Seismic Analysis of Low-Rise Commercial Building with Roof Top Telecommunication Tower

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Abstract

The mobile phones have become an important part of everyday human life. A day without them topples down our day to day activities. As a result the number of towers for transmitting and receiving communication signals has grown unprecedentedly over the years. The situation is so grave that the land availability for placing the tower is limited. They are thus being positioned at building rooftops with the added advantage of better coverage for signals. However the host structure should be checked for the additional loads brought in by the rooftop telecommunication towers. In the present study, seismic analysis of a low rise commercial building with towers of height 9m, 15m, 21m and 27m is performed with SAP2000 software. The most favourable position of tower on the roof is identified by placing the tower at different positions. Stresses and axial forces in the top storey structural members and the influence of tower height on building are studied. The results obtained from modal analysis and response spectrum analysis of the structure are tabulated, compared and conclusions drawn. From the results it is concluded that the building need to be designed for resisting earthquake loads. And as the height of tower on rooftop increase there is considerable decrease in building frequency. The minimum displacement in the host structure is found when the tower was placed at the centre of the building roof, making it an optimal position for placing the tower.

Keywords— *Rooftop tower, Host structure, Telecommunication tower, Modal analysis, Response spectrum analysis.*

I. INTRODUCTION

India has more than 250,000 cell phone towers at present and according to an estimate it is expected to have mobile towers just double this number by 2020, making it one of the fastest growing telecommunication market. To enhance both the coverage area and network reliability, more and more telecommunication towers are being installed nowadays. But for their installation we need adequate land and place which fulfill all network connectivity requirements [2]. Due to huge growth in population and the available land already been used for public and private infrastructures, there is scarcity of adequate land for installation of towers. Therefore popularity of roof top towers has increased to fulfill the network and land requirements. But we forget to notice that our buildings are not designed as per seismic provisions of IS code for considering the additional tower load and this could prove disastrous and cause severe damage to lives and properties during severe earthquake. The availability of land which satisfies ideal installation conditions in urban areas is extremely limited giving no alternative but to adopt roof top towers.

In this study, seismic analysis of a low rise commercial building with towers of height 9 m, 15 m, 21 m and 27 m [10] is performed with SAP2000 software. The most favourable position of tower on the roof is identified by placing at different positions [6]. Stresses and axial forces in the top storey structural members and the influence of tower height on building are studied. The selection of the towers is made to cover a wide range of tower heights, from 9 m to 30 m, in order to identify some common trends in behaviour. This also aims at studying the seismic effect on the tower structures by carrying out the modal analysis and response spectrum analysis.

II. MODELLING AND ANALYSIS

In the modelling of telecommunication tower, the towers have been idealized as space frame and modelled using frame element in SAP 2000 software. The connections for both towers assumed to be rigid. Four towers with heights 9 m, 15 m, 21 m and 27 m are considered for analysis. The combined building-tower models were named T9, T15, T21 and T27 based on the height of tower on the rooftop.

The behaviour of towered building is studied under earthquake effect, types of soils and at various positions of tower at the roof of building. In the present studies of G+2 building with a tower of 15 m height placed at two different positions and analysis of seismic force is done. The grade of concrete used is M30 and steel for main and transverse reinforcement is Fe 415.

A. Modelling Details of Tower

Table I : Details Of Rooftop Tower

Sl. No.	Particulars	Size
1	Height of tower	9m,15m,21m and 27m
2	Height of straight portion At top of tower	6m,12m,15m and 21m
3	Height of slant portion	1.5m
4	Effective base width	1.8m
5	Effective top width	1m
6	No. of1.5m high panels	2
7	Type of sections used	ISA100X100X10 for chords ISA45X45X5 for braces
8	Material property	Fe250

B. Modelling Details of the Building

Table II : Building Description (Preliminary Data)

Sl. No.	Particulars	Size
1	Number of floors	3
2	Floor height	2m + 4m
3	Number of bays	3 in x direction 2 in y direction
4	Column grid size	4x6x5m and 8x6m
5	Beam size	350x400mm
6	Column size	450 x 600mm
7	Slab thickness	200 mm
8	Wall thickness	External: 200mm Internal: 150mm
9	Imposed load	3 kN/m^2
10	Specific weight of RCC	24 kN/m^3
11	Specific weight of infill	20 kN/m^3

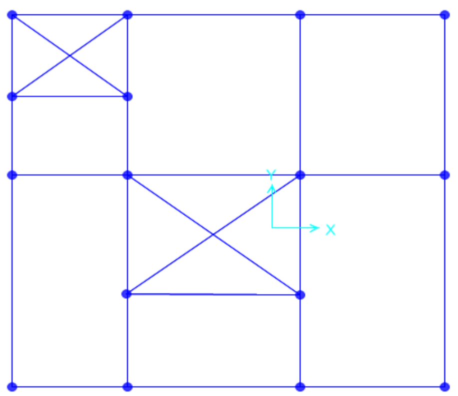

Fig.1. Different Tower Positions on the Building

The towers are placed at two different positions at the roof of the building for analysis. The best position for placing tower on the building chosen for seismic analysis was determined from further analysis.

