Modal Analysis of Steel Junction Tower with and without Damage

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***Abstract*— In recent years, India's energy sector has grown tremendously. About 80% of the electricity consumed in India is generated by coal thermal power plant. The efficiency of the thermal power plants depends on the robust infrastructure and interacting components of the plant. Among various components of the coal thermal power plant, the steel junction tower is considered to be the key component subjected to, complex structural arrangements and loading conditions. The design of steel junction tower is based on the codal provisions of IS800-2007 and IS1893-2005. In this paper, the modal analysis is carried out on the steel junction tower FE model using STAAD Pro V8i SS6. The FE models with and without damage present in the column at critical locations are analyzed and compared. The results of the modal analysis are investigated to study the global responses of the modeled steel junction tower.**

Keywords—Steel Junction Tower, Modal Analysis, Frequency, Mode Shapes, Damage.

I. INTRODUCTION

In recent years, India's energy sector has grown tremendously. About 80% of the electricity consumed in India is generated by coal thermal power plant. The efficiency of the thermal power plants depends on the robust infrastructure and interacting components of the plant. Among various components of the coal thermal power plant, the steel junction tower is considered to be the key component subjected to, complex structural arrangements and loading conditions in various directions. Therefore the study on the responses and performance of steel Junction tower is important. There is very limited published literature available on the complex steel junction tower. An extensive literature survey has revealed that various studies related to steel building frames subjected to various types of static and dynamic loading, but no publications were available on complex steel junction tower.

The detection of damage to structures in an extreme event such as earthquake might seem a trivial task, considering the abundance of shattering images after such an occurrence. Often, serious structural damage may be virtually invisible, however it has become evident with many steel framed buildings. A large number of moment resisting frames sustained severe damage in the beam to column moment connection regions, which only became evident after expensive inspection procedures that required the removal of wall cladding and fire proofing. The method of modal testing has been used in many cases in an attempt to detect and characterize damage that structure has endured as result of an extreme event such as earthquakes, wave forces or corrosion. It is growing field of research since invisible defects in structure such as offshore rigs or buildings, where structural members are covered with cladding can pose severe risks of collapse if not identified and repaired in time. Inspection methods can be very expensive and great benefit can be gained by narrowing the potential damage area with analytical and measuring tools. Although the technique of damage detection appears very promising, in practice it still remains very difficult to characterize damage in complex structure in all but the most severe cases.

In this paper, the modal parameter of the steel junction tower before after damage that structure has endured due to any reason due to extreme event such as earthquakes, corrosion, etc. are investigated. In the present numerical study the modal analysis was carried out on the steel junction tower FE model using STAAD Pro V8i SS6. The FE models with and without damage present in the column at critical locations are analyzed and compared. The results of the modal analysis are investigated to study the global responses of the modeled steel junction tower.

II. COMPLEX STEEL JUNCTION TOWER

The complex steel Junction tower (JT) is the major component of coal thermal power plant. These tall supporting tower like structures are mainly constructed to support belt conveyors carrying the coal and to transfer them from one location to another (shown in Figure1). In the present study the JT considered is steel braced structure located in Raichur. The total height of JT with four floor levels is 82.250m and with three platforms and roof. Length of tower (X-direction) is 13.200m and the width of tower (Z-direction) is 14.000m The floors are at elevation +56.250m, +62.600m, +67.800m, +72.850m and these floors are made up of RCC slabs over structural steel beams except for the floor at the elevation +67.800m fabricated with chequered plates. All floors are provided with hand railings all around the floor openings and surface drain is provided for rain water drainage at the

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periphery of the structure. Coal dust-Bag filters are provided at the elevation 79.350m, to minimize the amount of loose dust particles present in the Junction Tower [2].

Figure 1 Adjacent component of Junction tower (Courtesy: BHEC)

III. MODELLING OF STEEL JUNCTION TOWER.

The complex steel junction tower and its components are idealized as spaced frames composed of frame elements (beams, columns and bracings). The Structures is braced in all directions to transfer lateral loads to foundation and to reduce the moments and to control the deflection. The 3D FE model of the steel junction tower is developed using STAAD.Pro V8i SS6. The material properties considered for various geometrical sections of the member are provided in Table 1. The geometrical sectional properties of various members (total 7446 numbers) were obtained from the previous study on static analysis and optimization of sections [2]. The structure is designed for static loading, equivalent static wind load, seismic load and also for gust wind load conditions.

The damage is induced in one of the corner columns of the structure at elevation +56.060m. The damage is induced as reduction in the flange thickness of 5mm each on both face, for a depth of 300mm. The 3D-FE model of the steel junction tower is shown in Figure 2.

The modal analysis on the FE models with and without damage present in the column at critical locations are conducted using STAAD.Pro V8i SS6.

Table 1 Details of Material properties of steel Junction Tower FE Model

Material	Concrete
Density	25 kN/m^3
Grade of concrete	M25
Young's modulus of elasticity	2x10^5 N/m^2
Material	Steel
Density	78.5 kN/m^3
Grade of steel	Fe 410
Poisons ratio	0.3

IV. MODAL ANALYSIS USING STAAD PRO

As a structural engineer it is important to understand dynamic characteristics of the structure. A modal analysis determines the vibration characteristics (natural frequency and mode shapes) of the structure, it also serves as the starting point for further detailed dynamic analysis. The fundamental frequency and mode shapes of the structural systems can be determined by solving un-damped free vibration equation (1) [6]:

$$K \phi = M \phi \Omega^2 \quad (1)$$

Where,
M, Mass matrix of the structure.
K, Stiffness matrix of the structure.
Ω, Eigen value matrix.
Φ, Corresponding Eigen vector matrix.

