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

FABIO SELLERI
Professore di Scienza delle Costruzioni, Facoltà di Architettura
Università di Roma
Roma, Italia

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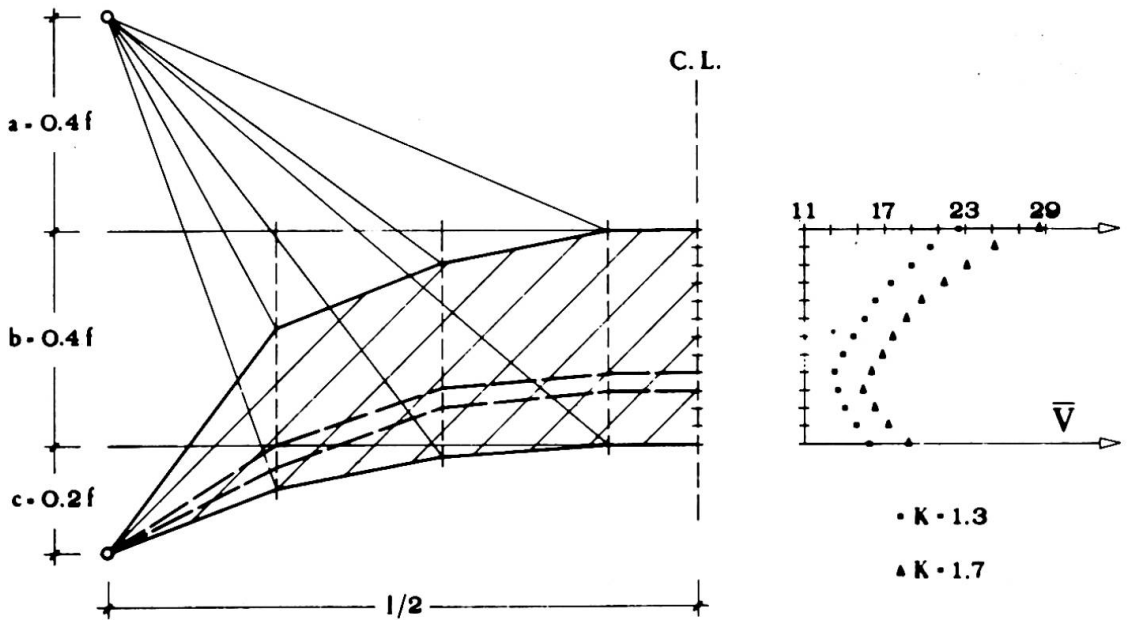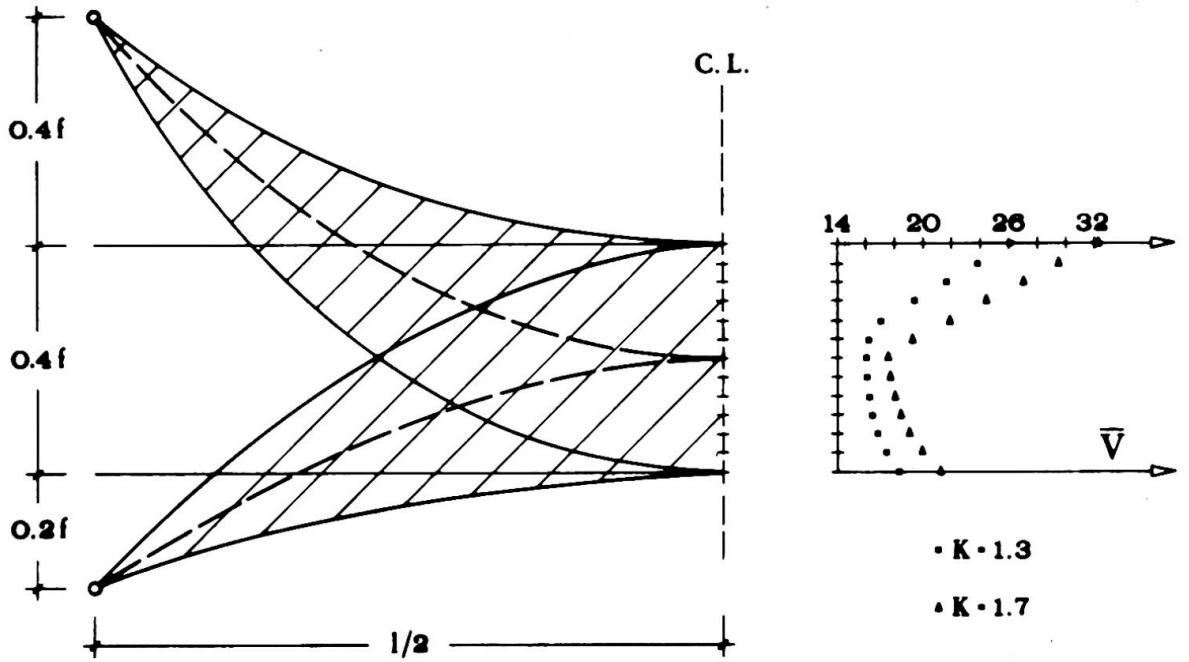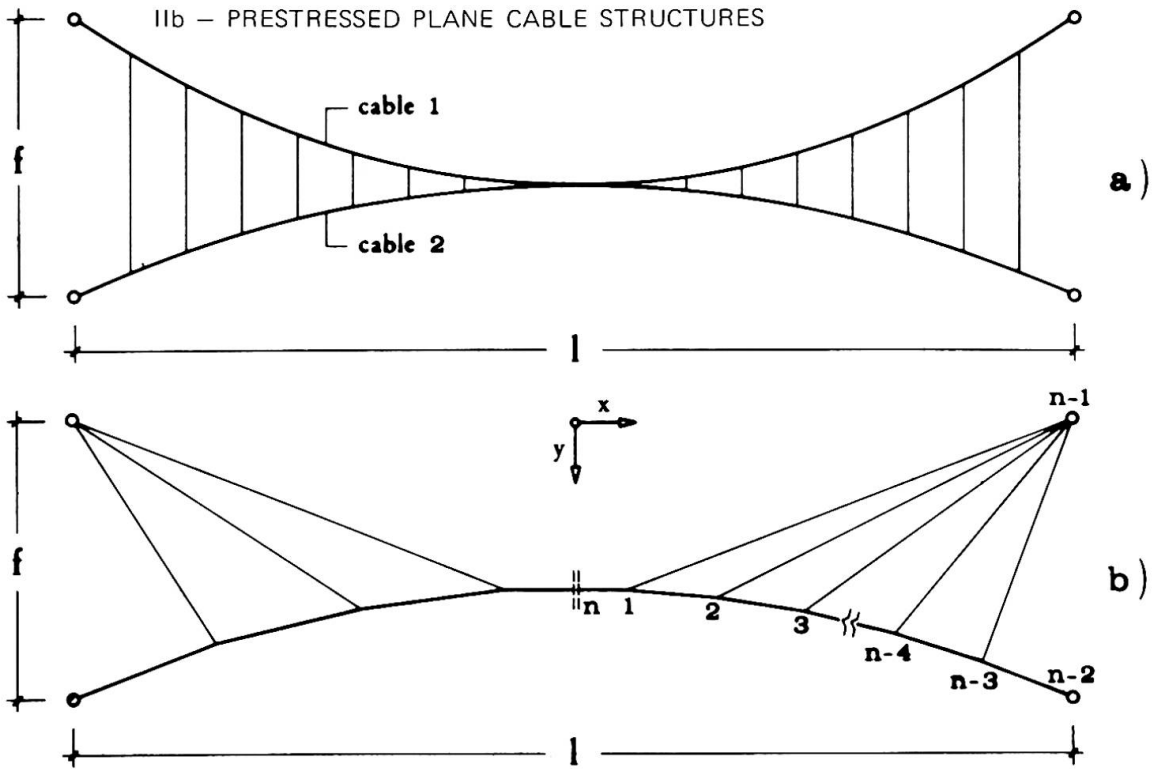
The TSHS are studied with continuous approach: the relevant com puter program (5) allows direct calculation of the areas of main ca bles and connecting roads once the geometry is fixed.