C. Analysis of the Structure

The Modal analysis is used to determine the vibration modes of a structure. These modes are useful to understand the behaviour of the structure.

Response-spectrum analysis is a statistical type of analysis for the determination of the likely response of a structure to seismic loading. The dynamic analysis (Response Spectrum Analysis) has been carried out on building- tower models using codal response spectra given by Seismic code (IS 1893: Part 1, 2002). The analysis has been performed by assuming fixed base at the base of the building on medium soil (Type II). The structures analysed for earthquake loading using response spectrum as per IS 1893:2002 in zone V with PGA 0.36g, importance factor (I) = 1 (importance factor depending upon the functional use of the structures, characterized by post-earthquake functional needs and economic importance) and response reduction factor (R) = 5 (depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations).

D. Loads and Load Combination

Loads considered are:

i. Gravity loads include dead loads (DL) and live loads (LL).

ii. Wind load (WL) and seismic load (EQ) calculation is done as per provisions given in Indian Standard Specification (IS: 875 (Part 3) – 1987 (Reaffirmed 2003), IS 1893 (Part 1): (2002).

iii. Load combinations are as follows:

a) 1.5x(DL+LL)

b) 1.5x(DL+LL)+1xWLX

c) 1.5x(DL+LL)+1xWLY

d) 1.5x(DL+LL)+1xEQX

Dead loads → Gravity load acting on the towers composed of its own weight and weight of antennas along with other appurtenances attached to it.
→ Weight of platform at top of tower is assumed as 0.82 kN/m^2.
→ Weight of the ladder and cage assembly is 10% of the total weight of the tower.
→ Weight of roof slab is taken as 4.5 kN/m^2.

Live load → 3 kN/m^2 at floor level.

III. ANALYSIS RESULTS

The results obtained from response spectrum analysis are studied and compared in this section.

A. Stresses and Axial Forces in Individual Rooftop Members of the Building

The stresses and axial forces obtained for the selected columns and beams on the roof of the building are compared for the different models. Fig. 2 and Fig. 3 show the comparison plot of axial forces for vertical and horizontal member of the building models. The axial forces are plotted in charts for the members mentioned above as;

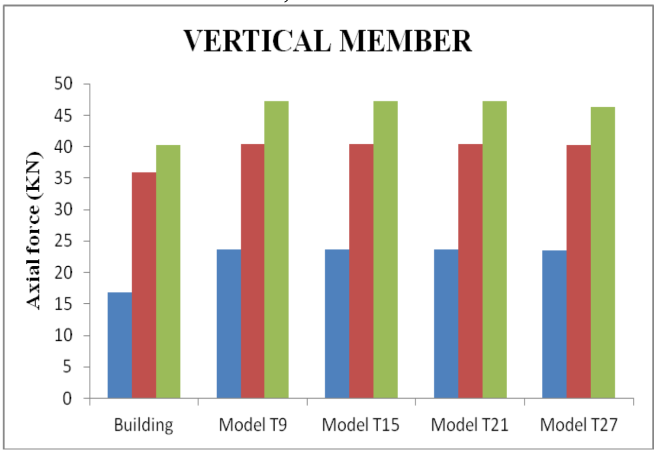

Fig. 2 The Graphical Representation of Axial Forces in Vertical Members of the Models (T9,T15,T21,T27)

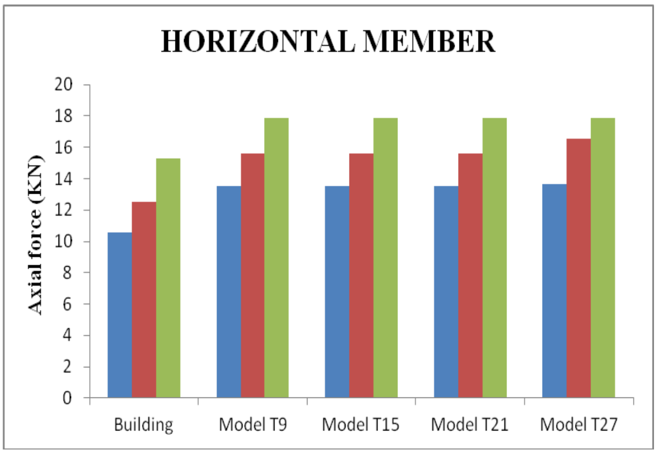

Fig. 3 The Graphical Representation of Axial Forces In Horizontal Members of the Models (T9,T15,T21,T27)

The axial force on columns and beams at the roof of building are plotted in Fig. 2 and Fig. 3. The axial force is marked on the x-axis and models on y-axis. It can be noted that the axial force is more in member 3 for both cases. This indicates that the structural members at roof of buildings with tower are prone to more axial forces than a building without a tower. Also the members in near proximity to roof tower are more vulnerable to seismic activity.

B. Comparison of Frequency

The towers are assumed to be mounted at two different positions on the roof of the building. This position minimises the torsional effects on the building as a whole and on the top portion, in particular. Fig. 4 shows the lowest frequencies building and of combined tower building models (T9, T15, T21and T27).

