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Enhancing Structural Stability in Cable Bracing Systems: The Benefits of an Additional Horizontal Member

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INTRODUCTION & AIM

Cable members behave in a highly non-linear manner, resembling chain links influenced by their own weight. Understanding this behavior necessitates a nuanced, non-linear analytical approach. SAP2000 software offers a robust suite of tools for precisely this purpose, enabling engineers to conduct thorough analyses of various structures. This research delves into a critical challenge: the limited capacity of cable members to withstand compressive forces effectively. To address this, the study introduces a novel chevron cable (inverted V shaped) bracing model within SAP2000. This model emphasizes tension-based strategies to mitigate cable loosening, thereby enhancing structural stability. By delving into static analyses under different pre-stressed forces and cable diameters, the research aims to refine cable bracing systems. It proposes the addition of a horizontal member to existing frames to gauge its effectiveness in stabilizing structures under varying conditions. This meticulous exploration offers valuable insights for structural engineering practitioners, paving the way for optimized designs and enhanced structural integrity.

METHOD

Horizontal Cable Member

For models with diverse loads or non-linear material characteristics, a frame member with non-linear analysis is necessary, limiting cable compressive force to accurately model behavior. For slender cables with predictable support movements, using the cable as a catenary element is more suitable, requiring non-linear analysis for large deformations and P-delta effects.

Features of Structural Models

The study investigates a 3m x 3m, two-dimensional steel frame with a Inverted V Shaped bracing, modeled in SAP2000. The horizontal member, made from the same cable as the brace, enhances static load performance. Beam and column profiles use IPE 160 sections. The proposed model, as depicted in Fig 1.

Structural Models Under Static Analysis

The position of the horizontal member (0.5m length) was analyzed under various pre-stressed forces (200, 300, 500 kg), cable diameters (2 and 3 cm), and fixed supporting condition at heights of 0.3 to 0.8 meters. Additionally, lengths from 0.2 to 1.6 meters were studied with a constant height. Material properties are provided in Table 1.

Load Specifications

In the frames under study, two types of loads are defined. One is the dead load (DEAD) and the other is a lateral load (OTHER) named Ex, with a magnitude of 15,000 kg force applied at the top left node where the beam and column intersect. Additionally, Combo 1: 1.4 DEAD + 1.7 Ex is defined as the load combination.

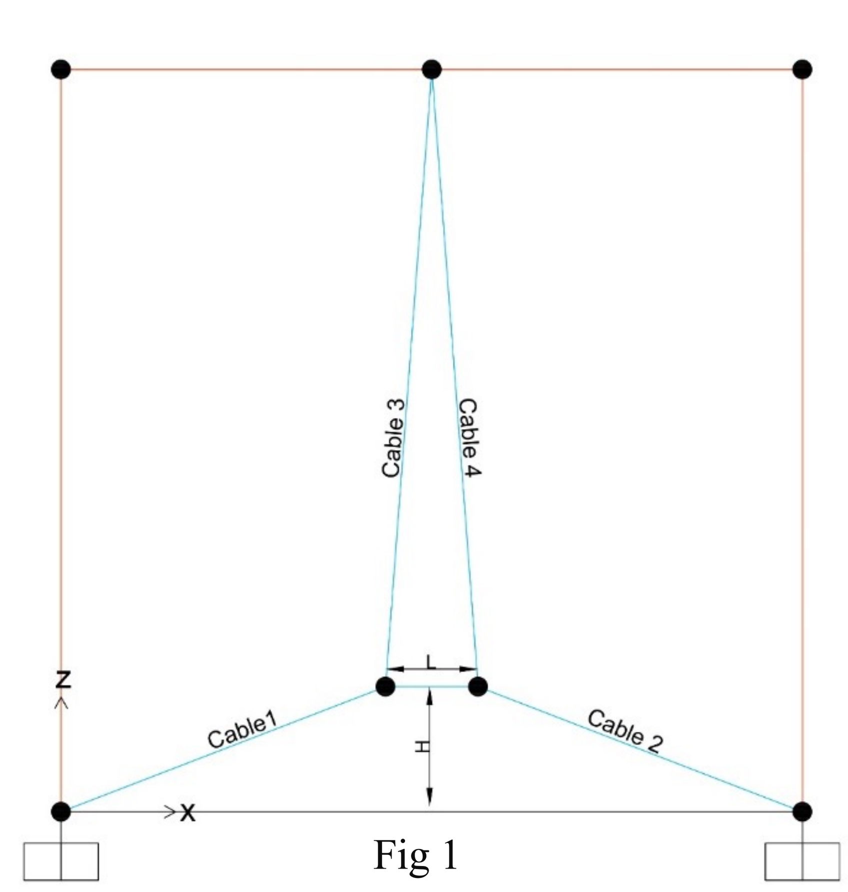

Fig 1

Material type	Specific weight (kg/m³)	Poisson's ratio	Ultimate stress (kg/cm²)	Yield stress (kg/cm²)	Elastic modulus (kg/cm²)
Steel	7850	0.3	2400	3700	2.1×10^6
Cable	7850	0.3	17000	16000	1.98×10^6

Table 1

RESULTS & DISCUSSION

Optimal Height of the Horizontal Member

- A single-story frame (3m x 3m) was studied to find the optimal height (H) of the horizontal member.
- Various factors were considered, including cable diameter, pre-stressed forces, and support conditions.
- The length of the horizontal member was fixed at 0.5 meters.
- The axial forces of cables 1 and 2 were evaluated at different heights.

