

# Analysis and Design of Tensegrity Based Walked – Way Bridge

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**Abstract:** *The term tensegrity was first used by legendary architect Buckminster Fuller during his experimentation with alternative structural systems. Fuller described works of tensegrity as “self-tensioning structures composed of rigid structures and cables, with forces of traction and compression, which form an integrated whole.” Tensegrity structures are lightweight structures composed of cables in tension and struts in Compression. Since tensegrity systems exhibit geometrically nonlinear behavior, finding optimal Structural designs are difficult. This results in interest concerning possibilities of applying tensegrity as load carrying structure in a pedestrian bridge design. Tensegrity structures are light in Weight therefore very efficient and deployable. As compared to their self-weight they can sustain a large amount of loading if designed properly. Now and further these structures are used in architecture purpose. However, design as well as the arrangement of struts and cable to achieve equilibrium. Tensegrity structures are lightweight structures created of cables in tension and struts in Compression. Since tensegrity systems exhibit geometrically nonlinear behavior, finding optimal Structural designs are difficult.*

*This results in interest about possibilities of applying tensegrity as load carrying structure in a pedestrian bridge design. Tensegrity structures are light in Weight therefore very efficient and deployable. As compared to their self-weight they can resist a large number of loading if designed properly. Now and further these structures are used in architecture purpose. Prioritizing energy efficiency, this research presents an optimized deployment strategy for tensegrity utility bridges, addressing key deployment challenges, such as local and global buckling, cable entanglement, and strut collision during deployment and post-deployment performance under in-service loading.*

*A novel Genetic Algorithm (GA)-based approach is developed to optimize both telescopic and non-telescopic deployment methods for tensegrity structure, with the choice of deployment strategy determined by geometric constraints specific to the deployment location.*

**Keywords:** Tensegrity, Pedestrian Bridge, Walk way Bridge, Tensegrity modulus, Design optimization

## I. INTRODUCTION

Tensegrity’ is a kind of new concept using which one can create lightweight and adaptable structures, giving the impression of a assembling of struts floating in the air. Tensegrity structures can be defined as a design of results when the ‘push’ provided by struts and the pull provided by tendons achieve a win-win relationship with each other. While pull is continuous, push is discontinuous, and the two balance each other, producing the integration of tension and compression. A Tensegrity Walkway Bridge is a modern structural system that combines tension and compression elements in a balanced, self stable configuration. The word “Tensegrity” is derived from “Tensional Integrity,” a concept introduced by architect and inventor Buckminster Fuller in the mid-20th century. It represents a unique structural principle where isolated compression members (struts or bars) are held together by a continuous network of tension members (cables or tendons) without the compression members touching each other. In a tensegrity bridge, this principle is applied to create a lightweight yet strong and flexible structure for pedestrian use. The walkway deck is



supported by a system of steel cables and struts, which together maintain the stability and shape of the bridge through tension–compression balance.

Compression members (usually steel tubes or rods) resist compressive forces and maintain the form of the structure. Tension members (usually high-strength cables) are continuously connected and carry tensile forces. The structure remains stable and rigid because the tensile network “pre-stresses” the system, keeping all components in equilibrium. This balance gives the tensegrity bridge its lightweight, efficient, and aesthetically appealing form.

A Tensegrity Walkway Bridge represents a perfect blend of art, architecture, and engineering innovation. Its ability to achieve strength through equilibrium of tension and compression makes it an excellent example of sustainable and efficient structural design. As cities move toward lighter, eco-friendly, and visually appealing infrastructure, tensegrity bridges are emerging as a promising solution for the future of pedestrian connectivity. Tensegrity structures consist of compression (bars) and tension (cables) members, where the cables surround bar

## **II. LITERATURE SURVEY / RELATED WORK**

tensegrity walkway bridge is a modern, lightweight, and innovative bridge structure that relies on the principle of tensegrity — a combination of “tension” and “integrity.” It is a structural system that maintains its shape and stability through a balance between tensile and compressive forces. In a tensegrity structure: Cables or tendons are always in tension, and Rods or struts are always in compression, and these two sets of elements do not touch each other directly but are held in place through a network of pre-stressed cables. The word “Tensegrity” was coined by Buckminster Fuller in the 1940s. The principle was first demonstrated by artist Kenneth Snelson, who created sculptures using floating compression elements connected by tension cables. The basic idea: “A stable structure can be formed by a network of cables in continuous tension and bars in discontinuous compression.” In a tensegrity bridge, the tension elements (steel cables) form a continuous network that stabilizes the compressive struts (steel tubes or rods), resulting in an efficient load carrying mechanism. In civil engineering, tensegrity systems are applied for: Lightweight bridges (pedestrian or temporary bridges), Roof structures (stadiums, exhibition halls), Deployable or foldable structures (space applications, military shelters), Architectural sculptures and pavilions. For walkway bridges, tensegrity principles are used to: Create elegant, high-strength pedestrian bridges, reduce self-weight and material consumption, Simplify construction and transportation due to modular design. Over the last decades, the tensegrity concept has received significant interest among scientists and engineers throughout disciplines such as architecture, civil engineering, biology, robotics and aerospace. The tensegrity concept offers a high level of geometrical and structural efficiency and results in modular and lightweight structures. However, few examples of tensegrity structures have been used for civil engineering purposes. Paronesso and Passera proposed a tensegrity platform for the 2002 Swiss National Exhibition in Yverdon. They also designed a tensegrity roof for the velodrome in Aigle (Switzerland). Designed by Schlaich, Bergermann and Partners, the Rostock tower (Germany) built in 2003 is probably the highest tensegrity tower (62.3 m). The tower is composed of a continuous assembly of six “simplex” modules.

