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Static and dynamic behaviour of tensegrity footbridges

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INTRODUCTION

Tensegrity structures are spatial structures based on compressed struts and tensioned cables. This is achieved by the pretension of the cables, allowing the tensegrity structures to withstand external loads such as the ones from a pedestrian footbridge. As a result, the lightweight of these structures leads to high strength to weight ratios making this solution an attractive one. However, its flexibility along with this lightweight could end up with not only high deflections but also high vibrations. This project studies the behaviour of these structures, showing the optimum parameters to avoid these problems and establishing initial design criteria.

FIGURE 1: Almere tensegrity footbridge. Benchmark footbridge

METHODOLOGY

In order to study the structural behaviour, an Oasys GSA computer model has been made taking the Almere bicycle and pedestrian bridge in Netherlands as a benchmark example for the parametric analysis.

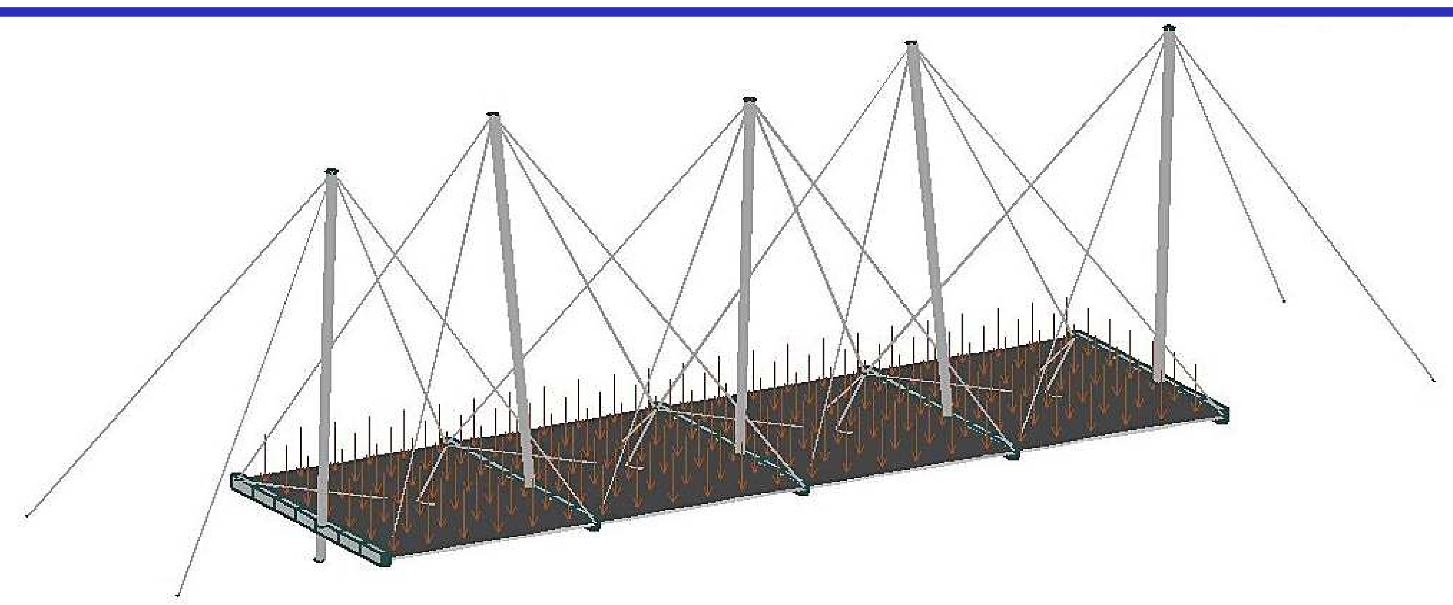

FIGURE 2: GSA benchmark footbridge model

STATIC BEHAVIOUR

The forces at mid-span are mainly taken in tension to the top of the pylon, and then to the supports through the cables. The parametric analysis implies that the structure behaves more efficient for cables/pylons axial stiffness ratios between kc/ks=0.025-0.05 since the external load is taken by the cables instead of the struts.

