Analysis & Design of Junction Tower at Thermal Power Plant

Renuka R
Assistant Professor
JIT, Davanagere, India

Abstract— Junction towers are the supporting structures which are constructed to provide a support for the belt conveyors to convey the coal to the power generation point at power generation plants. The junction towers are mainly made of steel.

Key words: JNT, Thermal Power Plant, Structural Analysis, Staad Pro

I. INTRODUCTION TO KPCL

The proposed site of Coal Based Thermal Power Plant Karnataka Power Corporation Limited is located near Kudatini village at about 22 km from Bellary town, on Hospet-Bellary NH-6, Karnataka state.

Karnataka Power Corporation limited (KPCL) a fully owned undertaking of the Govt of Karnataka is a premier power generating company, established in 1970. KPCL is currently operating and maintaining power stations with an installed capacity of 6500MW in Karnataka state including thermal, hydel, solar and wind power project.

II. COMPONENTS

The salient features of the proposed expansion unit-3 are furnished below.

<table>
<thead>
<tr>
<th>Name of the Project</th>
<th>Bellary Thermal Power Station (BTPS) Unit-3, 700 MW Coal fired Power Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>N 15°11’58’’</td>
</tr>
<tr>
<td>Longitude</td>
<td>E 76°43’23’’</td>
</tr>
<tr>
<td>Elevation</td>
<td>475m above MSL</td>
</tr>
</tbody>
</table>

Here we made an attempt to learn the steps which are involved in construction activity from the undertaken project. The project mainly deals with analysis and design of JUNCTION TOWER at BTPS Ballary.

We are assigned by our guide for the job of analyzing and designing of a JNT. To meet this requirement, we are suggested to consult Ninganna T R Chief engineer (civil) BTPS Ballary. And also we are suggested to consult Ananda D S Executive engineer (KPCL design office, Bangalore).

We selected a plan of JNT-16 (G+4) among various components of BTPS.

II. COMPONENTS

The salient features of the proposed expansion unit-3 are furnished below.

A. Coal Handling System (CHS)

1) WAGON TIPPLER (WT)
2) BELT CONVEYOR (BCN)
3) JUNCTION TOWER (JNT)
4) PENT HOUSE (PH)
5) PRIMARY CRUSHER HOUSE (PCH)
6) SECONDARY CRUSHER HOUSE (SCH)
7) EMERGENCY RECLAIMING HOPPER (ERH)

This section covers general requirements for design, construction fabrication and erection of various structures, buildings and facilities for the coal handling system, covering complete civil and structural works. Some of the important areas of works are described below.

B. TUNNELS, PENT HOUSE

Tunnels are of underground RCC constructions. A PCC shall be provided to direct the drainage on to one side of the tunnel. A small trench shall be provided on that side of the tunnel to lead the drainage to the nearest sump. Tunnel shall be provided with RCC/Brick work for ventilation duct.

Where the tunnel enters the ground level a pent house is provided of RCC construction. Pent house shall be provided with lifting beam to lift equipment to the tunnel. Tunnel shall provided with walk way on either side of the conveyer. Single pipe handrail shall be fixed to the tunnel wall.
C. CONVEYOR GALLERIES AND TRESTLES

Overhead conveyor shall be housed in a suitably enclosed gallery of structural steel. Maximum span of gallery shall be limited to 24 m unless higher span is necessitated due to site constraints.

1) Single and Double Conveyors:

For single conveyor walkways shall be provided on either side. For double stream conveyor gallery one central and two side walkways shall be provided. Walk ways shall have minimum width of 750mm, in case of space restriction minimum allowable clear width shall be 600mm.

Both sides of the central and side walkways shall be provided with pipe handrails with kerb plates using pipe of medium class as per IS:1169 having 32mm nominal size. Handrails shall not be connected to conveyor supporting stringer. Floors of the conveyor gallery shall be provided with seal plates and walk way shall be constructed with anti-skid arrangement.

