A contribution to the optimum design of prestressed plane cable structures

A Contribution to the Optimum Design of Prestressed Plane Cable Structures

Une contribution au calcul optimal de structures planes de câbles prétendues

Ein Beitrag zur Optimierung von ebenen vorgespannten Seiltragwerken

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A research for the optimum design of prestressed plane cable structures is here biefly referred.

The starting point are P. Pedersen's (1) and G.N. Vanderplaats and F. Moses's (2) papers, where trusses are optimized when cross-sectional areas and joint coordinates are the design variables. The techniques here used must be substantially changed to be applied to prestressed cable structures. This is due to initial prestress (the necessary prestress to grant the wanted design requirements) which is to be kept constant under different loading conditions while cross-sectional areas and the geometry of the structure change. This need really complicates the computational process since, keeping the initial prestress constant, big changes in bar forces correspond to small displacements in joints.

Two kinds of prestressed plane cable structures have been optimized: a standard scheme[1] [Fig. 1,a] and a new type of prestressed cable-stayed structure [2] [Fig. 1,b] whose good static and dynamic behaviour had been shown in a previous work (3).

Both types of structures satisfy the necessary and sufficient conditions for fully stressed design, when at least two load systems are considered. Two uniformly distributed loads, a downward load (p_{max}) and an upward load (p_{min}), are here considered besides prestressing.

The problems relating to prestressed cable structures are of non-linear type. Yet, linear theory has been used because the very many checks carried on by the non-linear theory (3),(4) showed that results from linear analysis are valid, at least as far as localization of good structural parameters is concerned.

