

Discussion

Cable Connections in Stayed Girder Bridges

Paper presented by WALTER PODOLNY, JR.
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The considerations of cable connections so well presented by Podolny in his usual thorough style are of importance in the design of cable stayed bridges, not only insofar as structural details are concerned, but also from the standpoint of the selection of the basic structural system for these bridges, its economy, esthetic values, aerodynamic behavior, and even factors such as the degree of indeterminacy underlying the basis of analysis of the structure.

Reference 20 describes some of these interrelationships. In particular it confirms the better economy of the bundled cable configuration (with stays converging from the tops of the pylons, such as in the Severin Bridge of Fig. 4), as compared with the more popular harp configuration of the North Bridge at Duesseldorf. It also justifies the increasing interest in A-frame pylons, permitting the type of space frame action shown on the Severin Bridge, Fig. 5a, which also improves the aerodynamic stability of the system. It clarifies the trend toward single-plane stay systems, located in the center mall of the roadway deck, such as on the elegant Friedrich Ebert Bridge at Duesseldorf with its torsionally stiff box girder spans, which attempts to achieve the advantages of the bundled cable configuration as much as possible. Most important of all these considerations is the trend toward a large multiplicity of closely spaced stay cables (as on the Friedrich Ebert Bridge), which as Podolny correctly notes achieves a condition approaching a continuous elastic supporting medium, and at the same time avoids distributional and shear lag problems associated with the transfer of stress across the deck.

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The degree of internal redundancy of the system depends on the number of connections (fixed or movable) of stay cables with the pylons, and the nature of the pylon connection at its base with the girder or pier. The girder is frequently made continuous over three spans. Figure 23 shows the order of redundancy for various single-plane systems of stayed girder bridges.

If the bridge has two planes of cables and double pylons, it usually also must be provided with a number of intermediate cross-diaphragms in the floor system, each of which is capable of transmitting moment and shear. The bridge may also have cross-girders across the top of the pylons. Each of these cross-members adds two redundants, to which must be added twice the internal redundancy of the single-plane structure, and any additional reactions in excess of those needed for external equilibrium as a space structure. The redundancy of the space structure is very high, usually of the order of 40 to 60. Therefore, the methods of plane statics are normally used, except for larger structures.

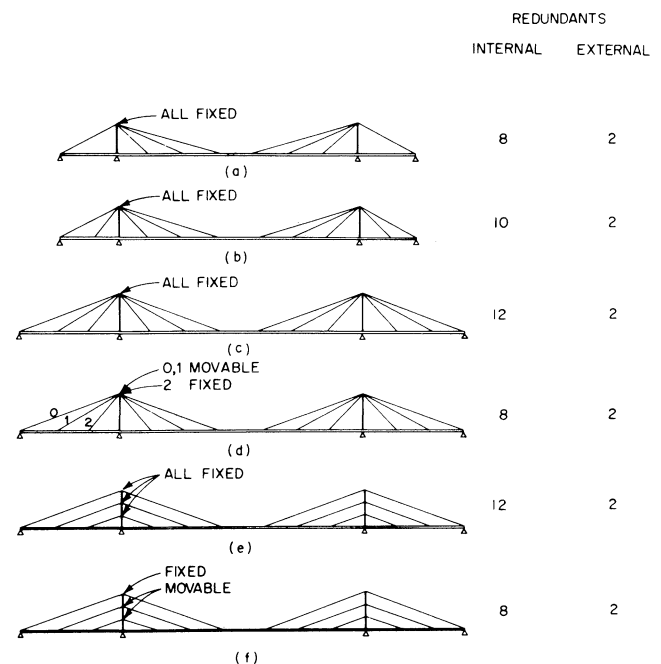


Fig. 23. Number of redundants in single-plane cable-stayed bridges

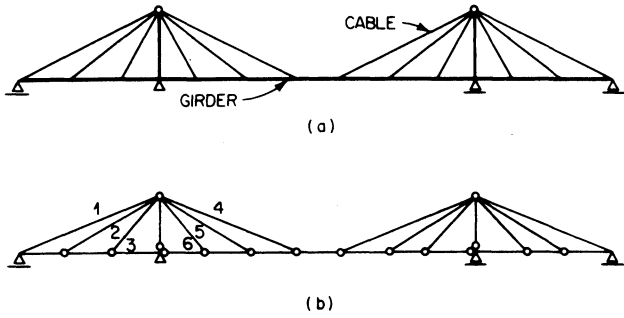


Fig. 24. Insertion of hinges in stayed continuous girder at cable-attachment points makes system statically determinate.