Conveyor gallery shall have permanently colour coated metal sheet roof and side cladding shall be of permanently colour coated non insulating metal. Roof framing shall be given a slope of 1 vertical: 3 horizontal. A continuous slot opening of 500mm height shall be provided on both sides. Windows shall have grills of wire mesh.

D. Trestles

In between transfer points four legged trestles, two legged trestles may be provided. Trestles shall generally provide using rolled beams only. For the purpose of analysis one end of the gallery shall be treated as hinged and other end as rollers.

E. Junction Tower

Junction towers are the major component of coal handling system. These are supporting structures for the conveyor system to transfer materials from one location to other location. All junction towers would be of structural steel with chequered plate covered floors.

F. Crusher House

This is the structure where large lumps of coal are crushed into small pieces.

Crusher house is of steel structure is of framed/braced design. Floors and roofs shall be of RCC. Roofs shall be given adequate slope for drainage. Adequate window shall be provided with steel glazed side hung windows using wired glass. Wherever monorails are projecting outside for lifting of equipment, steel sliding doors shall be provided. Crusher shall be mounted on the floor framing using vibration isolation system. Handrail shall be provided around all big openings and kerb plates shall be provided around all small openings.

G. Stacker Cum Reclaimers

It is the place used to store excess coal and it is used whenever necessary. Stacker cum reclaimer rail shall be supported on RCC foundations giving continuous support to the rails. The beams supporting the rails shall be given expansion joint preferably every 30m. Stacker/ reclaimer conveyor support shall also be provided connecting the above two beams.

The entire coal storage area from drain to drain shall be provided with properly sloped PCC paving over rubble soling with properly compacted subgrade. The PCC paving shall be of nominal mix of grade M15, 150mm thick with nominal temperature reinforcement laid over 230mm thick compacted sand and rubble filling. RCC drains with removable precast RCC slotted cover shall be provided on either sides of each coal stack.

These drains shall be so designed to carry the drainage from coal yard to the decantation tank. After 30 minutes storage settlement the decanted water shall be lead to coal pile run off pond and further pumped to ash pond.

IV. INTRODUCTION TO JUNCTION TOWER-16

Junction tower is important structure in Coal Handling System. Inspite of other Junction Towers we have chosen Junction tower-16 for analysis and design because four belt conveyors join at this point those are BCN 33A/B, BCN 36A/B, BCN 28A/B.

Junction tower or Transfer houses are one of the major component of CHP. Junction towers are provided for coal handling conveyor system or any other material conveyor system, to change direction of conveyor from one direction to other direction.

The change of direction is achieved by way of dropping the material from upper level to lower level of conveyor running in different direction. The junction towers also facilitates in transferring one belt conveyor to other belt conveyor going in two or more direction.

The Junction tower also accommodates horizontal and vertical gravity take up in order to maintain the belt tension as per the design requirements. It also houses Dust Extraction System, screw conveyors Inline Magnetic Separators, Cranes/ Monorails etc.

V. INTRODUCTION TO STAAD-PRO

A. Analysis of Junction Tower

Analysis is carried out using STAAD-Pro software package.

Appropriate load and its combinations, for most unfavorable effects are chosen for design.
B. STAAD PRO

STAAD Pro is comprehensive structural engineering software that addresses all aspects of structural engineering including model development, verification, analysis, design and review of results. It includes advanced dynamic analysis and push over analysis for wind load and earthquake load.

STAAD Pro is a comprehensive and integrated design and finite element analysis tool. The exponential growth of the Indian as well as the global construction industry has directly impacted the demand for structural engineers.

It has become important for civil design engineers to be well equipped with the structural software like STAAD Pro, since most of the companies are using STAAD as a tool for designing massive structures, it is imperative that professionals should get trained in this field too to gain advantage in the highly competitive construction market.