1. Henceforth indicated by TSHS (two surface hanging structure).

2. Abbreviated by PCSS .

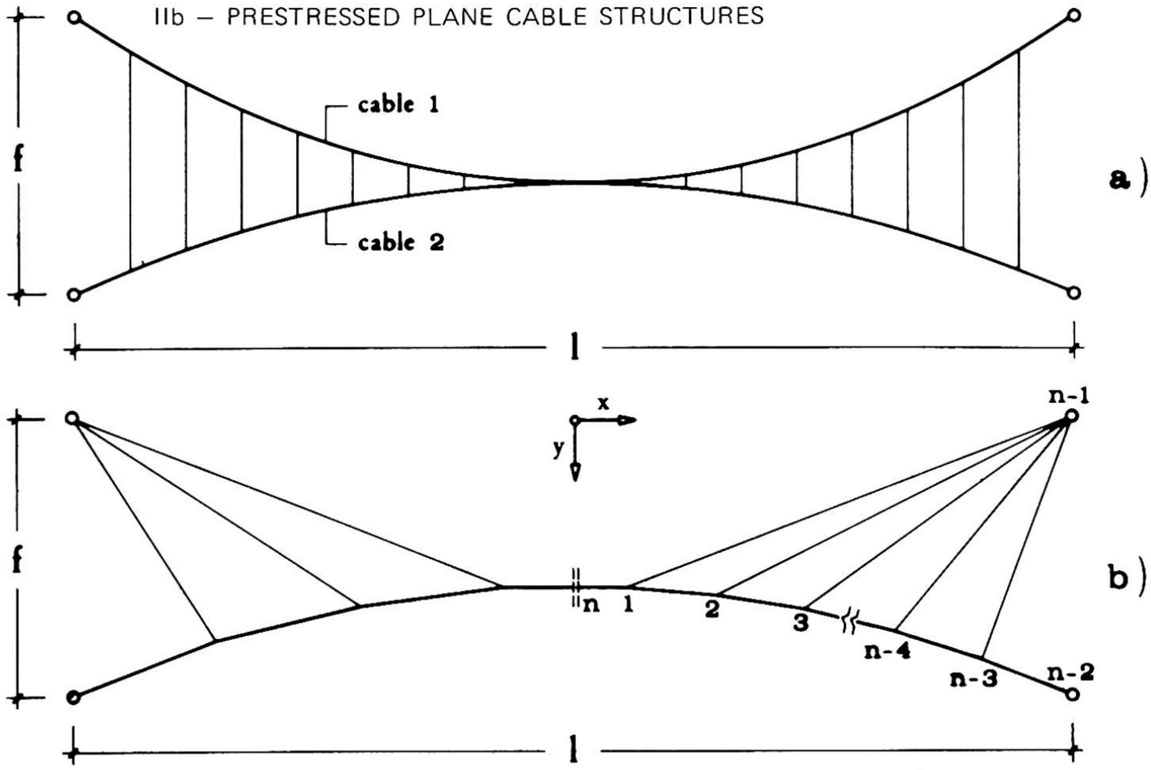

Fig. 1

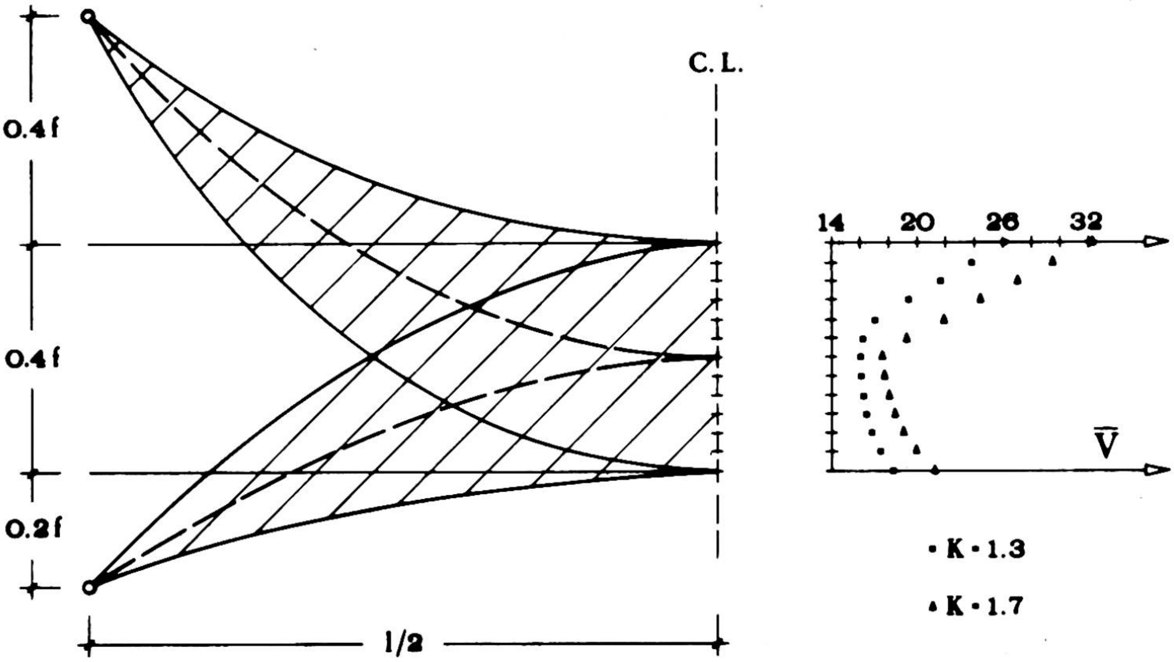

Fig. 2

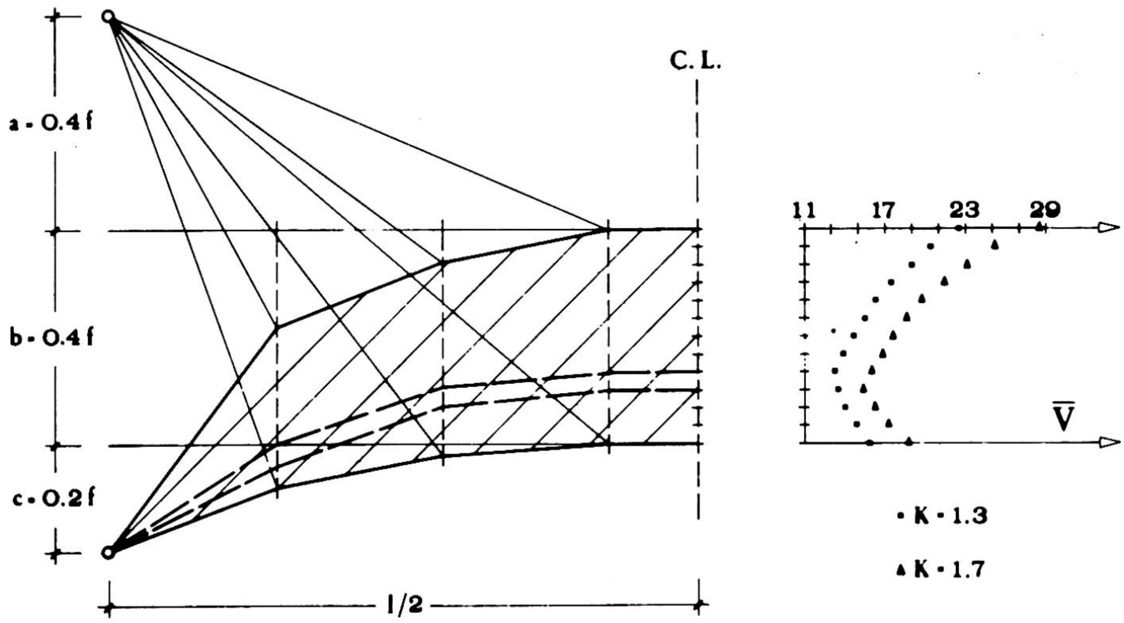

Fig. 3

The TSHS are studied with continuous approach: the relevant computer program (5) allows direct calculation of the areas of main cables and connecting roads once the geometry is fixed.

The PCSS are calculated by a discrete approach, specifically by displacement method: bar cross-sectional areas, when the geometry is fixed, are calculated by successive iterations (6) with a somewhat rapid convergence.

As an exemplification some results are graphically reported in Fig. 2 and in Fig. 3.

In either cases $f/l = 0.10$, $\bar{p} = |p_{max}| / |p_{min}| = 5.00$, $K = 1.3 \div 1.7$ (K is a number which quantifies the initial prestress) and $\bar{V} = (V\sigma_a)/(|p_{min}| l^2)$, where V is the volume of structure and σ_a is the allowable normal stress.

As it known, the fully stressed design of redundant structures coincides with the optimum design in peculiar situations only, which do not occur here.

The global optimum is determined by a process of successive iterations similar to Pedersen's (1). For each iteration, the problem of moving the design variables (cross-sectional areas and joint displacements) is worked out as a Linear Programming problem. Moreover, thanks to preliminary researches developed by fully stressed design, which gives solutions quite near to the global optimum, local minima can be avoided.

