusion

Six H150 x 150 x 31.5 kg beams were selected to temporarily support the elevator machine room floor, safely carrying the floor, materials and workers during construction. Reusing steel beams already on site saved procurement time, lowered cost and made installation and removal easier.

Recommendations

Temporary structure design is critical to construction safety, and using materials already in the project can greatly reduce construction cost.