COMPARATIVE STUDY ON ANALYSIS AND DESIGN OF STRUCTURAL STEEL ELEMENTS WITH INDIAN STANDARD CODES AND AMERICAN INSTITUTE OF STEEL CONSTRUCTION CODES

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Abstract: The intended satisfactory performance, safety, and attractiveness of a building are highly concerned in the field of structural engineering. The sustainability of a building towards loads, wind load, and seismic loads play a vital role in the designing of the construction. Safe, low-cost construction is always a big challenge for structural engineers in the countries like India. The aim of this project steel structure are analyzed and designed, in this project, the steel structure is analyzed using STAAD pro-2007 and validated by manual calculation. The minimum design load followed for American is AISC7-05 and for the seismic loads AISC 7-2005 and for the Indian structure IS 875, IS 1893 respectively. The steel structures are designed with the specifications of India IS 800-2007 and later with the specification of American AISC 360 – 05. To the American design, AISC 360 is applied for foundation and AISC 05 is given as connector design. In the case of Indian design IS 456, IS 800 -2007 are applied respectively. The bill of quantity and analysis for the comparison is based on the IS and later is AISC. An integrated comparative analysis especially stresses ratio in the structure and bill of quantity will help to take important decisions to construct an efficient building.


INTRODUCTION

Steel-framed buildings [SFB] are commonly in use for industrial purposes. SFB’s classified into three broad categories:

a) Warehouse and factory buildings.

b) Large span storage buildings.

c) Heavy industrial process plant structures.

VARIOUS COMPONENTS OF THE BUILDING

i. Truss members [TM]

ii. Purlins [P]

iii. Beams connecting the trusses to form bays. [B-FB]

iv. Galvanized iron corrugated or profiled sheets [GIC]

v. Columns made up of RCC [CRCC]

vi. External walls of 30cm thick brick [WALL]

TYPES OF STRUCTURAL STEEL

i. Beams

ii. Channels
LIMIT STATE DESIGN IN IS
A Civil Engineering Designer has to ensure that the structures and facilities he designs are
i. Fit for their purpose [FP]
ii. Safe [S]
iii. Economical and durable [ED]

The uncertainties affecting the safety of a structure are due to
i. Uncertainty about loading [UAL]
ii. Uncertainty about material strength [UMS]
iii. Bending moments [B.M.]

LIMIT STATE DESIGN IN AISC
Allowable Strength Design (ASD).

Modeling of The Structure
The steel structure model Geometry is prepared in STAAD Pro which is followed be Analysis and Design

Figure 1 Geometry Properties of Plinth Beam Layout

Figure 2 Section and elevation
ANALYSIS CRITERIA AND ASSUMPTIONS

Analysis procedure and criteria for the analysis are in accordance with design basis. The roof truss and connections are designed in accordance with IS 800-2007 and AISC 360-09 general construction in steel-code of practices.

Analysis Software

The structural analysis is performed using the Bentley’s STAAD Pro software, which is based on finite element analysis technique.

System of Units

Length - Meters (m)
Force - kilo Newton (kN)
Moment- kilo Newton meter (kN-m)
Stress - MPa or N/mm²

Steel Material

The material properties of the structural steel members are as listed below.
Young’s modulus, E - 310,000N/mm²
Shear Modulus, G - 80,000 N/mm²
Density - 7850 kg/m³
Poisson’s ratio - 0.3
Coefficient of Thermal Expansion- 11.7 x 10⁻⁶/°C

Coordinate System

The structure has been aligned 00 to the True North. The principal axes in STAAD Pro are oriented as given below:

The X global axis is towards east
The Y global axis is pointing to upward.
The Z global axis is towards north
ANALYSIS & DESIGN

BUILDING SPECIFICATION:

Site Location: Thiruvallur (Chennai)
Purpose: WARE HOUSE
Type of structure: STEEL
Length of the building (l): 102.3 m
Width of the building (w or b): 75 m
Height of the building (h): 14.8 m

Soil Report Recommendations
Type of Foundation: Isolated
Safe Bearing Capacity: 17 t/m²
Depth of Foundation: 2.5 m

