ANALYSIS AND DESIGN OF TURBINE BUILDING USING HIGH STRENGTH STEEL

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Abstract*: *Structural steel is advantageous material in construction industry because of its constructability and high strength to mass ratio. Steel frame is composed of structural steel members of different shape and size, which is connected with each other to transfer loads and provide complete rigidity against heavy loads. The advantages associated with the high strength steel is utilized in this study. Use of High Strength Steel (HSS) with increasing economic design requirements is increased and it also fulfills the most of structural requirements. Compatibility and sustainability of high strength steel needs to be analyzed. In this research, E450 and E350 grade steels have been used to design the turbine building. Dead, Live, Wind, Seismic and Crane loads are applied to the turbine building as per IS 875:1987, IS 875:2015, IS 1893(1):2002, and IS 1893(4):2005, respectively and designed as per specification given in IS 800:2007 using Staad.pro software. Built-up, Indian, and Jindal sections are provided to the structural elements. After the comparison of results of E350 and E450 grade steels, it is concluded that by using HSS, less amount of HSS steel is required as compare to conventional steel. Structural member size decreases and hence overall weight of the turbine building is reduced. Reduction of steel results in overall construction cost.

***Keywords*: Turbine building, High strength steel, Staad.pro software.**

(Article history: Received: 3rd May 2020 and accepted 25th June 2021)

I. INTRODUCTION

The steel structures are built from structural steel members of different shape and size. Steel differs from concrete in its characteristics, compressive strength and tensile strength. Due to high strength, hardness, ductile properties and stiffness of structural steel, it has now become significant material in construction industry. Many experimental studies executed on mechanical properties of High Strength Steel (HSS) to study the behavior of HSS under certain conditions. Li et al. [1] did an experimental study on HSS and observed that reduction in strength of HSS due to reheating should be considered in seismic design. Qiang et al. [2] also studied on mechanical properties of HSS after the fire. Wang et al. [3] studied temperature effect on strength and modulus of elasticity of HSS. Steel is perfect material for alteration, refurnishing, and expanding with negligible interruption. Steel structure is easily erected and it is connected by bolted or welded connections. Now a days, steel structure is pre-engineered, which is easy to assemble on construction site. In recent years, Rao and Vishwanath [4] carried out the optimization of steel structure from conventional steel frame to Pre-Engineered Building (PEB) structure and concluded that utilization of steel is less in PEB structure as compared to the conventional steel frame. Steel framed construction can withstand all kinds of external pressure such as wind, earthquake and thunderstorm. Steel structure requires low maintenance and it has long lifespan. Structural steel has been classified by The Bureau of Indian Standards (BIS) based on its ultimate strength or yield strength. The mechanical properties of steel largely depend upon its chemical compound, rolling methods, rolling thickness, thermal treatment and stress history. Primary substances such as carbon, Sulphur, phosphorus, manganese and silicon influence the mechanical properties of steel. Of these, mechanical properties of steel maximum are influenced by carbon.

A. Advantages of the steel structure

- Steel members have high strength to mass ratio. Therefore, a steel member of a compact size is able to withstand heavy loads, decrease space in construction and improving architectural view.
- Steel members can be easily lifted and transported. Therefore, pre-fabricated structure can be frequently provided and hence speed of construction can be achieved.
- It has a high durability and assured quality.
- Steel structure can be strengthened after some times, if necessary. It just includes the welding of additional member.
- By employing bolted connections, steel structure can be effortlessly demolished and transferred to the other site quickly.

- It could be the perfect water and gas resistant structure, if the joints were properly taken care. Hence, it can often be used to construct water tanks.
- Steel is reusable material.

B. Disadvantages of the steel structure

- When steel structure is built in exposed condition, it is subjected to corrosion.
- Steel structure needs fireproof treatment, which increases cost.
- Skilled labor is required.

STAAD.Pro is today the most widely used software tool in the civil engineering.