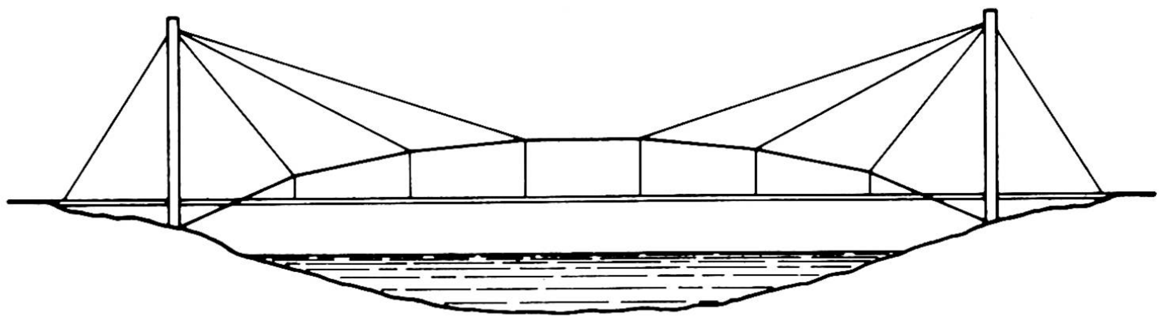

Fig. 4

The optimization process has emphasized the advantages of PCSS over TSHS when volume is the merit function. On the other hand, PCSS have a much better static and dynamic behaviour than TSHS, as it has been largely demonstrated (3), (4).

The extension of the proposed scheme [Fig. 1,b] to long span bridges [see Fig. 4] seems therefore reasonable. To this aim, it is necessary to conform the computational technique already formulated. This will be the purpose of future researches, where the effects of the moving loads and of the wind will be specifically considered.

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SUMMARY

The optimization of prestressed plane cable structures is presented and in particular the optimum design of a new kind of structure, whose good static and dynamic behaviour has already been reported on. Some conclusions and suggestions for future developments are given.

RESUME

On présente l'optimisation de structures planes de câbles prétendues et particulièrement le calcul optimal d'une nouvelle structure, dont une étude a déjà souligné le bon comportement statique et dynamique. Quelques conclusions et idées sont présentées pour de futurs développements.

ZUSAMMENFASSUNG

Es wird über die Optimierung von ebenen vorgespannten Seiltragwerken berichtet und besonders über die optimale Geometrie eines neuartigen Tragwerks; das gute statische und dynamische Verhalten dieses Tragwerks wurde schon früher hervorgehoben. Einige Bemerkungen über die zukünftigen Entwicklungsmöglichkeiten beschliessen diesen Beitrag.