Calculation of Dead Load & Live Load on Mezzanine Floor

Table 1 (as per IS-875(part1&2) Dead load & Imposed Loads)

<table>
<thead>
<tr>
<th>Dead Load (as per 875 P1)</th>
<th>Thickness (m)</th>
<th>Unit weight kN/m²</th>
<th>Total load Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead load of the slab (175mm tk)</td>
<td>0.175</td>
<td>25</td>
<td>4.375 kN/ m²</td>
</tr>
<tr>
<td>Floor Finish Ceiling Plastering</td>
<td>0.05</td>
<td>21</td>
<td>1.05 kN/ m²</td>
</tr>
<tr>
<td></td>
<td>0.012</td>
<td>21</td>
<td>0.25 kN/ m²</td>
</tr>
<tr>
<td>TOTAL Dead Load</td>
<td></td>
<td></td>
<td>5.675 kN/ m²</td>
</tr>
<tr>
<td>Live Load on Mezzanine</td>
<td></td>
<td></td>
<td>1 t/m²</td>
</tr>
</tbody>
</table>

LOADS ON TRUSS

Dead Load & Live Load

Dead load is taken as 400 kg/ m²
AS PER IS 875 PART I
Live load is taken as 750 kg/ m²
AS PER IS 875 PART II

Wind Load Calculations:
(as per is 875 part iii-1987)
Length of the building (l) = 102.3 m
Width of the building \((w)\) = 75 m
Height of the building \((h)\) = 14.8 m
Angle of slope \((\theta)\) = 3°
\(h/w = 14.8/75 = 0.20\) IS875-(Part 3)
Basic wind speed \(V_b = 50\) m/Sec (table 2)
\(K_1 = 1.08\) (clause 5.3.3.1)
Cat-2 class - c \(K_2 = 0.97\) (clause 5.3)
\(K_3 = 1.00\) (clause 5.4)
Design wind speed \(V_z = V_b \times K_1 \times K_2 \times K_3\)
\(= 50 \times 1.08 \times 0.97 \times 1.00\)
\(= 52.8\) m/s
Design wind pressure \(P_z = 0.6V_z^2\)
\(= 0.6 \times 52.38^2\)
\(= 1646.19864\) N/m²
\(= 1.65\) kN/m²

### Table 2 External pressure

<table>
<thead>
<tr>
<th></th>
<th>EF</th>
<th>GH</th>
<th>EG</th>
<th>FH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>-0.900</td>
<td>-0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90°</td>
<td></td>
<td>-0.8</td>
<td>-0.4</td>
<td></td>
</tr>
</tbody>
</table>

Internal pressure co-efficient \(C_{pi} = \pm 0.5\) (clause 6.2.3.2)
External pressure co-efficient (cpe) \(h/W < \frac{1}{2}\)
\(\theta = 90\) Wind is acting + z direction
Wind load \(= (C_{pe} - C_{pi})\)

### Table 3 Wind load in+ Z direction (\(\theta = 90\)) due to +ve internal pressure

<table>
<thead>
<tr>
<th>Bay of wall (m)</th>
<th>Factor ((C_{pe} - C_{pi}))</th>
<th>Pressure ((\text{kN/m}^2))</th>
<th>Wind load ((\text{kN/m}))</th>
<th>Point Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windward</td>
<td>3.8</td>
<td>-1.3</td>
<td>1.65</td>
<td>-8.132</td>
</tr>
<tr>
<td>Leeward</td>
<td>7.6</td>
<td>-0.9</td>
<td>1.65</td>
<td>-11.26</td>
</tr>
<tr>
<td>Leeward</td>
<td>9.35</td>
<td>-0.9</td>
<td>1.65</td>
<td>-13.853</td>
</tr>
<tr>
<td>Leeward</td>
<td>4.675</td>
<td>-0.9</td>
<td>1.65</td>
<td>-6.926</td>
</tr>
</tbody>
</table>