- STAAD Pro programming is broadly utilized as a part of the structural analysis and designing structures – towers, buildings, bridges, transportation facilities, utility and industrial structures. Designs can include building structures incorporating culverts, petrochemical plants, bridges, tunnels, piles; and construction materials such as timber, steel, concrete, aluminum and cold-formed steel.

Steel buildings and connections can also be designed and successfully rendered to view the real-life resembling images for detailed clarity.

II. Objectives of the Study

The main objectives of the study are:

- To analyze and design the turbine building using HSS.
- To estimate the load and material reduction when using HSS.
- To increase the usable floor area of the structure.
- To estimate the material saving in connection due to HSS.
- To enhance the structural performance under dynamic loading.

III. Methodology

This paper presents design of the turbine building using HSS E450 grade and conventional steel E350 grade. Dead, Live, Wind, Seismic and Crane loads are applied to the building and analysis is performed for the turbine building. After the analysis, structure is designed as per IS 800:2007 LSM in staad.pro using E450 and E350 grade steels and reduction in steel is calculated. The turbine building configuration is listed in Table 1.

IV. Modeling

Table 1 Data of the turbine building

Capacity	660 MW
Building Width (m)	42 AB bay – 30 BC bay – 12
Building Length (m)	124
Building Height (m)	AB bay – 32.20 BC bay – 34.50
Mezzanine floor height (m)	+ 9.00
Operating floor height (m)	+ 17.00
Deaerator floor height (m)	+ 25.40
Crane capacity	AB bay – 200 T BC bay – 50 T
Thickness of metal deck slab (m)	0.250
Effective depth of R.C.C. (m)	0.175
Thickness of wall (m)	0.230
Height of wall (m)	4.00
Thickness of screed (m)	0.05
Seismic zone	III
Basic wind speed, V_b (m/s)	47

Figure 1 indicates the plan of the turbine building and Figure 2 indicates the isometric view of the turbine building.

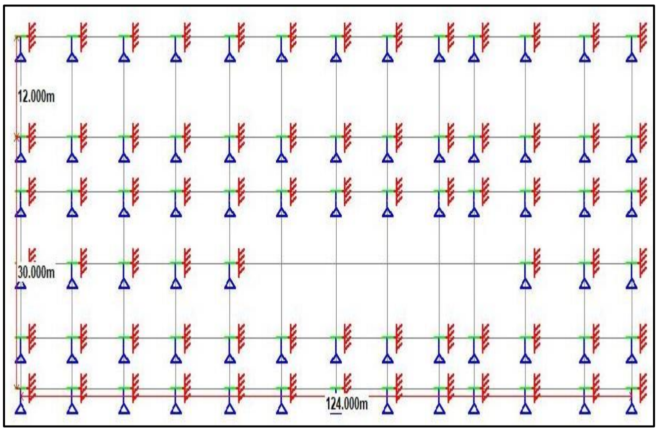

Figure 1 Plan of the turbine building

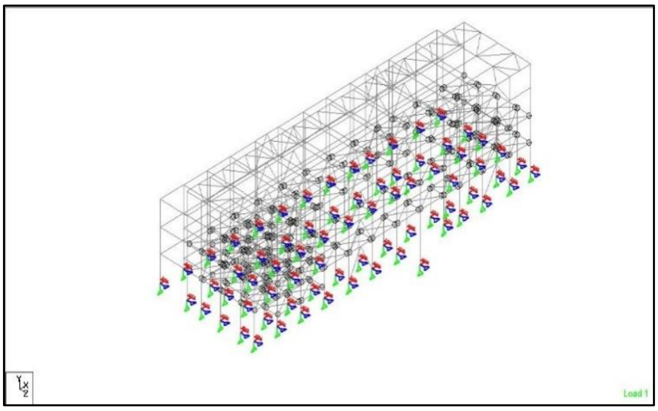

Figure 2 Isometric view of the turbine building

V. Load Calculation

A. Dead Load [5]

At +3.50 m, +9.00 m, +12.50 m, +17.00 m floor level:

