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DESIGN OF CRANE BEAM FOR ROLLING LOAD USING STAAD

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Abstract: The STAAD model and the numerical calculation of the crane beam are presented in this document. Here the problem was solved by the finite element method. The analysis of the pure force and the moment of bending of the beam of the crane were made using advanced software with highly efficient modeling possibilities. The movement of the crane car along the beam was also taken into account in the study. The research carried out allows the evaluation of the maximum cutting tension and the maximum bending moment for the critical position of the rolling load that is applied in order to design the beam of the crane of the required resistance.
Keyword: STAAD model, Design the Crane Beam,

I. INTRODUCTION

Cranes are one of the most common ways to transport loads, therefore, the main task of the aerial crane is to handle and transfer heavy loads from one position to another. They can be applied in many areas, such as in powerhouses for lifting heavy machines and turbines, in automobile factories, in heavy industry and in shipyards. Its design characteristics vary widely according to its main operational specifications, such as: type of crane movement, weight and type of the load, location of the crane, geometric characteristics and environmental conditions. [1] [2]

This paper includes the analysis of the numerical strength of the concrete crane beam. The problem was solved by the finite element method. The analysis was carried out for the concrete beam, with a rectangular cross section. The design and analysis were carried out using the STAAD Pro software. As a result of the calculations made, the forces, bending moments and displacements of the beam structure of the crane were obtained. Critical load conditions were found for maximum shear force and maximum bending moment, and beam safety was verified at that load condition and reinforcement was provided for the beam accordingly. [3]

II. DESIGN LOAD

Loads acting on concrete crane beam are discussed below:-

2.1 Dead Load

Dead load of crane beam is calculated from concrete volumes taken off from physical dimensions of the beam. Self-weight of the beam has to be considered as dead load and also weight of rails and hand rails can be taken.

2.2 Live Load

The live load such as load for movement of men is considered for inspection and other purposes on the beam.

2.3 Earthquake Load

The seismic coefficients are calculated based on recommendations of IS 1893-2002. The various parameters considered are given below;

Zone Factor (Z) = Depends on the zone in which the building lies.

Response Reduction Factor (RF) = Depends on type of building

Importance Factor (I) = According to use of building

2.4 Moving Load

As per the loading details obtained from crane manufacturer, the moving crane load is generated at an interval of 0.1 m in longitudinal direction.

2.5 Calculation for Horizontal / Lateral Surge forces due to Crane

Along with the moving crane load, horizontal and lateral surge forces also act on the beam, which are calculated according to clause 6.3 of IS 875- Part 2, the calculation is done as mentioned below-

- Vertical load at Crane Girder = 10 percent of (wt. of crabs + wt. lifted by cranes
- Horizontal traction force along the rail = 5 percent of static wheel loads

III. LOAD COMBINATIONS

The following loads have been considered for analysis;

- Dead Load (DL)
- Live Load (LL)
- Moving Crane Load (CL)
- Earthquake Load (+X) (EQ)
- Earthquake Load (-X) (EQ)
- Earthquake Load (+Z) (EQ)
- Earthquake Load (-Z) (EQ)
- Horizontal & Vertical Thrust

The following load combinations have been considered for analysis (Refer Table no. 4, IS: 800:2007), given in Table 1;

TABLE 1: Load Combinations Considered

Sl. No.	Design Load Combination
1.	1.0 DL + 1.0 LL
2.	1.5 DL + 1.5 LL
3.	1.5 DL + 1.5 EQ
4.	0.9 DL + 1.5 EQ
5.	1.0 DL + 1.0 LL + 1.0 CL
6.	1.5 DL + 1.5 LL + 1.5 CL
7.	1.2 DL + 1.2 LL + 1.2 EQ + 1.2 CL
8.	1.2 DL+ 1.2 LL + 0.6 EQ + 1.2 CL

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IV. FEM ANALYSIS

The Design and Analysis has to be carried out in STAAD PRO V8i Software. First of all, the beam is made using the beam element in STAAD and required property is assigned and end conditions are defined using Support command, it may pinned or fixed or whatever connection is defined according to site condition to be provided.