### Table 4 Wind load in- Z direction (\(\theta = 90\)) due to +ve internal pressure

<table>
<thead>
<tr>
<th>Bay of wall (m)</th>
<th>Factor ((C_{pe} - C_{pi}))</th>
<th>Pressure ((\text{kN/m}^2))</th>
<th>Wind load ((\text{kN/m}))</th>
<th>Point Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee</td>
<td>3.8</td>
<td>-0.9</td>
<td>1.65</td>
<td>-5.630</td>
</tr>
<tr>
<td>Lee</td>
<td>7.6</td>
<td>-0.9</td>
<td>1.65</td>
<td>-11.260</td>
</tr>
<tr>
<td>Lee</td>
<td>9.35</td>
<td>-0.9</td>
<td>1.65</td>
<td>-13.853</td>
</tr>
<tr>
<td>Wind</td>
<td>4.675</td>
<td>-1.3</td>
<td>1.65</td>
<td>-10.005</td>
</tr>
</tbody>
</table>
Table 5 Wind load in +X direction (θ = 0) due to +ve internal pressure

<table>
<thead>
<tr>
<th>Bay of wall (m)</th>
<th>Factor (Cpe-Cpi)</th>
<th>Pressure (kN/m²)</th>
<th>Wind load (kN/m)</th>
<th>Point load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>3.8</td>
<td>-1.4</td>
<td>1.65</td>
<td>-8.758</td>
</tr>
<tr>
<td>Wind</td>
<td>7.6</td>
<td>-1.4</td>
<td>1.65</td>
<td>-17.516</td>
</tr>
<tr>
<td>Wind</td>
<td>9.35</td>
<td>-1.4</td>
<td>1.65</td>
<td>-21.549</td>
</tr>
<tr>
<td>Lee ward</td>
<td>4.675</td>
<td>-1.4</td>
<td>1.65</td>
<td>-10.774</td>
</tr>
<tr>
<td>Lee ward</td>
<td>3.8</td>
<td>-0.9</td>
<td>1.65</td>
<td>-5.630</td>
</tr>
<tr>
<td>Lee ward</td>
<td>7.6</td>
<td>-0.9</td>
<td>1.65</td>
<td>-11.260</td>
</tr>
<tr>
<td>Lee ward</td>
<td>9.35</td>
<td>-0.9</td>
<td>1.65</td>
<td>-13.853</td>
</tr>
<tr>
<td>Lee ward</td>
<td>4.675</td>
<td>-0.9</td>
<td>1.65</td>
<td>-6.926</td>
</tr>
</tbody>
</table>

LOAD COMBINATIONS
Dead load + Live load
Dead load + Live load + Wind load
Dead load + Live load + Wind load + X
Dead load + Live load + Wind load - X
Dead load + Live load + Wind load + Z
Dead load + Live load + Wind load - Z
Dead load + Wind load + X
Dead load + Wind load - X
Dead load + Wind load + Z
Dead load + Wind load - Z
Dead load + Seismic load + X
Dead load + Seismic load + Z

APPLICATION OF POINT WIND LOAD ON TRUSS ALONG +Z DIRECTION (WIND WARD & LEE WARD)

Figure 6 Applications of Wind Load +Z Direction (WW&LW)

SEISMIC LOAD (AS PER IS 1893 – 2002 PART II)
Zone factor: Z = 0.16
Response reduction factor: R.F = 3
Importance Factor I = 1
Rock & Soil site factor: SS = 1
Type of structure: ST = 2
Damping ratio: DM = 0.02
Figure 7 Application Of Dead Load & Live Load:

**COMPARISON OF STEEL FRAME (IS Code & AISC Code)**

<table>
<thead>
<tr>
<th>Std. Code</th>
<th>Section Size</th>
<th>Working Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS</td>
<td>ISMB300</td>
<td>2387.474 kN</td>
</tr>
<tr>
<td>AISC</td>
<td>W18X46</td>
<td>3185.78 kN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Std. Code</th>
<th>Section Size</th>
<th>Yielding Strength (kN)</th>
<th>Rupture Strength (kN)</th>
<th>Shear Strength (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS</td>
<td>IS100X100X8</td>
<td>426.36,63</td>
<td>450.38kN</td>
<td>355.87kN</td>
</tr>
<tr>
<td>AISC</td>
<td>L4X4X5/16</td>
<td>319.28</td>
<td>418.56kN</td>
<td>269.00kN</td>
</tr>
</tbody>
</table>