It’s a known fact that computers reduce man hours required to complete a project, and knowledge of STAAD will ensure fast and efficient planning as well as accurate execution.

STAAD Pro is a general purpose program for performing the analysis and design of a wide variety of types of structures.

The basic three activities which are to be carried out to achieve that goal –
1) model generation
2) the calculations to obtain the analytical results
3) result verification - are all facilitated by tools contained in the program's graphical environment.

C. STAAD Pro consists of the following

The STAAD Pro Graphical User Interface: It is used to generate the model, which can then be analyzed using the STAAD engine. After analysis and design is completed, the GUI can also be used to view the results graphically.

The STAAD analysis and design engine: It is a general-purpose calculation engine for structural analysis and integrated Steel, Concrete, Timber and Aluminium design.

To start with we have solved some sample problems using STAAD Pro and checked the accuracy of the results with manual calculations. The results were to satisfaction and were accurate. In the initial phase of our project we have done calculations regarding loadings on buildings and also considered seismic and wind loads.

Structural analysis comprises the set of physical laws and mathematics required to study and predicts the behaviour of structures. Structural analysis can be viewed more abstractly as a method to drive the engineering design process or prove the soundness of a design without a dependence on directly testing it.

D. Advantages of STAAD PRO

- Fast and gives accurate results.
- Accurate and quick production of plans for massive constructions
- Reduces cost and saves labour.

VI. MODELING OF STRUCTURE

The framed structure is idealized as an assemblage of area, node, line and objects. Those objects are used to represent column, beam, bracing and link/ spring physical members. The basic frame geometry is defined with reference to a simple three dimensional grid system. With relatively simple modeling techniques, very complex framing situation may be considered.

The structure may be unsymmetrical and non-rectangular in plan. Tension behaviour of the floor and inter storey compatibility of the floor are accurately reflected in the results. The solution enforces complete three dimensional displacement compatibility, making it possible to capture tubular effects associated with the behaviour of tall structure having relatively closely spaced columns.

The column, beam and brace elements may be non-prismatic, and they may have partial fixity at their end connections. They also may have uniform, partial uniform and trapezoidal load patterns, and they may have temperature loads, seismic loads, monorail loads. The effects of the finite dimensions of the beams and columns on the stiffness of a frame system are included using end offsets that can be automatically calculated.

Modeling is done by using STAAD-PRO (v8i version) software. For this purpose the preliminary step is to prepare grid layouts. As our selected structure is (G+4) storey, The next step is to define the material properties, beam details, column details and the load combinations by referring to IS 456-2000, IS 800.

A. Material properties

- Material name: concrete, steel
- Density of concrete: 25 kN/m³
- Modulus of elasticity: 254.91 X10³ N/m²
- Poisson’s ratio: 0.2
- Grade of concrete: M25
- Grade of steel: Fe 500

B. Load combinations

Analysis is carried out for gravity loads using partial safety factor as 1.5, Earth quake loads using partial safety factor as 1.2, Mono rail loads, Equipment loads, Temperature loads, Wind loads. The following loads have been considered in the structural analysis and design as per IS code 456-2000 and IS 800.

- Density of RCC = 25 kN/m³
- Density of Steel = 78.50 kN/m³

VII. LOADS AND LOAD COMBINATIONS

A. Dead Load

Dead Loads consists of the weights of the structure complete with finishes, fixtures, partitions, wall panels and all equipment of semi-permanent nature including tanks silos, beams, partitions, roofing, piping, cable trays, bus ducts etc., the content of tanks, silos, beams and hoppers etc., shall be measured at full capacity for this purpose.

The unit weight of material shall be considered for computation of loads given in IS:875 (part-I)
B. Imposed load

Imposed loads in different areas shall include live loads, dust loads, minor equipment loads, cable trays, small pipe racks, hanger erection loads, operation/maintenance loads, etc.

The loads considered shall not be less than that specified in IS:875 (part- II).