Any change to the structural parameters or presence of damage has various effects on modal parameters (natural frequency, mode shapes and damping ratio).

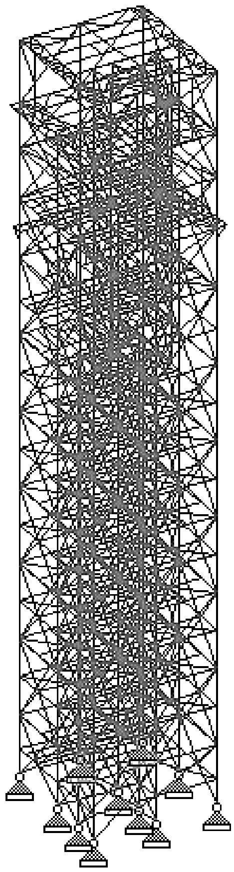

Figure 2 3D-FE model of the steel junction tower

In STAAD.PRO the Eigen problem is solved for structure frequencies and mode shapes considering a diagonal, lumped mass matrix, with masses possible at all active degrees of freedom (DOF) included. For extraction of Eigen values the structural analysis software uses the subspace iteration technique. The dynamic characteristics of 3D FE model is studied by performing modal analysis.

V. RESULTS AND DISCUSSION.

The results of the modal analysis on 3D-FE models with and without damage present in one of the corner column at critical locations are analyzed and further compared to investigate the global responses of the modeled steel junction tower. Table 2 provides the details of the frequency in Hz and time period in seconds for both the damaged and undamaged 3D FE model of steel junction tower.

Table 2 Modal Frequencies and Periods of 3D-FE model of steel junction tower

Steel Junction Tower FE Model				
Mode	Undamaged		Damaged	
	Frequency	Period	Frequency	Period
	cyc/sec	sec	cyc/sec	sec
1st Mode	2.4060	0.415627	2.3982	0.416982
2nd Mode	2.4067	0.415506	2.3994	0.41677
3rd Mode	2.4069	0.415472	2.4031	0.416122
4th Mode	2.4070	0.415454	2.4033	0.416086
5th Mode	2.6860	0.372300	2.6636	0.375434
6th Mode	2.6867	0.372203	2.6747	0.373869
7th Mode	2.6869	0.372176	2.6751	0.373821
8th Mode	2.6870	0.372162	2.6752	0.373802
9th Mode	2.9420	0.339904	2.9139	0.34318
10th Mode	2.9430	0.339789	2.9157	0.342972

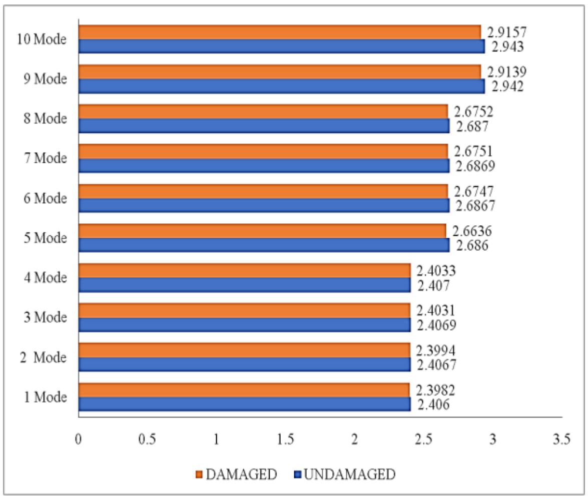

Figure 3 Modal Frequencies of steel junction tower 3D-FE Model

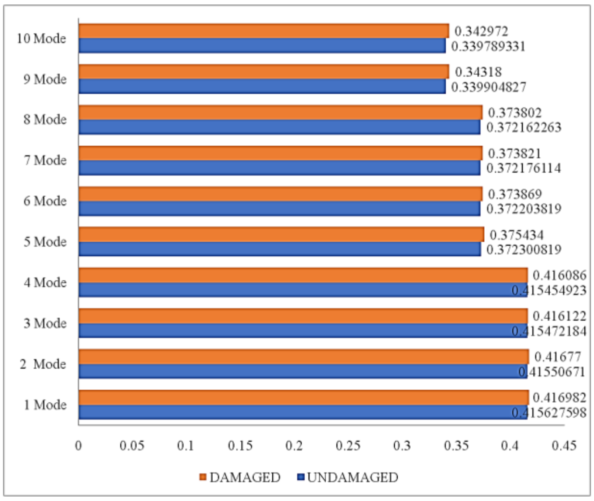

Figure 4 Modal Frequencies of steel junction tower 3D-FE Model

Figure 3 and Figure 4 provides the details of the modal frequency and the period of the steel junction tower FE model with and without damage. It is evident the global response modal response of the FE model indicates detectable shift in the natural frequency and thereby change in time period of the structure.

VI. CONCLUSIONS

- From the modal analysis the modal parameters such as the natural frequency, mode shapes are the primary indicators for determining change in the system.
- The observations under linear modal analysis of 3D complex steel junction tower are mainly focused only on to compare the variation in the modal frequency for all the FE model cases considered.
- As expected the structural natural frequency increases with increasing modes of vibration.
- By comparing the model with and without damage cases detectable shift in natural frequencies at change in global property due to the induced damage is indicated.
- From this initial study on modal frequency help in determining the presence of damage in the structure, therefore for a structure of such complex nature with invisible defects at unknown location can be identified by simple modal testing that cannot be achieved by expensive visual inspection.

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