After this, loads are applied on the beam and primary analysis is done for the beam to find the critical condition for maximum bending moment and maximum shear force to occur. In general, maximum bending moment is find to be at the centre and maximum shear force occurs at the supports for moving point load and uniformly distributed load, but in case of multiple point load it may vary if all the points are not lying on the beam at the same time and hence to be checked for the critical condition.

The summary of reactions, Bending Moment and Shear Force required for design calculations of crane beam under most severe loading condition is noted, all Forces are in kN and all moments are in kN.m. These values are used for further calculation of beam, and final design can be checked in output file by checking on concrete design. [4]

Now, here is an example to illustrate the design of crane beam for rolling load on STAAD.

Let us considera case where, a crane beam of length 10m is to be designed for gantry of span 21m. Let the column size be 1250mm x 1000mm, and beam size be 1500mm X 1000mm. The wheel load for a wheel after impact be 607.9 kN.Now, calculating all the value as discussed above and putting it in STAAD.

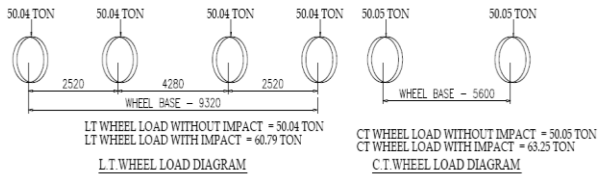

Figure – 1: Moving Load

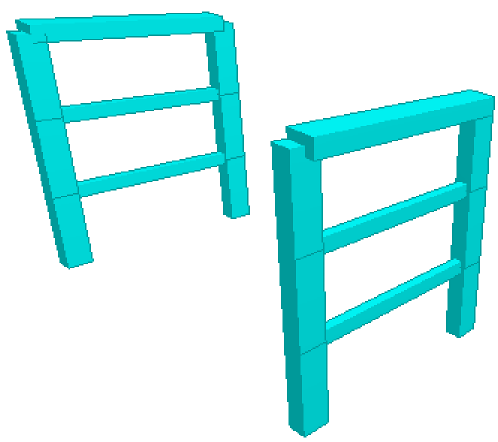

Figure 2- Frame for crane beam analysis in STAAD

The following loads are considered for structural design of various components of superstructure;

Dead Load-
The dead load for structural analysis will include self-weight of crane beam.

Live Load
The live load considered for the crane beam is 1kN/m for movement of men for inspection etc.

Earthquake Load-
The seismic coefficients are calculated based on recommendations of IS 1893-2002. The various parameters considered are given below;

Zone Factor (Z) = 0.16 for Zone III
Response Reduction Factor (RF) = 3.0 for ordinary RC Moment Resisting Frame
Importance Factor (I) = 1.5 for Power House
Rock and Soil Site Factor (SS) = 1.0
Damping Ratio (DM) = 0.05 (5%)

Based on above values Horizontal and vertical seismic coefficients are calculated directly in STAAD. However, as per clause 6.4.4 of IS 1893-2002, for underground structures and foundations at depths of 30 m or below, the design horizontal acceleration spectrum value shall be taken as half the values ontained from calculations. Accordingly, the factor of 0.5 is applied for calculated horizontal and vertical seismic coefficients in both direction.

