Design of BTS Tower Using Tensegrity Principle

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Abstract - *Towers are one of the most essential and common structures which are being constructed quite frequently to provide better facilities to the people. Hence efficiency and economy in construction of such structures becomes an important aspect. This project had been taken up with the view to provide an alternate method of designing towers implementing tensegrity. The project aims at analysis of an existing telecommunication tower for the given load condition followed by the subsequent redesign for the same tower structure using tensegrity principle and present a comparison between the two an outcome. The purpose of the project was to study the behaviour of a tensegrity based tower structure under a general set of loading condition and to seek its utilization in certain commonly used structure to bring in efficiency in construction along with a subsequent reduction in the construction cost .The modeling and analysis for the structure was to carried out using STAAD Pro, with the wind load being given the highest priority. A comparison between the net deflection of the tensegrity based tower was also being carried out along with the optimization of the member dimensioning for the given set of material with the view of economizing the construction operation.*

Key Words: **Telecommunication Tower , Tensegrity Principle, STAAD Pro ,Wind load, Deflection etc**

1. INTRODUCTION

The importance of a tower for antenna is ever-increasing as telecom companies are continuously expanding their cell phone services. There is fierce competition among telecom companies to widen their subscriber base. However, many cell phone subscribers complain about connectivity problems or network congestion in areas where telecom companies do not have adequate telecom antennas to serve their growing subscriber base.

The only solution to a network congestion problem is to install more telecom antennas in areas where there is network congestion. The telecom antennas are required to be installed at a height because radio signals are most powerful above ground level. The telecom tower provides a platform to install telecommunication equipment and other accessories used in telecommunications.

The height of the tower for antenna also plays an important role in determining the area that will be covered by the antennas fitted on a telecom tower. The height at which the antenna is fixed also plays an important role in the efficiency of a telecommunication network.

A BTS or Base Transceiver Station has equipment for the encryption and decryption of communications, spectrum filtering equipment, antennas and transceivers. A BTS typically has multiple transceivers that allow it to serve many of the cell's different frequencies and sectors.

Tensegrity structures are 3-D trusses where members are assigned specific functions. Some members remain in tension while others are always in compression. Usually for compressive members, solid sections or bars are used; and string or cable type elements can be used as the tensile members.Most bar–string configurations will not be in equilibrium. Hence, if constructed they will collapse to a different shape. Only bar–string configurations which are pre-stressed and in a stable equilibrium will be called Tensegrity structures. If well designed, the application of forces to a Tensegrity structure will deform it into a slightly different shape in a way that supports the applied forces. Tensegrity structures are based on a completely different approach. Instead of the "Weight and support" strategy, they are made as a "system of equilibrated omni directional stresses". Furthermore, they do not have to be supported as they are self-equilibrated and pre stressed, so they are not depending on gravity factors for their own equilibrium. Tensegrity structures as "internally pre-stressed, free standing pin-jointed networks, in which the cables or tendons are tensioned against a system of bars or struts." This implies that there are only axial forces present in the system and there is no torque. The bars (compression members) are rigid bodies and the strings(tensional members) are one-dimensional elastic bodies.

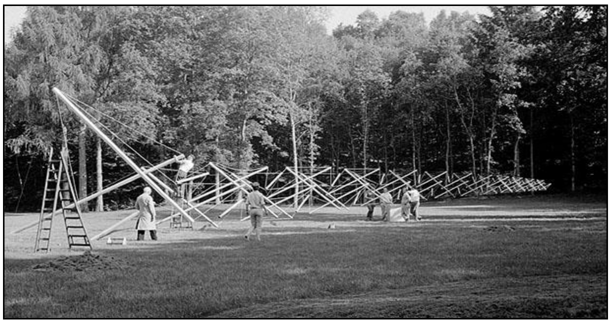

Fig- 1: tensegrity structure

1.1 Aim And Objective

The project aims at analysis of an existing telecommunication tower for the given load condition followed by the subsequent redesign for the same tower structure using tensegrity principle and present a comparison between the two an outcome .The purpose of the project was to study the behaviour of a tensegrity based tower structure under a general set of loading condition and to seek its utilization in certain commonly used structure to bring in efficiency in construction along with a subsequent reduction in the construction cost.

1.2 Scope

Field of Tensegrity structures has a great scope of both research and real time usage. The structures that we analyzed could further be worked on and can be subjected to various other loadings like the seismic loads, snow loads, etc. There are many other structures like sheds and bridges that can be constructed using concept of tensegrity. Also these structures can be made more sustainable and echo friendly.

1.3 Advantages over Conventional System

Tensegrity as a structural system offers many advantages over conventional structural systems. The benefits offered are elaborated as follows:

1. **Tension Stabilizes the Structure:**

A compressive member loses stiffness as it is loaded, whereas a tensile member gains stiffness as it is loaded. Stiffness is lost in two ways in a compressive member: In the absence of any bending moments in the axially loaded members, the forces act exactly through the mass center. The material spreads which increases the diameter of the central cross section; whereas tensile members reduce its cross-section under load. In the presence of bending moments since the line of application of force is away from the center of mass, the bar becomes softer due to the bending motion. For most materials, the tensile strength of a longitudinal member is larger than its buckling strength (sand, masonry, and unreinforced concrete are exceptions to this rule). Hence, a large stiffness-to-mass ratio can be achieved by increasing the use of tensile members.