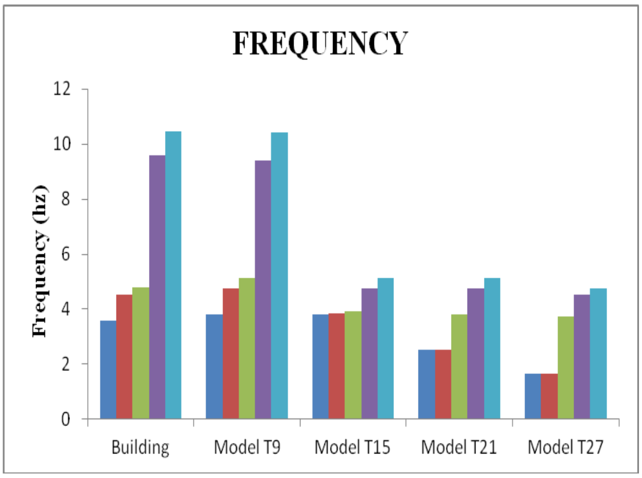

Fig. 4 The Graphical Representation of Frequency of The Models

The frequency is given in the y-axis and models on x-axis of the graph shown above. The frequency is found to decrease as the height of the tower on the building increase. This decrease in frequency is due to the increase in mass of the structure as a whole.

C. Inter Storey Drift from Seismic Analysis of Building Based on Tower Position

In the present studies of G+2 building with telecommunication towers, towers of different height are placed at different position and seismic analysis is done. The building is assumed to be situated in seismic ZONE V as defined in Indian Seismic Code IS 1893 (Part I):2002. The grade of concrete used is M30 and steel for main and transverse reinforcement is Fe 415 and soil beneath the structure is analysed for different types of soil. The analysis was carried in two sections i.e. Analysis for different soil condition & by changing the position of tower.

Inter storey drift is defined as the displacement of one level with respect to the other level above or below. All displacements that are produced by the response spectrum method are positive numbers.

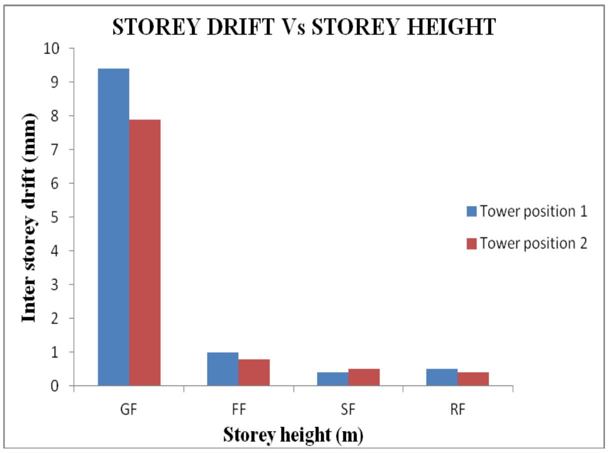

Fig. 5 Comparison of Inter Storey Drift in the Building

In the Fig. 5, a comparison of inter storey drift in the building with respect to storey height for two different positions of tower are shown. The x-axis shows inter storey drift and y-axis shows storey height. From the graph it can be noted that inter storey drift is maximum for tower position 1 (TP 1) compared to the other tower position 2 (TP 2). Also the storey drift is maximum at ground floor level.

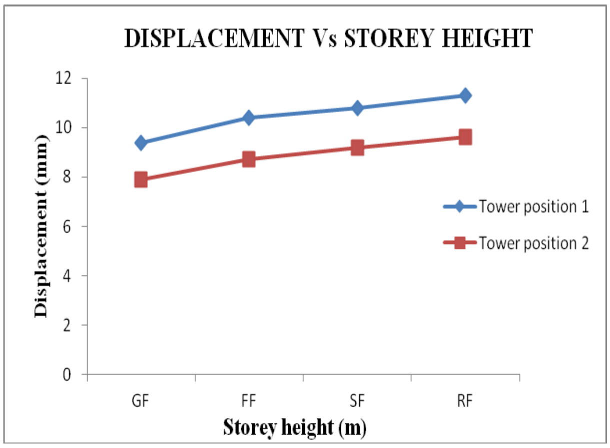

Fig. 6 Comparison of Inter Storey Drift in the Building

The Fig. 6 shows a comparison of displacement in building stories with respect to storey height for two different positions of tower are shown. The y-axis shows storey displacement and x-axis shows storey height. The displacement seems to increase with storey height. However the displacement of storey is more in building with tower position 1.

IV. CONCLUSION

The following conclusions were drawn from the analysis results.

- The response spectrum analysis of the structure indicates that the position of tower on the host structure and its height influences axial forces and stresses in building members. The structural member at rooftop i.e., beams and columns nearer to the tower were found to be more vulnerable to seismic loading.
- The fundamental frequencies tend to increase in the combined building tower models implying that the host structure has to be analysed and designed for seismic effects.
- Both modal and response spectrum analyses underlay that whenever a tower is placed at building rooftop, there is significant changes in building behaviour.
- Also the displacement increases with height of structure. Minimum displacement in the host structure was found when the tower was placed at the centre of the building roof. Hence it can be selected as optimal position for placing the tower.

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