Floor finish	= 1.20 kN/m^2
R.C.C.	= 4.375 kN/m^2
Metal sheet	= 0.1 kN/m^2
Secondary beam	= 1.0 kN/m^2
Total dead load	= 6.675 kN/m^2

At +32.20 m (AB bay):

Screed	= 1.20 kN/m^2
R.C.C.	= 1.625 kN/m^2
Metal sheet	= 0.1 kN/m^2
Total dead load	= 2.925 kN/m^2

At +25.40 m (BC bay – Deaerator floor):

Water proofing	= 3.00 kN/m^2
R.C.C.	= 4.375 kN/m^2
Metal sheet	= 0.1 kN/m^2
Total dead load	= 7.475 kN/m^2

On Column:

G.I. sheet	= 0.1 kN/m
Self weight of runners	= 0.5 kN/m
Total dead load	= 0.6 kN/m

B. Live Load [6]

AB bay = 1.5 kN/m^2 (At 3.5 m,9.0 m,12.5 m,32.20 m)
= 15 kN/m^2 (At 17.0 m)

BC bay = 1.5 kN/m^2 (At 3.5 m)
= 15 kN/m^2 (At 9.0 m, 25.40 m)
= 20 kN/m^2 (At 17.0 m)

C. Wind Load [7]

Wind load is calculated as per IS 875 (3):2015 and basic wind speed selected as major wind speed given in code.

Wind pressure at different height of the turbine building listed in Table 2.

Basic wind speed, V_b, (m/s) = 47
Terrain category = 3
Design life = 100 Years

$$V_z = k_1.k_2.k_3.k_4 \quad (1)$$

$$P_z = 0.6\, V_z^2 \quad (2)$$

k_1 = 1.07
k_3 = 1 (upwind slope <3°)
k_4 = 1
k_2 =

Table 2 Wind pressure

Ht. (m)	V_b (m/s)	k_1	k_2	k_3	k_4	V_z (m/s)	P_z (kN/m^2)
0	47	1.07	0.91	1	1	45.76	1.256
3.25	47	1.07	0.91	1	1	45.76	1.256
8.75	47	1.07	0.91	1	1	45.76	1.256
12.25	47	1.07	0.937	1	1	47.12	1.332
16.75	47	1.07	0.9825	1	1	49.40	1.464
25.15	47	1.07	1.04	1	1	52.30	1.641
32.50	47	1.07	1.056	1	1	53.10	1.692

D. Seismic Load [8-9]

Seismic load is applied to the structure as unidirectional. Seismic load has considerable effect in horizontal direction as X and Z. Here assumed that turbine building is located in earthquake region III. Seismic definition is applied according IS 1893(4):2005 in Staad pro.

- Zone factor = 0.16
- Response reduction factor = 5.0
- Importance factor = 1.75 (For category 2)
- Damping ratio = 0.02
- Rock and soil site factor = 2 (For medium soil)

E. Crane Load (200 T crane)

200 T crane is installed in AB bay to carry turbine auxiliaries and other machines. It is placed at +25.40 m height. It is the double girder EOT crane with two hooks. One is the main hook and another is the auxiliary hook. The data required for the crane load are listed in Table 3.

Table 3 200 T crane specification

Crane capacity	200 T
Crane type	Double girder EOT crane
Min. hook approach	1.5 m
Wheel base	6 m
No. of wheel	8
Self-wt. of girder	2000 kN
Wt. of Trolley, electric motor, hook, etc.	400 kN
Maximum wheel load [10-11]	820 kN

F. Crane Load (50 T) [12]

50 T crane data are directly taken from the vendor's broacher and listed in Table 4. 50 T crane is installed in BC bay to carry other auxiliaries and machines. It is placed at +9.0 m height.

Table 4 50 T crane specification

Crane capacity	50 T
Crane type	Double girder EOT crane
Min. hook approach	1.3 m
Wheel base	5.4 m
No. of wheel	4
Maximum wheel load	350 kN

G. Machine Load

The operating weight of the pressure heater is 120 T.
The operating weight of the deaerator is 800 T.