2. **Tensegrity Structures are Efficient:**

Efficiency of a structure increases with the minimal mass design for a given set of stiffness properties. Tensegrity structures use longitudinal members arranged in a very unusual pattern to achieve maximum strength with small mass.

3. **Tensegrity Structures are Deployable:**

Since the compressive members of Tensegrity structures are either disjoint or connected with ball joints, large displacement and deployability in a compact volume is possible in Tensegrity structures. This feature offers operational and portability advantages. A portable bridge, or a power transmission tower made as a Tensegrity structure could be manufactured in the factory, stowed on a truck or helicopter in a small volume, transported to the construction site, and deployed using only winches for erection through cable tension. Deployable structures can save transport costs by reducing the mass required, or by eliminating the requirement of humans for assembly.

4. **Tensegrity Structures are Easily Tunable:**

The same deployment technique can also make small adjustments for fine tuning of the loaded structures, or adjustment of a damaged structure.

5. **Tensegrity Structures can be more reliably modeled:**

All members of a Tensegrity structure are axially loaded. Perhaps the most promising scientific feature of Tensegrity structures is that while the structure as a whole bends with external static loads, none of the individual members of the Tensegrity structure experience bending moments. Generally, members that experience deformation in two or three dimensions are much harder to model than members that experience deformation in only one dimension. Hence, increased use of tensile members is expected to yield more efficient structures.

6. **Tensegrity Structures can Perform Multiple Functions:**

A given tensile or compressive member of a Tensegrity structure can serve multiple functions. It can simultaneously be a load-carrying member of the structure, a sensor (measuring tension or length), an actuator (such as nickel-titanium wire), a thermal insulator, or an electrical conductor. Therefore by proper choice of materials and geometry the electrical, thermal, and mechanical energy in a material or structure can be controlled.

2 Data Collection

The detail for an existing tower was collected from the office of the BHARAT SANCHAR NIGAM LIMITED, CIVIL WING situated at Irikkur, Kannur. The bts tower is of 40 m height with followed by the department square sections having a design specification of Gopalpur type as.

Table -1: Details of an existing tower

SL.NO	TOWER ELEVATION	MEMBER DESCRIPTION	SECTION
1	0 to 8.5m	LEG MEMBER	ISL 150X150X12
		BRACING	ISL 75X75X6
2	8.5m to 16.5m	LEG MEMBER	ISL 130X130X12
		BRACING	ISL 65X65X6
3	16.5m to 24.5m	LEG MEMBER	ISL 110X110X10
		BRACING	ISL 65X65X6

4	24.5m to 32.5m	LEG MEMBER	ISL 100X100X8
		BRACING	ISL 50X50X6
5	32.5m to 40m	LEG MEMBER	ISL 75X75X6
		BRACING	ISL 50X50X6

3 Modeling

The initial modeling phase dealt with the generation of the existing tower structure with the specifications already been provided in the plan. The sections and the corresponding elements were modeled according to the existing conditions.

Software Used

STAAD:

It is one of the most widely utilized analysis software utilized for designing any type of structure, providing options for implementing a wide range of constructional materials like steel, concrete, timber, aluminum, and cold-formed steel projects, regardless of complexity. One can confidently design structures anywhere in the world using over 80 international codes, reducing the need to learn multiple software applications. The provision of flexible modeling environment and advanced features such as dynamic change revisions and management allows:

- Lower total cost of ownership
- Increase design productivity
- Reduce project costs and delays

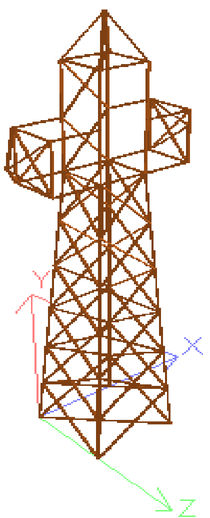

Fig- 2: 3D rentering view of existing tower

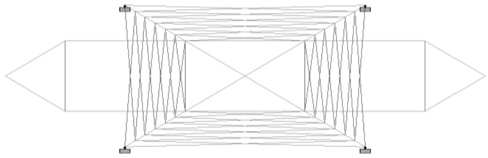

Fig -3: Projected plan of the ground surface

4 Analysis

The generated existing structure was then analyzed by subjecting to the following loading conditions, using STAAD pro V8i.

- Dead load
- Self weight of the tower
- Self weight of antenna
- Wind load

The response of the structure to the above mentioned loading conditions were observed and the net deflection of the structure was noted for comparison.

Design Wind Speed (V_z)

The basic wind speed for any site shall be obtained from the code or from the weather department and shall be modified to include the following effects to get design wind speed, V_z at any height, Z for the chosen structure:

(a) Risk level,

(b) Terrain roughness and height of structure,

(c) Local topography, and

(d) Importance factor for the cyclonic region.

