PARAMETRIC MODELLING AND ANALYSIS OF TENSEGRITY STRUCTURES

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Tensegrity structures are based on a set of discontinuous compressible elements within a network of continuous tension elements, with isolated compressed elements (struts or bars) and prestressed tension elements (tendons or cables) that form a stable network. They are dominated by tensile elements, while more material-intensive compression elements are minimised. Tensegrity structures fail mainly due to low material efficiency, member instability, and excessive deflections when compared to rigid structures made with slender elements. The spatial geometry, axial stiffness, member layout, and connectivity of tensegrity structures directly affect the type of structural failure, including strength, instability, and stiffness. This study presents a systematic parametric study on overall axial stiffness variation of the 3-bar tensegrity prism to check the effect of the level of prestressing and other geometric parameters such as the height of the tensegrity cell, type of the tensegrity cell (number of compression members), radius of the tensegrity cell, area of the cables & struts, twisted angle of the top and bottom cable tringles, and the point load acting on nodes.

The tensegrity unit studied here is the T3- prism. It is also termed 3-bar tensegrity. The 3-bar tensegrity has nine cables and three struts in which struts are isolated from each other. The cables are assumed to have solid circular cross-sections whereas struts are assumed to be circular hollow to achieve an optimum structure. All members of tensegrity structures are either loaded in axial compression or tension. This means the structure will only fail due to cable yield or buckling of struts. Since the compression members are not transmitting loads over a longer distance, they are not subject to higher buckling loads. The prestressed cables are mostly used for these structures to have better stability to resist higher deflections. In this study, a 3-bar tensegrity cell was analysed using parametric modelling by applying three-point loads in the z-direction to the cell's top nodes. In order to determine the minimum mass necessary under yielding constraints, the static analysis optimises the tensile forces in the cables and the compressive forces in the struts in the presence of certain external forces. In order to acquire the parametric results of the 3-bar tensegrity cell, the Karamba3D structural analysis tool was utilised. It is fully embedded within the Grasshopper parametric design environment, a plug-in for the Rhinoceros3D computer-aided design program.

The tensegrity cell's stability improves with height, which also causes an increase in mass and displacements. When the radius, type, and point loads acting on the tensegrity cell increase, the tensegrity cell tends to become more unstable, leading to cell instability because of poor stress distribution among the members. The tensegrity cell becomes more stable while simultaneously increasing its mass by increasing its compression area, tension area, and twisted angle. As a result, while designing the optimised design, mass and stability should both be taken into consideration. Most of the tensegrity structures are constructed by combining diverse types of general tensegrity configurations. After modelling and finalising the solutions for tensegrity configurations, an optimum tensegrity geometry for any application can be defined by combining and scaling these basic tensegrity configurations.

Keywords: Tensegrity networks, Prestress, Cables, Struts, Optimal configuration

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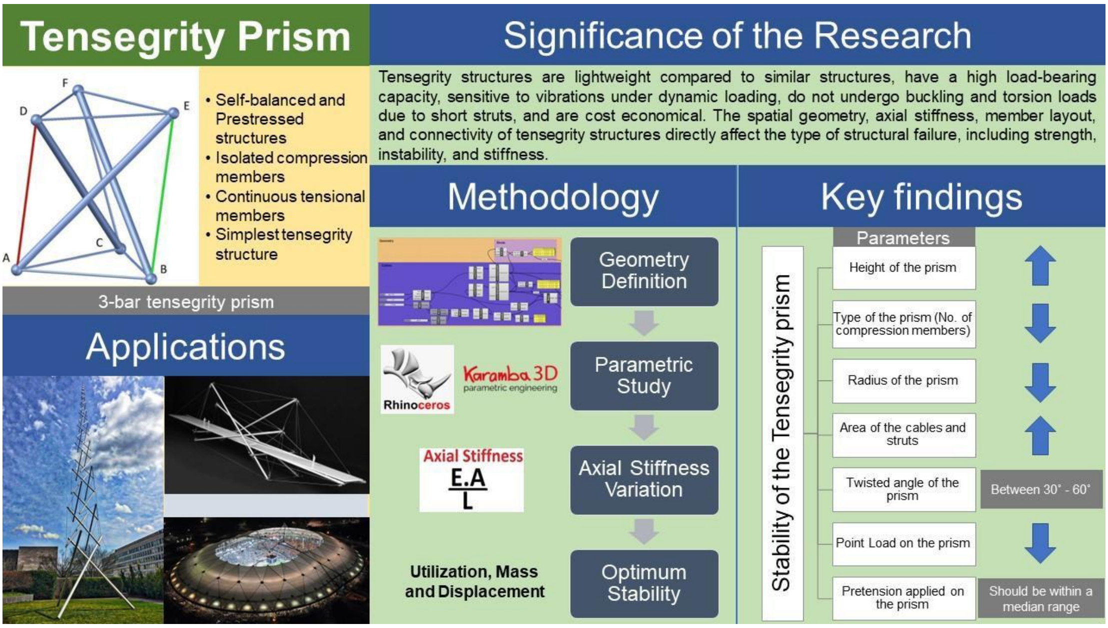
Tensegrity Prism
F
D
E
A
C
B
• Self-balanced and Prestressed structures
• Isolated compression members
• Continuous tensional members
• Simplest tensegrity structure
3-bar tensegrity prism
Applications
Significance of the Research
Tensegrity structures are lightweight compared to similar structures, have a high load-bearing capacity, sensitive to vibrations under dynamic loading, do not undergo buckling and torsion loads due to short struts, and are cost economical. The spatial geometry, axial stiffness, member layout, and connectivity of tensegrity structures directly affect the type of structural failure, including strength, instability, and stiffness.
Methodology
Geometry Definition
Rhinoceros
Karamba 3D
parametric engineering
Parametric Study
Axial Stiffness
E.A
L
Axial Stiffness Variation
Utilization, Mass and Displacement
Optimum Stability
Key findings
Stability of the Tensegrity prism
Parameters
Height of the prism
Type of the prism (No. of compression members)
Radius of the prism
Area of the cables and struts
Twisted angle of the prism
Between 30˚ - 60˚
Point Load on the prism
Pretension applied on the prism
Should be within a median range