Moving Crane Load
One EOT crane operating is proposed for design. As per the loading details obtained from crane manufacturer, the moving crane load is generated at an interval of 0.1 m in longitudinal direction. The wheel loads considered for moving crane load are given below in Table 1;

TABLE 2: Wheel Load Considered for Moving Crane

Sl. No.	Load (KN)	Distance (m)	Remarks
1	607.9	-	Loads for EOT Crane
2	607.9	2.52	
3	607.9	4.28	
4	607.9	2.52	

Calculation for Horizontal / Lateral Surge forces due to Crane
According to clause 6.3 of IS 875- Part 2, the calculation is done as mentioned below-
Vertical load at Crane Girder = 10 percent of (wt. of crabs + wt. lifted by cranes)
= ((10 / 100)x (320+ 1500)) / 4 (per wheel)
= 45.5 kN
Moment due to this Load = 45.5 x 1.0 = 45.5 kNm
Here, 1.0m is assumed distance of load from the centroid for calculating moment.

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Horizontal traction force along the rail = 5 percent of static wheel loads
= (5 x 500.4) / 100
= 25.02 kN
Moment due to this Load= 25.02 x 1.0 = 25.02 kNm
Here, 1.0m is assumed distance of load from the centroid for calculating moment. Now, after assigning the supports and dead load, live load, earthquake load and moving wheel loadon the beam elements, critical load combinations are applied, primary analysis is done and lining is checked for loading conditions. Load combination number for maximum bending force and maximum shear force is obtained. After that secondary analysis is done individually for crane position for maximum bending moment and maximum shear force after applying horizontal and lateral surge forces and now the values of bending moment, shear force and torsion are used to design the concrete beam manually or STAAD itself also designs the beam which can be seen in output viewer option of STAAD.

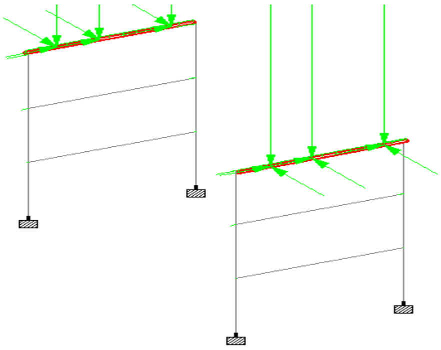

Figure 3- Load Condition for maximum bending moment (secondary analysis-1)

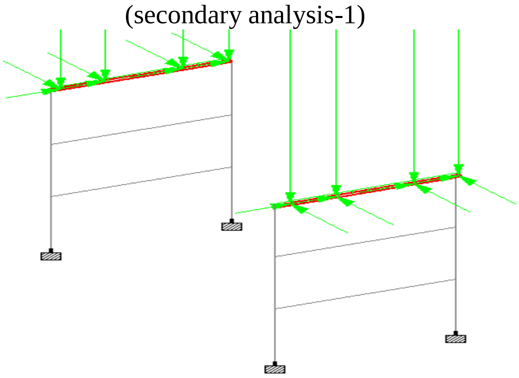

Figure 4- Load Condition for maximum shear force (secondary analysis-2)

Table 3: For the above values in the table, Crane can be designed manually or can be referred to STAAD output design

Sl. No.	Name of Component	Max. Shear Force (Fy) (kN)	Max. Bending Moment in Z-dir. (Mz) (kNm)	Torsion (T) (kNm)	Beam No.	Load Case	Node No.
	Secondary Analysis-1 for maximum Bending Moment Condition						
1	Crane beam (1500(B) X1000(D))	1649.835	**2462.775**	2.927	17	206	15
	Secondary Analysis for maximum Shear Force Condition						
2	Crane beam (1500(B) X1000(D))	**2289.84**	2383.336	5.920	18	205	16