It can be mathematically expressed as follows:

$$V_z = V_b k_1 k_2 k_3 k_4$$

Where,

V_b = design wind speed at any height z in m/s,

k_1 = probability factor (risk coefficient),

k_2= terrain roughness and height factor,

k_3 = topography factor, and

k_4 = importance factor for the cyclonic region.

5 Redesign the existing tower using Tensegrity principle

The existing tower was redesigned based on tensegrity principle by referring to the Snelson 's Needle Tower for the same tower height of 40m as of the existing tower using properties as PIP1524M for the compression members and cables of.02m diameter for the tension members. Also for the tension members, the pre tensioning was kept constant to a value of 1kN.

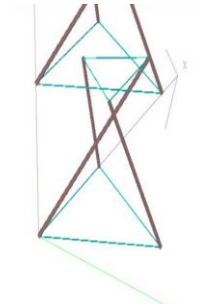

Fig- 4: 3D rentering view of tensegrity tower

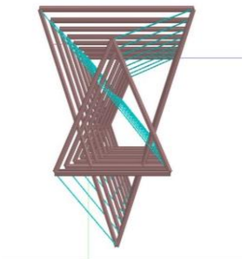

Fig -5: Projected plan of the ground surface of tensegrity tower

Key features:

- The square sections were converted into triangular section ns of equal area
- The members were classified under compression only and tension only members
- Cables were utilized for the tension members
- IS pipe sections were implemented for the compression bearing members
- The foundation was assumed to be fixed
- No direct connection has been provided between the tension and compression members
- Pre stressing of the cable members were applied.
- The joints between cables and pipes were designed as pin jointed.

The loading conditions had been kept the same as that adopted for the analysis of the existing structure. Initially, the compression members were assigned pipe section of IS PIP1524M conforming the IS specifications and cables of 2cm diameter were assigned for the tension members.

Fig- 6: snelson needle tower

6. RESULT AND COMPARISON

Final analysis result of existing tower and tensegrity tower are determined and these result compared.

6.1 Result

			Horizontal	Vertical	Horizontal	Resultant	Rc
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad
Max X	17	2 wind load	37.175	0.523	-5.289	37.553	-0.000
Min X	17	1 DEAD LOA	-0.655	-0.531	0.682	1.085	0.000
Max Y	64	2 wind load	26.767	6.184	-3.465	27.689	-0.000
Min Y	62	1 DEAD LOA	-0.495	-38.346	-2.421	38.425	0.000
Max Z	17	1 DEAD LOA	-0.655	-0.531	0.682	1.085	0.000
Min Z	17	2 wind load	37.175	0.523	-5.289	37.553	-0.000
Max rX	67	2 wind load	6.553	-4.819	-0.192	8.136	0.001
Min rX	29	1 DEAD LOA	0.024	-0.299	-0.021	0.301	-0.002

Fig- 7: Deflection results for the final existing tower structure

For the existing structure, the net deflection obtained is 3.717cm which is below the permissible deflection value of 34.9cm (40tan (.05).

			Horizontal	Vertical	Horizontal	Resultant		Rotationa
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad
Max X	17	2 WIND LOA	63.580	1.198	2.215	63.630	0.000	-0.00
Min X	62	1 DEAD LOA	-6.198	-35.770	-3.212	36.444	-0.002	-0.00
Max Y	64	2 WIND LOA	44.354	12.001	1.539	45.974	0.000	0.00
Min Y	57	1 DEAD LOA	-3.624	-54.183	0.631	54.307	-0.001	-0.00
Max Z	17	2 WIND LOA	63.580	1.198	2.215	63.630	0.000	-0.00
Min Z	62	1 DEAD LOA	-6.198	-35.770	-3.212	36.444	-0.002	-0.00
Max rX	60	1 DEAD LOA	-3.804	-29.079	0.968	29.343	0.001	-0.00
Min rX	62	1 DEAD LOA	-6.198	-35.770	-3.212	36.444	-0.002	-0.00

Fig- 8: Deflection Results for the final Tensegrity based tower structure

The final net deflection for the tensegrity based tower obtained from STAAD analysis is 6.358cm.

6.2 Comparison

The responses of the existing tower and the tensegrity based tower were obtained at the end of the STAAD analysis under similar loading conditions which are tabulated as follows.

Table- 2: Comparison of two tower structure

SL.NO	PARAMETERS	EXISTING TOWER	TENSEGRITYBASED TOWER
1	DEFLECTION	3.717cm	6.358 cm
2	TOTAL WEIGHT	169.71KN	11.75 KN
3	NUMBER OF MEMBERS	175	72

7. CONCLUSION

From the obtained result we get the deflection of tensegrity tower is more than that of existing tower .But in the case of total weight and number of member it will be economical in the case tensegrity tower .From it can be seen that the conventional method of tower construction provides a more stabilized structure than that of the tensegrity based methods under similar loading conditions taking deflection under consideration. However, in terms of constructional costs, tensegrity principle provides a more economical structure when compared to the existing structure for the same height.

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