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 some- what rapid convergence.

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

In either cases $f/1 = 0.10, \bar{p} = |p_{max}| / |p_{min}| = 5.00$, $K = 1.3 \div 1.7$ (K is a number which quantifies the initial prestress) and $\bar{V} = (V\sigma_a)/(|p_{min}| 1^2)$, 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 i- terations similar to Pedersen's (1). For each iteration, the problem of moving the design variables (cross-sectional areas and joint di splacements) is worked out as a Linear Programming problem. Moreo- ver, thanks to preliminary researches developed by fully stressed design, which gives solutions quite near to the global optimum, lo- cal minima can be avoided.
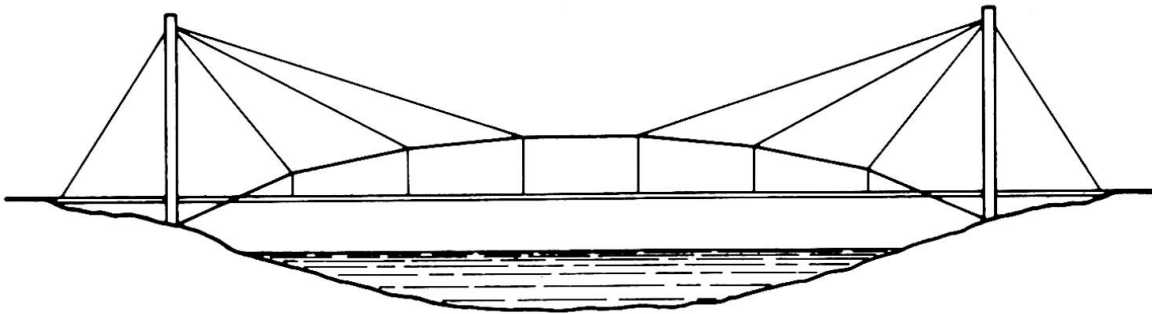

Fig. 4

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.

REFERENCES.

1. P. PEDERSEN, On the Optimal Layout of Multi-purpose Trusses. Computers & Struc
    tures, Vol. 2, 1972.

2. G.N. VANDERPLAATS and F. MOSES, Automated Optimal Design of Structures. Journ.
    of the Struct. Div. ASCE, Vol. 98, ST 3, 1972.

3. F. SELLERI e O. SPADACCINI. Su una struttura a stralli nel quadro delle ten-
    sostrutture piane. Atti dell'Ist. di Scienza delle Costr.,   Univ.   di   Pisa,
    n. 208, Vol. XIV, 1974.

4. O. SPADACCINI, Aspetti costruttivi di una tensostruttura a stralli: funi di
    bordo e problemi di montaggio. Atti dell'Ist. di Scienza delle Costr.,   Univ.
    di Pisa, n. 213, Vol. XIV, 1975.

5. F. SELLERI and O. SPADACCINI, Optimal Design of Prestressed Plane Cable
    Structures. J. Struct. Mech. (To appear).

6. F. SELLERI, Progetto ottimo di una tensostruttura piana strallata. Atti dell-
    l'Ist. di Scienza delle Costr., Univ. di Pisa, n. 215, Vol. XIV, 1975.

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 parti-
culièrement 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 be-
richtet 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.