## **III. PROBLEM STATEMENT**

Modern urban environments demand innovative, lightweight, and sustainable structural systems for pedestrian bridges that can efficiently span moderate distances while maintaining aesthetic appeal, structural stability, and ease of construction. Traditional bridge designs— such as beam, arch, or suspension types—often require heavy materials, deep foundations, and complex construction techniques that increase cost and environmental impact. The challenge, therefore, lies in developing a walkway bridge structure that: Minimizes the use of material without compromising strength and stability, is lightweight, modular, and easy to assemble or dismantle, exhibits high structural efficiency by effectively utilizing both tension and compression elements, Maintains visual transparency and an elegant architectural form suitable for public and urban spaces. A Tensegrity Walkway Bridge provides a potential solution to these challenges. Tensegrity structures are composed of a network of isolated compression members (struts) suspended within a continuous tension system (cables or tendons), achieving a self-stressed, stable configuration. However, the



application of tensegrity principles to pedestrian bridge design introduces several engineering challenges that form the core of this study,

including:

- Ensuring adequate load-carrying capacity and stiffness under pedestrian and environmental loads (wind, vibration, etc.).
- Achieving structural equilibrium between tension and compression forces.
- Optimizing the geometry for stability and minimizing deflection or oscillation.
- Selecting suitable materials for cables and struts that provide strength, durability, and corrosion resistance.
- Simplifying fabrication and assembly methods to make the structure practical for real-world implementation.

#### IV. DESIGN AND ANALYSIS

**4.1 DESIGN:** A pedestrian bridge composed of tensegrity x shape modules. A span of 8 m and a distance from the ground of 3 m are assumed. The bridge geometry is chosen such that it has the minimum internal space required for two pedestrians to walk side-by-side (Figure 3). This space can be represented by a rectangle with a height of 2 m and a width of 1.5 m.

**A. Material characteristics:** Tensegrity structures generally consist of soft members (cables) and hard members (struts). It is essential to determine the material properties i.e. the Young's modulus (E), yield strength and the ultimate strength of both the tension and the compression members before they can be employed for fabrication. In this study Indian Standards IS 4923 (1997) Hollow steel section for structural use (specification), were used as compression members. The market conforming to IS 2365 (1997) Steel wire suspension ropes for lifts, elevator and hoists, were used as tensile members.

Table1: properties of MS tube as per IS 4923-1997

Parameters	Value
Designation	150x150x5 (MM)
Depth or Width (D)	150
Thickness	5 (Mm)
Weight	22.26 Kg/M
Area of section	28.36 CM <sup>2</sup>
Moment of inertia	982.12 Cm <sup>4</sup>
Radius of Gyration	5.89 Cm
Elastic Modulus	130.95 Cm <sup>3</sup>
Plastic modulus	152.98Cm <sup>3</sup>

Table2: Properties of standard wire as per IS 2365-1997

Parameters	Value
Nominal bore diameter	20 mm
Thickness	2.6 mm
Mass	1.21 Kg/m
Max outside diameter	21.8mm
Min outside diameter	21
Tolerance in thickness	-10%+unlimited
Minimum tensile strength	320N/mm <sup>2</sup>

Parameters Value

Nominal bore diameter 20 mm



**B. Using STAAD Pro**

In general analysis of member consists of two main parts. In first part, the determination of loads and reactions was done. In second part, determination of internal forces in the members. The types of members namely were modelled, analyzed and designed through STADD PRO software package as per Indian code provisions. The model developed was ensured with stability conditions.