C. Wind load

Wind load on structure shall be calculated as per provisions of IS:875 (part -III). The wind shall be assumed to blow in any direction and on unfavourable condition shall be considered for design. Wind loads generally be estimated based on 3 sec gust wind as per IS:875 (part- III) however wind loads for slender structure (having height to width ratio exceeding 5) shall be calculated using gust factor method also and higher of the two wind load values shall be considered for analysis.

In design of stricture, wind force on equipment supported on frame including all fixtures, piping, staircase, ladders etc., shall also be considered.

D. Seismic Loads

Seismic forces shall be as per zone III of IS:1893 part I

The importance factor for all power plant buildings and structures shall be taken as 1.75 as per IS:1893 part – IV( clause 2.17 Table 5 category 2, Table 2).

E. Temperature loads

Expansion and contraction due to changes of temperatures of materials of a structure shall be considered and adequate provisions shall be made for the effects produced. The maximum distance of the expansion joint shall be as per the provisions of IS: 800 and IS:456 for steel and concrete structures respectively.

Analysis shall be carried out for ambient temperature variations. The temperature variation shall be considered as 2/3 of average maximum annual variation in temperature. The structure shall be designed to withstand thermal stress due to 50% of the temperature variation. Coefficient of thermal expansion of steel shall be taken as per IS:800.

F. Equipment load

Static and dynamic loads of major equipments are based on the manufacturer’s data of the supplied equipments and shall be considered in design in addition to the live load. Air and gas duct loads shall include weight of insulation, duct attachments dust accumulation loads, seismic, wind and other loads applicable.

G. Crane, mono rail, elevator and track mounted vehicle loads

Crane girders and supporting columns shall be designed for vertical and horizontal forces (including impact forces) as per crane vendor’s data. All lifting beams and mono rails shall have their design loads

H. Basic Load Data

1) Dead Load:

Self-Weight of structure is taken by STAAD self-weight command.

1) DEAD LOAD FOR TYPICAL FLOOR PANELS: ON TYPICAL PANELS
2) Slab thickness = 150 mm
3) Self weight of slab = 0.150 X 2.5 = 0.375 T/ m²
4) Floor Gradient (1/80)x8.0 =0.1
   Average Thickness =0.05 m
5) Floor Finish =0.05 ( D.L. of Floor finish is 2.4 T/ m² as = 0.1x2400 = 0.240 T/ m² (as per KPCL specs Vol V Pg 048 )
   TOTAL = 0.615 T/ m²
   SAY 0.650 T/ m²
6) Dead load on staircase = 0.100 T/ m²
7) Dead load of sheeting 0.016 T/ m²
8) Dead load of parapet wall = 0.125X2.5X0.9 = 0.281 T/m
9) Dead load from conveyor gallery : -( Ref Mechanical Drawing)
10) Dead load of wall cladding, runner etc. 50 kg/ m²
  (APPROXIMATELY)
11) Load due to duct or cable tray = 150 kg/m
2) Live Loads:

Imposed loads are the weights of the structures which changes with the mode of operation.

1) Live load, dust load, cable tray, small pipe racks/hangers,
2) Minor equipment loads, Erection loads, Operation / maintenance loads, etc.

The following minimum live loads shall be adopted for design of Transfer tower structures in the belt conveyor system.

   1) Floors of Junction: 5 kN/ m²
   2) Equipment loads: as per actual
   3) Access platform and stairs: 5 kN/ m²
   4) Dust load on Floors: 1 kN/ m²

3) Seismic Analysis:

   $A_h = \frac{Z I S_a}{2 R g}$

   - Zone factor (Z) = 0.16 ( Zone III , Table-2, pg.no. 16 IS 1893:2002 part-I)
   - Importance factor (I) = 1.75 (Table 2, category 2 ; Table 5 )
   - Response reduction factor (R) = 4 (Table 7 ,pg. no. 23 IS 1893:2002 part-I)
   - Damping = 0.02 ( Table 4, pg. No. 11 IS 1893:2002 part-IV)