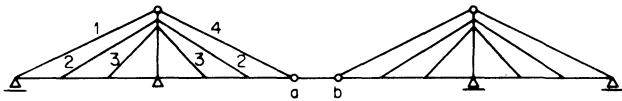


Fig. 25. Insertion of hinges at *a* and *b* reduces indeterminacy of cable-stayed girder.

It is convenient to select as redundants the bending moments in the girder at those points where the cables and pylons join the girder. When these redundants are set equal to zero, an articulated, statically determinate truss base system is obtained (Fig. 24b). When the loads are applied to this choice of base system, the stresses in the cables do not differ greatly from their final values; thus, the cables may be dimensioned in a preliminary way.

Other approaches are also possible. One is to use the continuous girder itself as a statically indeterminate base system, with the cable forces as redundants. But computation is generally increased.

A third method involves imposition of hinges, for example at points *a* and *b* in Fig. 25, so placed as to form two coupled symmetrical base systems, each statically indeterminate to the fourth degree. The influence lines for the four indeterminate cable forces of each partial base system are at the same time also the influence lines of the cable forces in the real system. The two redundant moments X_a and X_b are treated as symmetrical and antisymmetrical group loads, $Y = X_a + X_b$ and $Z = X_a - X_b$, to calculate influence lines

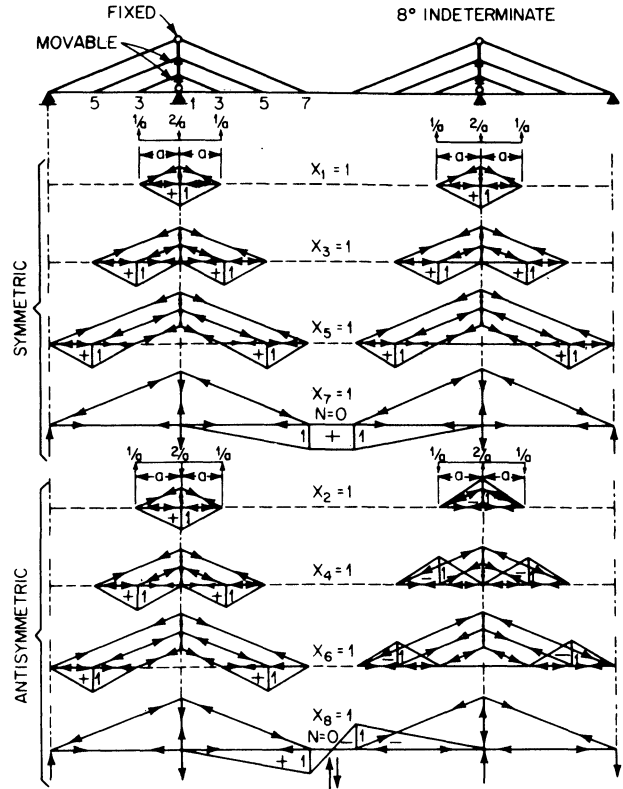


Fig. 26. Forces induced in cable-stayed bridge by independent symmetric and antisymmetric group loadings. (From O. Braun, "Neues zur Berechnung statisch unbestimmter Tragwerke," *Stahlbau*, no. 25, 1956.)

for the 10-degree indeterminate structure shown. Kern moments are plotted to determine maximum effects of combined bending and axial forces.

A similar concept is illustrated in Fig. 26, which shows the application of independent symmetrical and antisymmetrical group stress relationships to simplify calculations for an eight-degree indeterminate system. Thus, the first redundant group X_1 is the self-stressing of the lowest cables in tension to produce $M_1 = +1$ at supports.

REFERENCES

20. Kavanagh, Thomas C. Section 14, Cable Supported Bridges, *Structural Steel Designers' Handbook*, F. S. Merritt, Editor, McGraw-Hill Book Co., New York, 1972.