Impact of Varied Pre-Stressed Forces on Optimal Height

- Different pre-stressed levels (200, 300, and 500 Kg) with a fixed cable diameter of 2 cm and fixed support were analyzed.
- Fig. 2 shows that maximum axial forces occur at 10% of the frame height, while minimum forces occur between 16% and 20%.
- Increasing pre-tensioning forces increased the axial forces.
- The axial force trend showed a decrease followed by an increase as the height increased.
- The minimum pre-tensioning force was deemed most suitable as it consistently produced tensile forces.

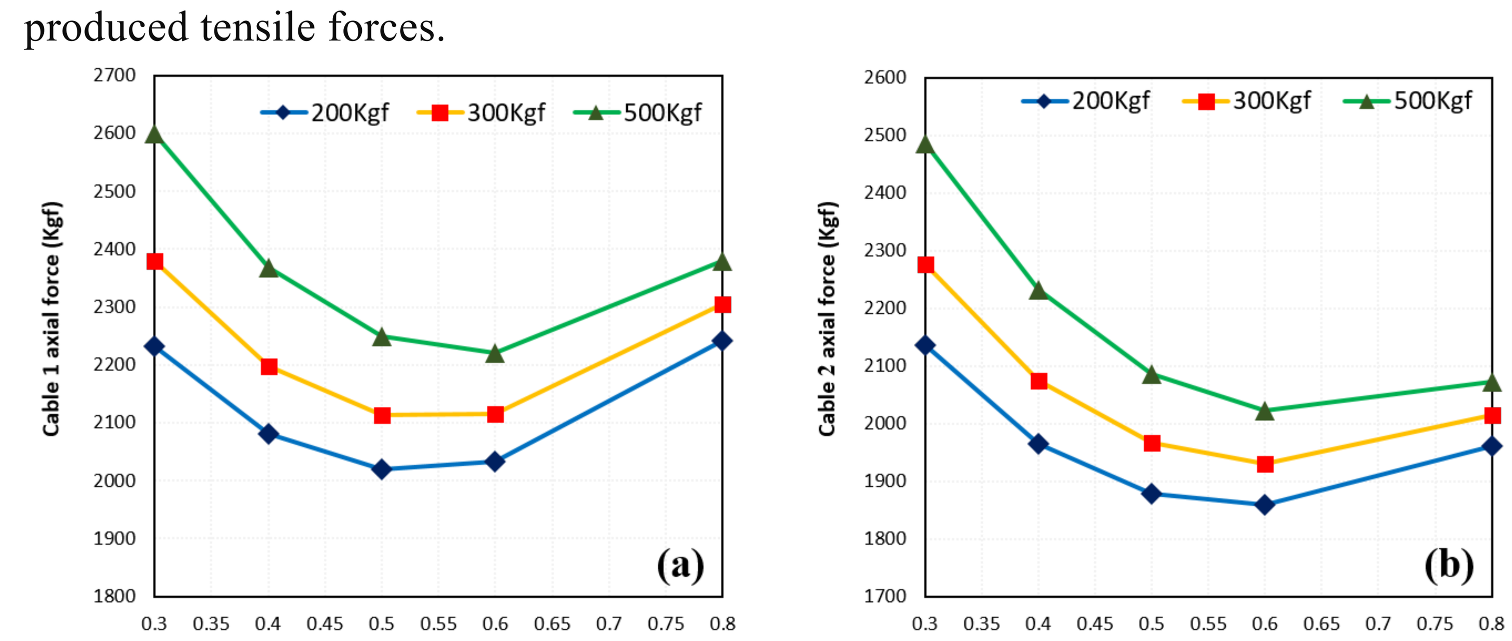

Fig 2

Impact of Different Diameters on Optimal Height

- Two scenarios were examined: cable diameters of 2 cm and 3 cm, with a consistent pre-stressed force of 500 kg and fixed support.
- Fig. 3 indicates that maximum axial forces for both diameters occur at 10% of the frame height, with minimum forces at 20%.
- Larger diameter cables (3 cm) exhibited higher axial forces than smaller diameter cables (2 cm).
- The axial force decreased with height initially, then stabilized.
- Smaller diameter cables showed better performance with lower axial forces.