**COMPARISON OF ANALYTICAL PARAMETERS:**

<table>
<thead>
<tr>
<th>Beam No:</th>
<th>Deflection (mm)</th>
<th>As Per IS</th>
<th>As Per AISC</th>
</tr>
</thead>
<tbody>
<tr>
<td>108</td>
<td>20</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>213</td>
<td>25</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>215</td>
<td>43</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>230</td>
<td>31</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>345</td>
<td>18</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>
**Table No. 9** Axial force due to load combination (kN)

<table>
<thead>
<tr>
<th>Beam No.</th>
<th>Axial force(kN)</th>
<th>As Per IS</th>
<th>As Per AISC</th>
</tr>
</thead>
<tbody>
<tr>
<td>108</td>
<td>336</td>
<td>313</td>
<td></td>
</tr>
<tr>
<td>213</td>
<td>329</td>
<td>311</td>
<td></td>
</tr>
<tr>
<td>215</td>
<td>124</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>230</td>
<td>345</td>
<td>321</td>
<td></td>
</tr>
<tr>
<td>345</td>
<td>322</td>
<td>296</td>
<td></td>
</tr>
</tbody>
</table>

**Table No. 10** Bending moments due to load combination

<table>
<thead>
<tr>
<th>Beam No.</th>
<th>Bending Moments (kN-m)</th>
<th>As Per IS</th>
<th>As Per AISC</th>
</tr>
</thead>
<tbody>
<tr>
<td>108</td>
<td>1487</td>
<td>1398</td>
<td></td>
</tr>
<tr>
<td>213</td>
<td>1363</td>
<td>1311</td>
<td></td>
</tr>
<tr>
<td>215</td>
<td>1278</td>
<td>1199</td>
<td></td>
</tr>
<tr>
<td>230</td>
<td>1562</td>
<td>1487</td>
<td></td>
</tr>
<tr>
<td>345</td>
<td>1432</td>
<td>1378</td>
<td></td>
</tr>
</tbody>
</table>

**STRESS RATIO OF STEEL ELEMENTS**

**Table No. 11** Stress Ratio for Beam

<table>
<thead>
<tr>
<th>Beam No.</th>
<th>Stress Ratio</th>
<th>As Per IS</th>
<th>As Per AISC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.988</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.988</td>
<td>0.99</td>
<td></td>
</tr>
</tbody>
</table>

**Table No. 12** Stress Ratio for Column

<table>
<thead>
<tr>
<th>Beam No.</th>
<th>Stress Ratio</th>
<th>As Per IS</th>
<th>As Per AISC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.93</td>
<td>0.929</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.93</td>
<td>0.929</td>
<td></td>
</tr>
</tbody>
</table>

![Graphical Representation View](https://example.com/fig9.png)

**Fig:** 9 Graphical Representation View

The various operations of the structure have been analyzed perfectly and the Indian Standard and American Standard codes have been followed correctly. The use of the software Auto Cad enabled to plan the structure more efficiently. The loads are calculated by as per Indian standard 875-1987 Part I, II and American Standard Minimum Design Loads for Buildings and Other Structures ASCE SEI 7-05. The truss and steel elements like a beam, column towards dead loads; live load and Lateral loads have been analyzed using the software STAAD Pro. We propose that this building has adequate strength to resist all the loads and meet its purpose of storage of materials in its life span. STAAD analysis results show that the structure can resist various loads coming on to it.
REFERENCES

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4. Prof. S.R. Sathish Kumar and Prof. A.R. Santha Kumar, “Design of Steel a Structure”.

IS Codes
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2. IS 1893 – 2002: Seismic load
3. IS 875(part 1) – 1987: Dead Loads
4. IS 875 (part 2) – 1987: Imposed Loads
5. IS 875 (part 3) – 1987: Wind Loads
6. AISC 360-10 Specification for Structural Steel Buildings
7. ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures
8. Sectional Table.

Journals
2. Mr. Arijit Guha “IS: 800 - INDIAN CODE OF PRACTICE FOR CONSTRUCTION IN STEEL AND ITS COMPARISON WITH INTERNATIONAL CODES” Institute for Steel Development & Growth (INSDAG).