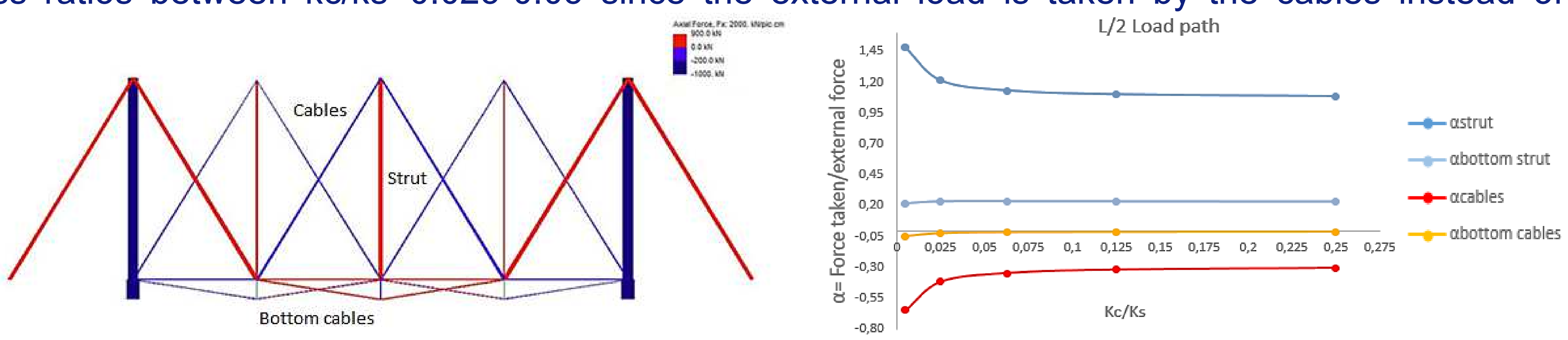

FIGURE 3: Load path parametric analysis

PRESTRESS AND NONLINEARITY

The structure behaves in a linear manner regardless the level of prestress and the structure stiffness, unlike other tensegrity structures, due to the short length of the cables. One of the main aims of the prestress level is to avoid the presence of slack cables.

	Prestress	ε0 (‰)	%Nku
SLS frequent	700 kN	1.39	19.71
SLS characteristic	1100 kN	2.18	30.98
ULS	1450 kN	2.87	40.83