STAAD FILE [6]

```
**************************************************
*************************
STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 10-May-18
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 367.845 0; 2 0 367.845 21.5; 3 10 367.845 0; 4 10 367.845 21.5;
5 0 372.845 0; 6 0 372.845 21.5; 7 10 372.845 0; 8 10 372.845 21.5;
9 0 377.845 0; 10 0 377.845 21.5; 11 10 377.845 0; 12 10 377.845 21.5;
13 0 382.845 0; 14 0 382.845 21.5; 15 10 382.845 0; 16 10 382.845 21.5;
MEMBER INCIDENCES
1 1 5; 2 2 6; 3 3 7; 4 4 8; 5 5 7; 6 6 8; 7 5 9; 8 6 10; 9 7 11; 10 8 12;
11 9 11; 12 10 12; 13 9 13; 14 10 14; 15 11 15; 16 12 16; 17 13 15; 18 14 16;
MEMBER OFFSET
17 START 0 0 -0.25
17 END 0 0 -0.25
18 START 0 0 0.25
18 END 0 0 0.25
DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 2.5e+007
POISSON 0.17
DENSITY 24
ALPHA 1e-005
DAMP 0.05
TYPE CONCRETE
STRENGTH FCU 25000
END DEFINE MATERIAL
MEMBER PROPERTY INDIAN
17 18 PRIS YD 1 ZD 1.5
1 TO 4 7 TO 10 13 TO 16 PRIS YD 1.25 ZD 1
5 6 11 12 PRIS YD 0.85 ZD 0.5
CONSTANTS
MATERIAL CONCRE.TE ALL
SUPPORTS
1 TO 4 FIXED
DEFINE MOVING LOAD
TYPE 1 LOAD 607.9 607.9 607.9 607.9
DIST 2.52 4.28 2.52 WID 21.5
DEFINE 1893 LOAD
ZONE 0.16 RF 3 I 1.5 SS 1 DM 0.05
SELFWEIGHT 1
LOAD 1 LOADTYPE Seismic  TITLE EQX+
1893 LOAD X 0.5
LOAD 2 LOADTYPE Seismic  TITLE EQX-
1893 LOAD X -0.5
LOAD 3 LOADTYPE Seismic  TITLE EQZ+
1893 LOAD Z 0.5
LOAD 4 LOADTYPE Seismic  TITLE EQZ-
```