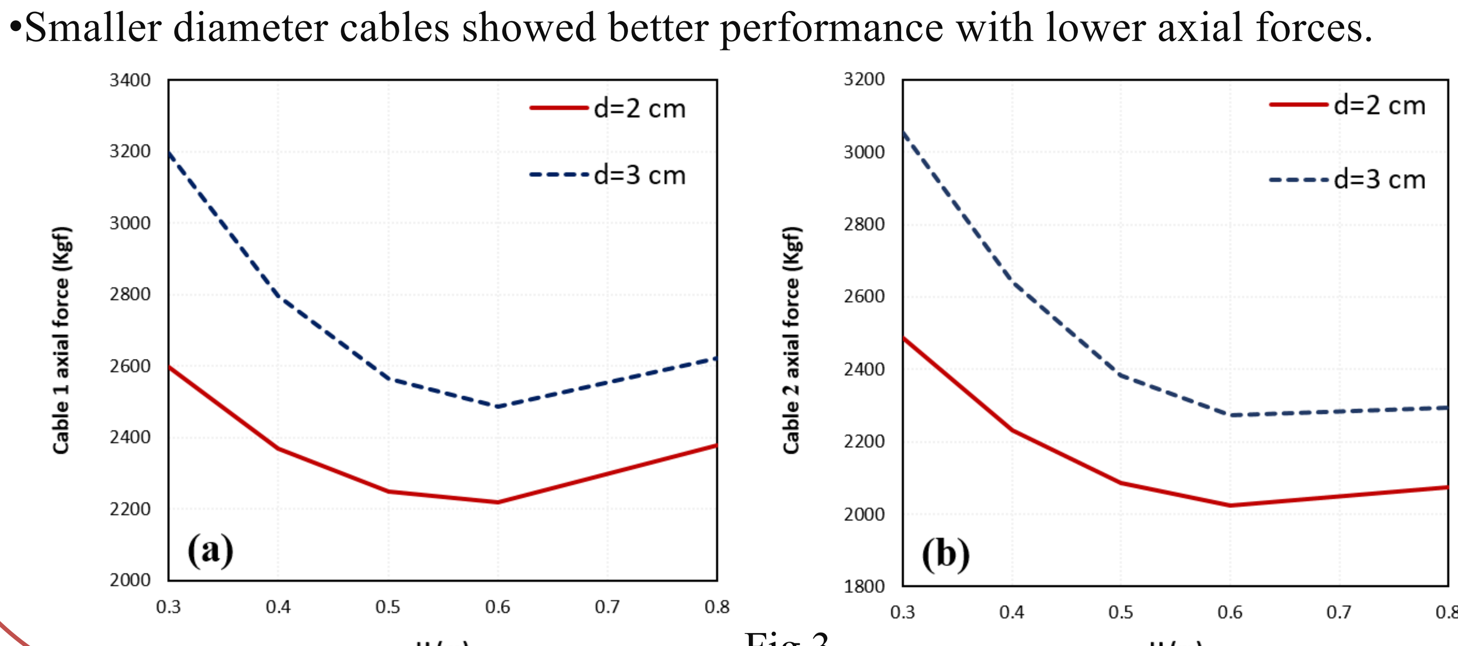

Fig 3

CONCLUSION

This research explored the behavior of cable, focusing on an innovative chevron cable bracing model to enhance stability and reduce cable loosening. Static analyses considered various pre-stressed forces and cable diameters. Key findings revealed that optimal horizontal cable height depends on pre-stressed forces, which achieved maximum axial forces at around 10% of frame height and minimum forces between 16% and 20%. The minimum pre-stressed force was most suitable. Smaller cable diameters were more efficient, resulting in lower axial forces. This research offers valuable insights for improving cable bracing systems, encouraging further refinement and application of the chevron cable bracing model in real-world structures.

References:

[1] M. Kawaguchi, I. Tatemichi, and P. Shan Chen, "Optimum shapes of a cable dome structure," *Eng. Struct.*, vol. 21, no. 8, pp. 719–725, Aug. 1999, doi: 10.1016/S0141-0296(98)00026-1.

[2] X. Lu, L. Xie, H. Guan, Y. Huang, and X. Lu, "A shear wall element for nonlinear seismic analysis of super-tall buildings using OpenSees," *Finite Elem. Anal. Des.*, vol. 98, pp. 14–25, Jun. 2015, doi: 10.1016/j.finel.2015.01.006.

[3] L. Pasticier, C. Amadio, and M. Fragiacomo, "Non-linear seismic analysis and vulnerability evaluation of a masonry building by means of the SAP2000 V.10 code," *Earthq. Eng. Struct. Dyn.*, vol. 37, no. 3, pp. 467–485, Mar. 2008, doi: 10.1002/eqe.770.

[4] S. Gowtham, M. Prakash, N. Parthasarathi, K. S. Satyanarayanan, and V. Thamilarasu, "2D-Linear static and non-linear dynamic progressive collapse analysis of reinforced concrete building," *Mater. Today Proc.*, vol. 5, no. 2, pp. 8775–8783, 2018, doi: 10.1016/j.matpr.2017.12.305.

[5] G. M. Calvi, T. J. Sullivan, and A. Villani, "Conceptual Seismic Design of Cable-Stayed Bridges," *J. Earthq. Eng.*, vol. 14, no. 8, pp. 1139–1171, Oct. 2010, doi: 10.1080/13632469.2010.505275.

[6] X. Y. Su, H. J. Kang, and T. D. Guo, "A novel modeling method for in-plane eigenproblem estimation of the cable-stayed bridges," *Appl. Math. Model.*, vol. 87, pp. 245–268, Nov. 2020, doi: 10.1016/j.apm.2020.05.026.