TABLE 1: Level of prestress to avoid slack cables

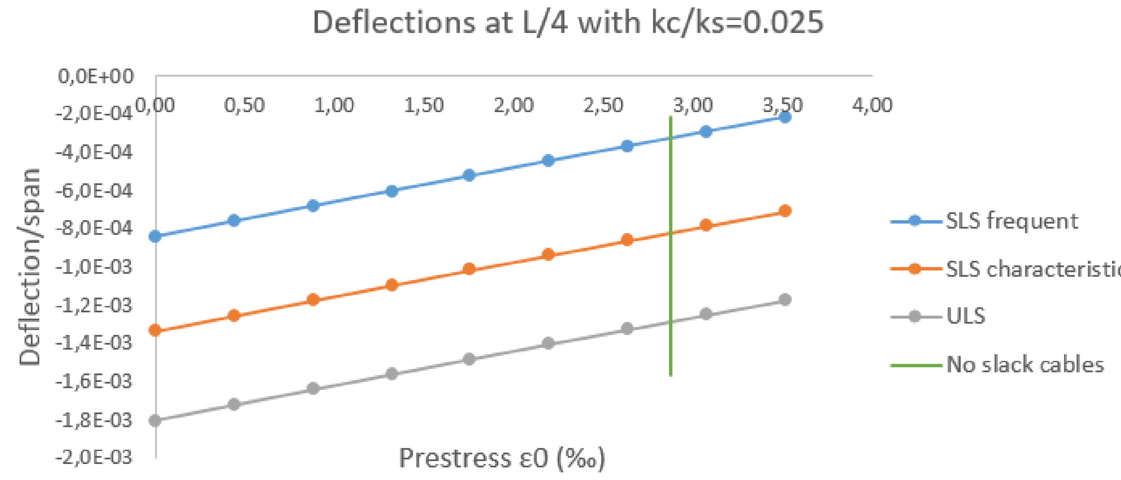

FIGURE 4: Deflections regarding the level of prestress

DYNAMIC BEHAVIOUR

The natural frequencies could be greatly reduced by the pedestrians' mass, ending up in excessive accelerations even if the structure itself does not have natural frequencies close to the common walking or running ones. A dynamic vibration analysis has been performed showing that tensegrity structures with the fundamental frequency above 3Hz will not have uncomfortable accelerations under dense crowds walking load cases.