H. Load Combination [13]

1. 1.5 (DL+LL) + 1.05 CL
2. 1.2 (DL+LL) + 1.05 CL + 0.6 WLX
3. 1.2 (DL+LL) + 1.05 CL + 0.6 WLZ
4. 1.2 (DL+LL+EQ+X) + 0.53 CL
5. 1.2 (DL+LL+EQ+Z) + 0.53 CL
6. 1.2 (DL+LL+EQ-X) + 0.53 CL
7. 1.2 (DL+LL+EQ-Z) + 0.53 CL
8. 1.5 DL + 1.5 WLX
9. 1.5 DL + 1.5 WLZ
10. 1.5 DL + 1.5 EQ+X
11. 1.5 DL + 1.5 EQ-X
12. 1.5 DL + 1.5 EQ+Z

13. 1.5 DL + 1.5 EQ-Z
14. 0.9 DL + 1.5 EQ+X
15. 0.9 DL + 1.5 EQ-X
16. 0.9 DL + 1.5 EQ+Z
17. 0.9 DL + 1.5 EQ-Z

VI. EFFECTIVE LENGTH FACOTR FOR SIGNLE STEPPED COLUMN [13]

Figure 3 shows a single stepped column and for that effective length factor is calculated as per Annex-D and Table-36, IS 800:2007. Figure 3 shows the single stepped column.

$K_1 = 0.88$
$K_2 = 3$

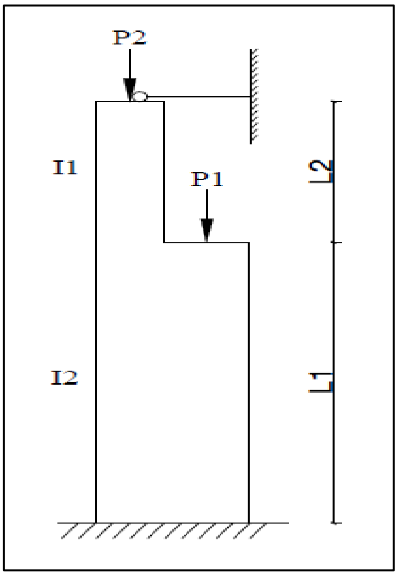

Figure 3 Single stepped column

VII. ANALYSIS OF THE TURBINE BUILDING

Shear force, bending moment, and axial force are important consideration for the design of the structure and therefore all the parameters are listed in Tables 5, 6 & 7 for the design of the turbine building.

Table 5 Shear force of the turbine building

Grade of steel [14]	Max. Shear force (kN)
E350	79,713.99
E450	73,658.58

Table 6 Bending of the turbine building

Grade of steel [14]	Max. Bending moment (kN.m)
E350	416.52×10^3
E450	327.24×10^3

Table 7 Axial force of the turbine building

Grade of steel [14]	Axial force (kN)
E350	525.54×10^3
E450	$437.33\ 10^3$

VIII. RESULTS

After the design of the turbine building quantity of steel is computed and listed in Table 8.

Table 8 Steel take off

Grade of steel [14]	Steel take-off (kN)	Steel take-off (T)
E350	1,80,57,382	18,05,738
E450	1,56,18,384	15,61,838

IX. OBSERVATION

When conventional steel is replaced by HSS steel there is improvement in structural performance under static and dynamic loading have been found. Also due to the reduced thickness of the proposed section, material saving can be insured which leads to cost saving. HSS also enhanced connection part of the structure, which is considered as weak part any structural member.

X. CONCLUSIONS

From this study, easily conveys that quantity of steel can be reduced using HSS.

- As HSS (E450) offers higher corrosion resistance and high strength to weight ratio, it is advantageous for the construction of steel turbine building.
- HSS reduces the structural member size which results into reduction of member weight and overall weight of the turbine building.
- This study presents that 14.50% reduction is achieved in steel quantity of the turbine building using HSS. Therefore, HSS offers reduction of steel quantity which results reduction in overall construction cost.

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