   $T_a = 0.085 h^{0.75}$

   - For steel frame building (pg. no. 24 IS 1893:2002 part- I)
   - $h= 26.7 m$
   - $S_a = \frac{1.36}{g} T$
   - $\Gamma_a= 0.998395$

   - For medium soil (pg. No 16 IS 1893:2002 part I)
   - $S_a/g= 1.362186$ (S/g) X damping = 0.027244
   - $\alpha h= 0.000954$

4) Wind load calculation:

   Direction of wind east to west
   a) Design data:
   - Basic wind speed Vb = 39 m/s
   - Risk factor k1 = 1.06
   - Topography factor k3 = 1
- For terrain category 2 and class C structure,
- Upto 10m height $k_2 = 0.98$
- From 10m to 15m $k_2 = 1.02$
- From 15 to 20m $k_2 = 1.05$
- From 20 to 30m $k_2 = 1.10$

b) Effective wind speed $V_z = V_b K_1 K_2 K_3$
- Upto 10m height $V_z = 39 \times 1.06 \times 0.98 \times 1 = 40.5132$ m/s
- From 10m to 15m $V_z = 39 \times 1.06 \times 1.02 \times 1 = 42.1668$ m/s
- From 15 to 20m $V_z = 39 \times 1.06 \times 1.05 \times 1 = 43.41$ m/s
- From 20 to 30m $V_z = 39 \times 1.06 \times 1.10 \times 1 = 45.47$ m/s

c) Wind pressure $P_d = 0.6V_z^2$:
- Upto 10m height $P_d = (0.6 \times 40.5132^2) = 984.79$ N/mm$^2$
  $100.3865$ kg/m$^2$
- From 10m to 15m $P_d = (0.6 \times 42.1668^2) = 1066.82$ N/mm$^2$
  $108.7486$ kg/m$^2$
- From 15 to 20m $P_d = (0.6 \times 43.41^2) = 1130.50$ N/mm$^2$
  $115.2396$ kg/m$^2$
- From 20 to 30m $P_d = (0.6 \times 45.47^2) = 1240.73$ N/mm$^2$
  $126.4761$ kg/m$^2$

5) **ANALYSIS OF JUNCTION TOWER-16**

- **3D STADD MODEL OF JNT-16**
- **PLAN AT FIRST FLOOR LEVEL**
- **SUPPORT DIAGRAM**
- **STADD FRAMING MODEL FOR JNT-16**


### Analysis & Design of Junction Tower at Thermal Power Plant

**Table:**

<table>
<thead>
<tr>
<th>Beam no.</th>
<th>Stress Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>165</td>
<td>0.3</td>
</tr>
<tr>
<td>192</td>
<td>0.4</td>
</tr>
<tr>
<td>199</td>
<td>0.4</td>
</tr>
<tr>
<td>206</td>
<td>0.5</td>
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<tr>
<td>179</td>
<td>0.5</td>
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<tr>
<td>238</td>
<td>0.5</td>
</tr>
<tr>
<td>234</td>
<td>0.3</td>
</tr>
<tr>
<td>329</td>
<td>0.4</td>
</tr>
</tbody>
</table>

**Critical load combination on beam:**

146 DL + LL + EQUIP + (WL + Z) + MR 5 + TEMP LOAD

**Maximum Bending moment diagram along z direction:**

11500 mm

**Section view of beam:**

**VIII. DESIGN OF JUNCTION TOWER-16**

**A. Design of Columns and Beams**

Design procedure is same as that of Design of columns and beams by using IS 456-2000 and SP-16.