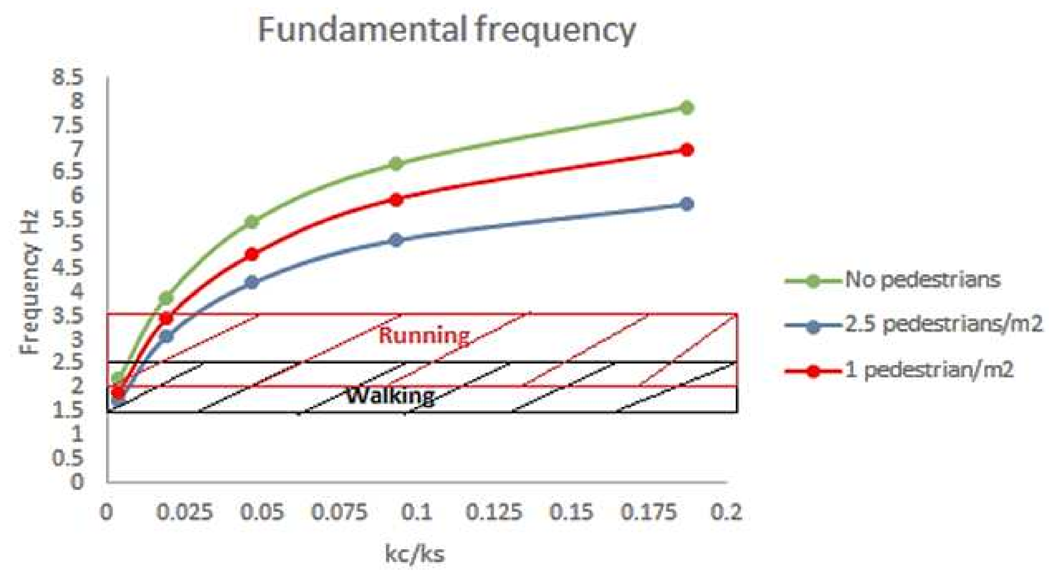

FIGURE 5: Fundamental frequency regarding pedestrians density

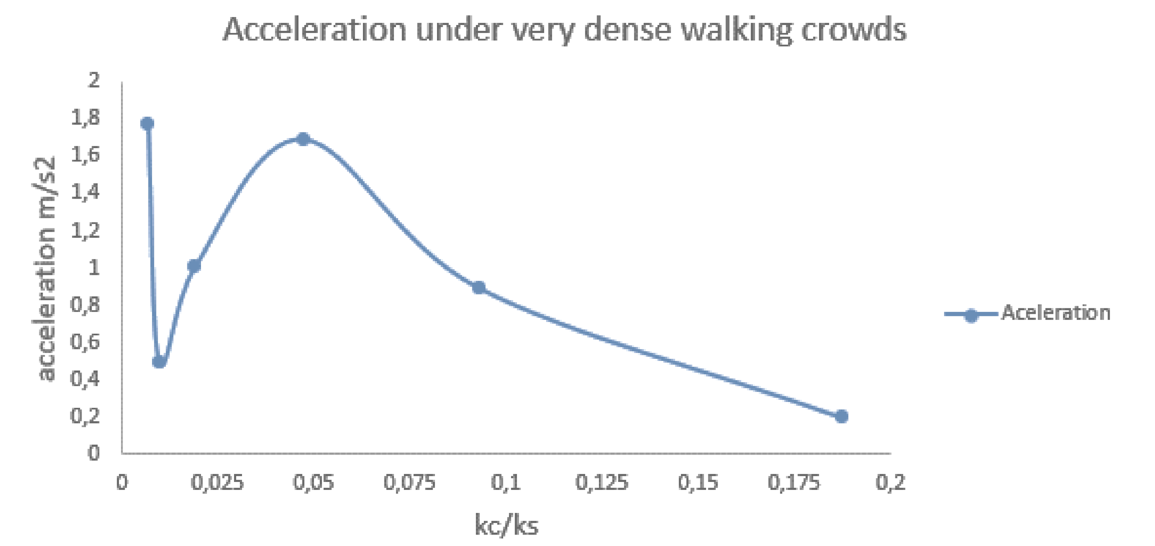

FIGURE 6: Accelerations regarding the axial stiffness ratio

CONCLUSIONS

- The optimum values of the prestress and the axial stiffness ratio between the cables and the pylons have been obtained.
- Excessive deflections can be avoided efficiently increasing the cables axial stiffness.
- Excessive vibrations can be avoided ensuring a fundamental frequency above 3Hz. This is efficiently achieved increasing either the cables axial stiffness or the deck bending stiffness.
- Linear behaviour due to the short length of the cables.
- Straightforward design criteria have been established with the purpose of obtaining initial dimensions.

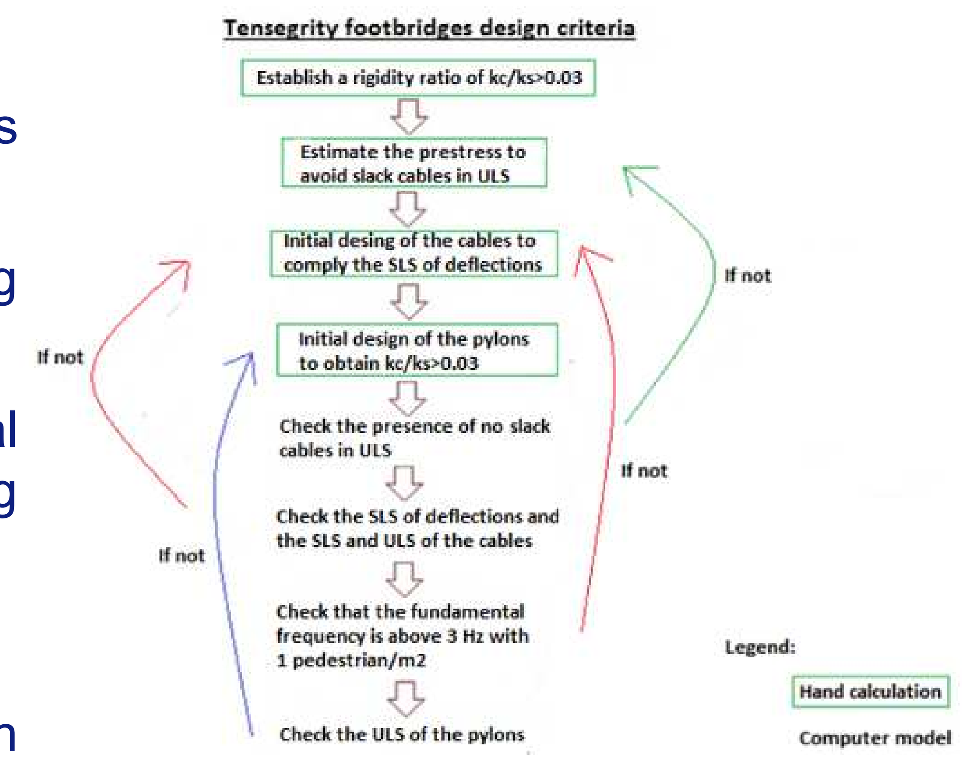

FIGURE 7: Design criteria

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REFERENCES

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