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1893 LOAD Z -0.5
LOAD 5 LOADTYPE Dead TITLE DEAD LOAD
SELFWEIGHT Y -1
LOAD 6 LOADTYPE Live TITLE LIVE LOAD
MEMBER LOAD
17 18 UNI GY -1
LOAD GENERATION 194
TYPE 1 -9.32 382.845 21.5 XINC 0.1
***********FOR PRIMARY ANALYSIS **
********(CLOSE IT WHILE SECONDARY 1,2 ANALYSIS)***********************
****
LOAD COMB 202 1.5 (DL+LL)
5 1.5 6 1.5
LOAD COMB 203 1.2 (DL+LL+ EQX+)
5 1.2 6 1.2 1 1.2
LOAD COMB 204 1.2 (DL+LL+ EQX-)
5 1.2 6 1.2 2 1.2
LOAD COMB 205 1.2 (DL+LL+ EQZ+)
5 1.2 6 1.2 3 1.2
LOAD COMB 206 1.2 (DL+LL+ EQZ-)
5 1.2 6 1.2 4 1.2
LOAD COMB 207 1.5 (DL+ EQX+)
5 1.5 1 1.5
LOAD COMB 208 1.5 (DL+ EQX-)
5 1.5 2 1.5
LOAD COMB 209 1.5 (DL+ EQZ+)
5 1.5 3 1.5
LOAD COMB 210 1.5 (DL+ EQZ-)
5 1.5 4 1.5
LOAD COMB 211 0.9 DL + 1.5 EQX+
5 0.9 1 1.5
LOAD COMB 212 0.9 DL + 1.5 EQX-
5 0.9 2 1.5
*LOAD COMB 213 0.9 DL + 1.5 EQZ+
*5 0.9 3 1.5
*LOAD COMB 214 0.9 DL + 1.5 EQZ-
*5 0.9 4 1.5
*LOAD COMB 215 DL+LL
*5 1.0 6 1.0
****
************************ SECONDARY ANALYSIS 1**************************
************ CRANE LOAD FOR MAXIMUM BENDING MOMENT***************
************ (CLOSE IT WHILE PRIMARY, SECONDARY 2 ANALYSIS)**********
****
*LOAD 201 LOADTYPE None TITLE HORIZONTAL & LATERAL
*MEMBER LOAD
*18 CON GZ -45.5 8.68
*17 CON GZ 45.5 8.68
*17 18 CON GX 25.02 8.68
*18 CON GZ -45.5 4.4
*17 CON GZ 45.5 4.4
*18 CON GZ -45.5 1.88
*17 CON GZ 45.5 1.88
*17 18 CON GX 25.02 4.4
*17 18 CON GX 25.02 1.88
*LOAD COMB 202 1.5 (DL+LL)
*5 1.5 6 1.5
*LOAD COMB 203 DL+LL
*5 1.0 6 1.0
*LOAD COMB 204 DL+LL+CL
*5 1.0 6 1.0 119 1.0 201 1.0
*LOAD COMB 205 1.5 (DL+LL) 1.5 CL
*5 1.5 6 1.5 119 1.5 201 1.5
*LOAD COMB 206 1.2 DL+ 1.2 LL+ 1.5 CL+ 0.6 EQX+
*5 1.2 6 1.2 1 0.6 119 1.5 201 1.5
*LOAD COMB 207 1.2 DL+ 1.2 LL+ 1.5 CL+ 0.6 EQX-
*5 1.2 6 1.2 2 0.6 119 1.5 201 1.5
*LOAD COMB 208 1.2 DL+ 1.2 LL+ 1.5 CL+ 0.6 EQZ+
*5 1.2 6 1.2 3 0.6 119 1.5 201 1.5
*LOAD COMB 209 1.2 DL+ 1.2 LL+ 1.5 CL+ 0.6 EQZ-
*5 1.2 6 1.2 4 0.6 119 1.5 201 1.5
*LOAD COMB 210 1.2 (DL+LL+EQX+)+ 1.2 CL
*5 1.2 6 1.2 1 1.2 119 1.2 201 1.2
*LOAD COMB 211 1.2 (DL+LL+EQX-)+ 1.2CL
*5 1.2 6 1.2 2 1.2 119 1.2 201 1.2
*LOAD COMB 212 1.2 (DL+LL+EQZ+)+ 0.53CL
*5 1.2 6 1.2 3 1.2 119 1.2 201 1.2
*LOAD COMB 213 1.2 (DL+LL+EQZ-)+ 0.53CL
*5 1.2 6 1.2 4 1.2 119 1.2 201 1.2
*LOAD COMB 214 1.5 (DL+ EQX+)
*5 1.5 1 1.5
*LOAD COMB 215 1.5 (DL+ EQX-)
*5 1.5 2 1.5
*LOAD COMB 216 1.5 (DL+ EQZ+)
*5 1.5 3 1.5
*LOAD COMB 217 1.5 (DL+ EQZ-)
*5 1.5 4 1.5
*LOAD COMB 218 0.9 DL + 1.5 EQX+
*5 0.9 1 1.5
*LOAD COMB 219 0.9 DL + 1.5 EQX-
*5 0.9 2 1.5
*LOAD COMB 220 0.9 DL + 1.5 EQZ+
*5 0.9 3 1.5
*LOAD COMB 221 0.9 DL + 1.5 EQZ-
*5 0.9 4 1.5
****
************************ SECONDARY ANALYSIS-2*************************
******************** CRANE LOAD FOR SHEAR FORCE**********************
************ (CLOSE IT WHILE PRIMARY, SECONDARY 1 ANALYSIS)**********
****
LOAD 201 LOADTYPE None TITLE HORIZONTAL & LATERAL
MEMBER LOAD
18 CON GZ -45.5 10.00