**B. Design of Bracing**

- The rigid frame structure deflects more than a braced structure.
- A Braced Frame is a structural system which is designed primarily to resist wind and earthquake forces. Members in a braced frame are designed to work in tension and compression, similar to a truss.
- Braced frame add stiffness to the structure.
- They are simple to design and analyze.
- In multi-storey buildings, reinforced concrete shear walls may replace the vertical steel bracing trusses. This type of construction is used in frames up to about five storey in height, where strength rather than stiffness governs the design.
C. Design of Side Runner

D. Design of Floor Slabs

E. Design of Slabs

1) General Approach:
Slabs are plate elements forming floors and roofs of buildings and carrying distributed loads primarily by flexure. A slab may be simply supported or continuous over one or more supports and is classified according to manner of support and there are two types slabs.
- One way slabs spanning in one way direction.
- Two way slabs spanning in both the direction.
- Slabs are designed by using the following theories of bending and shear.

The following methods of analysis are available.
1) Yield line theory,
2) Elastic analysis - idealization into strips,
3) Finite element method.

IX. INTRODUCTION TO SLABS
Slabs are plate elements forming floors and roofs of building and carrying distributed loads primarily by flexure. Inclined slabs may be used as ramps for multi-storey car parks. A stair case can be considered to be an inclined slab. A slab may be supported by beams or walls and may used as the flange of a T- or L-beam. Moreover, a slab may be simply supported or continuous over one or more supports and is classified according to the manner of support:
1) One way slabs spanning in one direction,
2) Two way slab spanning in both the directions,
3) Circular slabs,
4) Flat slabs resting directly on columns with no beams and
5) Grid floor and ribbed slabs.

A. One Way Slabs
One way slabs are those is which the length is more than twice the breadth. One way slab can be simply supported continuously on the two opposite sides so that the loads are carried along one direction only. The direction in which the load is carried in one way slabs is called the span. It may be in the long or shorter direction since the corresponding bending moment shear forces are the least. The main reinforcement are provided in the span direction steel is also provided in the transverse direction, to distribute any unevenness that may occur in loading and for temperature and shrinkage effects in that direction. Reinforced concrete slabs supported on two opposite sides or on all four sides with the ratio of long to short span exceeding 2 are referred to as one way slab.

B. Two Way Slabs
When slabs are supported on four sides, two-way spanning action occurs. Such slabs may be simply supported or continuous on any or all sides. The deflections and bending moments in a two way slab are considerably reduced as compared to those in a one way slab.

Thus, a thinner slab can carry the same load when supported on all the four edges. In a square slab, the two way action is equal in each direction. In long narrow slabs, where the length is greater than twice the breadth, the two way action effectively reduces to one way action in the direction of the short span although the end beams to carry some slab loads. Two way slabs should have their longer span not exceeding two times the shorter span.

All slabs are designed as two way slabs with different end conditions.
E. DESIGN OF RAFT

STAAD MODEL FOR RAFT WITH FULL SECTION

BASE PRESSURE DIAGRAM

MAXIMUM STRESS (VON MISSES) DIAGRAM

MAXIMUM MOMENT DIAGRAM ALONG Y-DIRECTION

MAXIMUM SHEAR STRESS DIAGRAM ALONG Y-DIRECTION

MAXIMUM SHEAR STRESS DIAGRAM ALONG X-DIRECTION
X. CONCLUSION

- The junction house is analyzed with the assumed sectional properties of members and it is designed in STAAD-Pro. All members have passed the design checks in STAAD-Pro.
- Transfer Tower, but steel is chosen for its durability and easy fabrication. Moreover steel Transfer Tower can be easily extended in future for its expansion.
- For the concrete tower of the same level as that of steel tower, the c/s of members is more and because of more headroom the weight and the space of the structure is also more and hence unfeasible.
- The junction house is analyzed with the assumed sectional properties of members and it is designed in STAAD-Pro. All members have passed the design checks in STAAD-Pro.
- The construction of concrete junction house is time consuming while steel junction house structure is faster to fabricate.
- Transfer Tower can be easily extended in future for its expansion.
- Steel is durable, recyclable.

REFERENCES

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IS CODE BOOKS