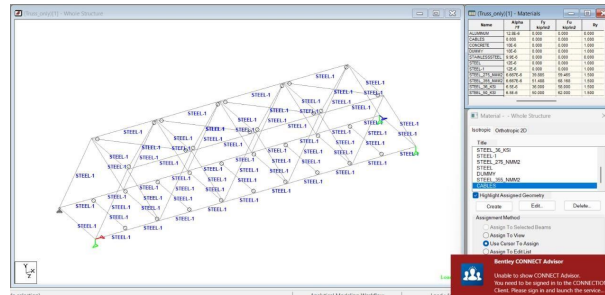


Fig:4.1 Detail staad modelling of walkway bridge.

**4.2 ANALYSIS :**

1. Main Member: - Tube 150x150x5 mm, Secondary member: - Tube 40x40x2.6mm Strud: - Pipe 89 mm Dia, Cable: - 0.02 m Dia
2. Loading: -
  1. Dead Load: -
    1. Selfweight: - 1.1
    2. Weight of Steel Sheet plate of 10mm thk.: -  $78.50 \text{ kN/m}^3 \times 0.010\text{mm} = 0.785 \text{ kN/m}^2$
    - 2.Live Load: -
 

Weight of Human = 75 kg = 0.75 kN/m<sup>2</sup>
  3. Load Combination: -
    1. DL+LL
    2. 1.5(DL+LL)
4. Spring Force in Cable: - 1 kN in Tension

Table3: the maximum deflection and forces in elements for different case

Node	L/C	Horizontal Fx KN	Vertical Fy KN	Horizontal Fz KN	Moment Mx KNm	My KNm	Mz KNm
58	2DL+LL	0	5.35	-0.115	0	0	0
59	2DL+LL	0	5.338	0.095	0	0	0
60	2DL+LL	0	5.35	-0.115	0	0	0
63	2DL+LL	-0.006	15.573	0.058	0.004	0.004	0
67	2DL+LL	0.006	15.573	0.058	-0.004	-0.004	0
71	2DL+LL	-7.897	15.444	-0.02	-0.008	-0.008	0
73	2DL+LL	0	15.564	-0.0489	0	0	0



## V. RESULT

Value on node the node numbers and the loading for case 1(load cases detail 2 kN) are shown in table. The structure was analysed and the maximum deflection and forces in elements for different cases are presented in tabular form in Table.

The maximum deflections obtained in analysis for different load case are shown in Table Maximum vertical deflection is observed in Case for the central top node and maximum deflection in horizontal direction at node 63 for Case. As per the codal practice, the value should be within span/250, which is 32 mm.

Hence, the maximum deflection is 40% of allowable limit. Similarly, the maximum forces in elements for different load case are shown in deflection Table. The results show that the maximum values are less than maximum carrying capacity. Though some of the cables are loosen due to less force than the prestressed equilibrium value, the structure will remain stable due to inherent redundancy.

## VI. CONCLUDING REMARK

1. Structural Performance: Gain insights into the structural behavior of tensegrity towers, including their strength, stiffness, and stability under various loads.
2. Design Guidelines: Develop design guidelines for tensegrity towers, highlighting key considerations for geometry, materials, and pre-stress levels.
3. Efficiency and Sustainability: Evaluate the potential benefits of tensegrity structures in terms of material efficiency, sustainability, and environmental impact.
4. Comparison with Conventional Structures: Compare the performance of tensegrity towers with conventional structural systems, highlighting advantages and limitations.

## REFERENCES

- 1) Landolf-Giosef-anastasios Rhode - Barbarigos, an "active deployable tensegrity structure", applied computing mechanics Laboratory (IMAC), EPFL-ENAC-IMAC station 18, CH-1015 Lausanne, Switzerland.
- 2) Rhode-Barbarigos, L., Bel Hadj Ali, N., Motro, R. and Smith, I.F.C. "Designing tensegrity modules for pedestrian bridges" Engineering structure Vol.32, No.4, 2010, pp 1158-1167.
- 3) Williamson, A., and Skelton, R.E., "A general class of tensegrity systems: Equilibrium analysis, Engineering Mechanics for the 21st Century", ASCE conference, La Jolla, 1998
- 4) Fuller, B., "Tensile-integrity structures", US Patent, 3, 063, 521, 1962.
- 5) Chu, R., "Tensegrity", Journal of Synergetic, 2(1), 1988.7.
- 6) IRC 24 2001 Standard specification & code of practice for road bridge (Section V) Steel road bridges.
- 7) IS 2365 1997 Steel wire suspension ropes for lifts elevators and hoists
- 8) IS: 1239 1990 Mild steel tubes tubular and other wrought steel fitting Specification- Part 1: Mild steel tubes bureau of India standards New Delhi.
- 9) IS:800 1984 Code of practice for general construction in steel bureau of Indian standards New Delhi.
- 10) IS:875 1987 Code of practice for design loads (other than earthquake) for building structures: parts 3 wind load bureau of indian standards New Delhi.