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17 CON GZ 45.5 10.00
17 18 CON GX 25.02 10.00
18 CON GZ -45.5 7.48
17 CON GZ 45.5 7.48
17 18 CON GX 25.02 7.48
18 CON GZ -45.5 3.2
17 CON GZ 45.5 3.2
18 CON GZ -45.5 0.68
17 CON GZ 45.5 0.68
17 18 CON GX 25.02 3.2
17 18 CON GX 25.02 0.68
LOAD COMB 202 1.5 (DL+LL)
5 1.5 6 1.5
LOAD COMB 203 DL+LL
5 1.0 6 1.0
LOAD COMB 204 DL+LL+CL
5 1.0 6 1.0 107 1.0 201 1.0
LOAD COMB 205 1.5 (DL+LL) 1.5 CL
5 1.5 6 1.5 107 1.5 201 1.5
LOAD COMB 206 1.2 DL+ 1.2 LL+ 1.5 CL+ 0.6 EQX+
5 1.2 6 1.2 1 0.6 107 1.5 201 1.5
LOAD COMB 207 1.2 DL+ 1.2 LL+ 1.5 CL+ 0.6 EQX-
5 1.2 6 1.2 2 0.6 107 1.5 201 1.5
LOAD COMB 208 1.2 DL+ 1.2 LL+ 1.5 CL+ 0.6 EQZ+
5 1.2 6 1.2 3 0.6 107 1.5 201 1.5
LOAD COMB 209 1.2 DL+ 1.2 LL+ 1.5 CL+ 0.6 EQZ-
5 1.2 6 1.2 4 0.6 107 1.5 201 1.5
LOAD COMB 210 1.2 (DL+LL+EQX+)+ 1.2 CL
5 1.2 6 1.2 1 1.2 107 1.2 201 1.2
LOAD COMB 211 1.2 (DL+LL+EQX-)+ 1.2CL
5 1.2 6 1.2 2 1.2 107 1.2 201 1.2
LOAD COMB 212 1.2 (DL+LL+EQZ+)+ 0.53CL
5 1.2 6 1.2 3 1.2 107 1.2 201 1.2
LOAD COMB 213 1.2 (DL+LL+EQZ-)+ 0.53CL
5 1.2 6 1.2 4 1.2 107 1.2 201 1.2
LOAD COMB 214 1.5 (DL+ EQX+)
5 1.5 1 1.5
LOAD COMB 215 1.5 (DL+ EQX-)
5 1.5 2 1.5
LOAD COMB 216 1.5 (DL+ EQZ+)
5 1.5 3 1.5
LOAD COMB 217 1.5 (DL+ EQZ-)
5 1.5 4 1.5
LOAD COMB 218 0.9 DL + 1.5 EQX+
5 0.9 1 1.5
LOAD COMB 219 0.9 DL + 1.5 EQX-
5 0.9 2 1.5
LOAD COMB 220 0.9 DL + 1.5 EQZ+
5 0.9 3 1.5
LOAD COMB 221 0.9 DL + 1.5 EQZ-
5 0.9 4 1.5
****
PERFORM ANALYSIS
START CONCRETE DESIGN
CODE INDIAN
CLEAR 0.04 MEMB 1 TO 4 7 TO 10 13 TO 16
CLEAR 0.025 MEMB 5 6 11 12 17 18
FC 25000 ALL
FYMAIN 500000 ALL
FYSEC 500000 ALL
MAXMAIN 25 ALL
MAXSEC 12 ALL
MINMAIN 10 ALL
MINSEC 8 ALL
RATIO 4 ALL
DESIGN COLUMN 1 TO 4 7 TO 10 13 TO 16
DESIGN BEAM 5 6 11 12 17 18
END CONCRETE DESIGN
FINISH

V. CONCLUSION

As crane beam are important elements and are used to carry extremely heavy loads, correct design is necessary. The STAAD modeling and numerical calculation of the crane beam was done and problem was solved by the finite element method, more precise calculation was done and moving load was analyzed for critical condition to find maximum bending moment and maximum shear force in beam for which beam must be accurately designed.

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