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Partially Anchored Composite Cable-Stayed Bridge

Pont haubané mixte à ancrage partiel

Teilweise verankerte Schrägkabelbrücke mit Verbundträgern

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SUMMARY

Compared to the self-anchored type, partially anchored cable-stayed bridges are more efficient for long span bridges because the axial forces in the main girders are decreased. Mixed girders are suitable in partially anchored systems because either axial compression or axial tension acts in the main girders depending on girder location along the bridge length. This paper treats one design example of a composite cable-stayed bridge with a 900 m center span and 300 m side spans.

RÉSUMÉ

En comparaison du type à auto-ancrage, l'ancrage partiel s'avère plus efficace pour les ponts haubanés à grande portée, car les forces axiales s'exerçant dans les poutres maîtresses diminuent. Les poutres mixtes sont mieux indiquées dans le système à ancrage partiel, étant donné que les efforts axiaux de compression ou de tension dans les poutres maîtresses dépendent de leur disposition le long du pont. Cet article présente un exemple de calcul de pont haubané à ancrage partiel, ayant une travée centrale de 900 m de portée et des travées latérales de 300 m de portée.

ZUSAMMENFASSUNG

Die teilweise verankertern Schrägkabelbrücken weisen gegenüber den voll verankerten Vorteile auf, da die Normalkräfte im Hauptträger kleiner sind. Verbundträger eignen sich speziell für teilweise verankerte Systeme, da die Längszug- (oder -druck)kräfte in den Hauptträgern wirken. Dieser Beitrag beschreibt eine Schrägkabelbrücke mit Verbundträgern mit 900 m Haupt- und 300 m Nebenspannweiten.

1. INTRODUCTION

Cable-stayed bridges are classified into three types according to the degree of anchoring used. These are self, fully, and partially anchored cable-stayed bridges. Using simple structural models for cable-stayed bridges (each anchorage type) and suspension bridges, cost comparisons show that partially anchored cable-stayed bridges are most efficient for span lengths up to about 2000 m (Refs. 1-3).

Partially anchored systems may be constructed either by using hinges which can not transmit axial forces into center or side spans, or by introducing pulling forces to the continuous main girders from the ends of the side spans. Anchorages are necessary in both types of partially anchored systems.

In partially anchored systems, the main girders in the vicinity of towers are in axial compression, while axial tension acts in the main girders in the middle parts of the center span and at the end parts of the side spans. From a material standpoint, composite main girders made of a steel member and a PC member may therefore be more efficient compared to conventional steel main girders or prestressed concrete main girders. Further investigations on partially anchored composite cable-stayed bridges are necessary for determining the validity of this hypothesis (Ref. 5).

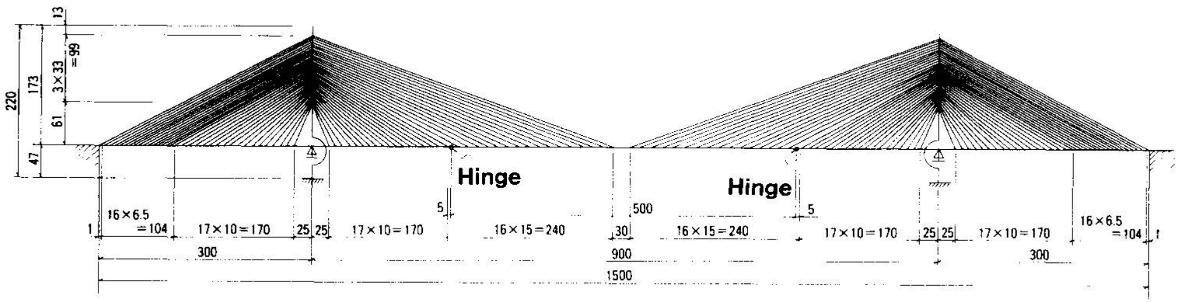

Fig.1 General View of Model Bridge

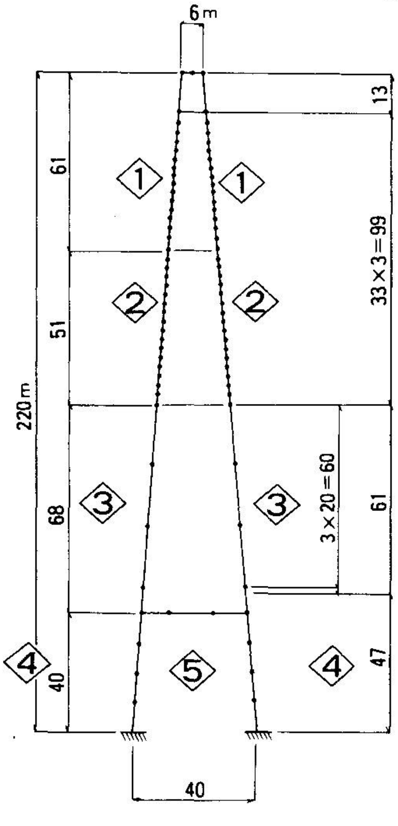

Fig.2 Tower

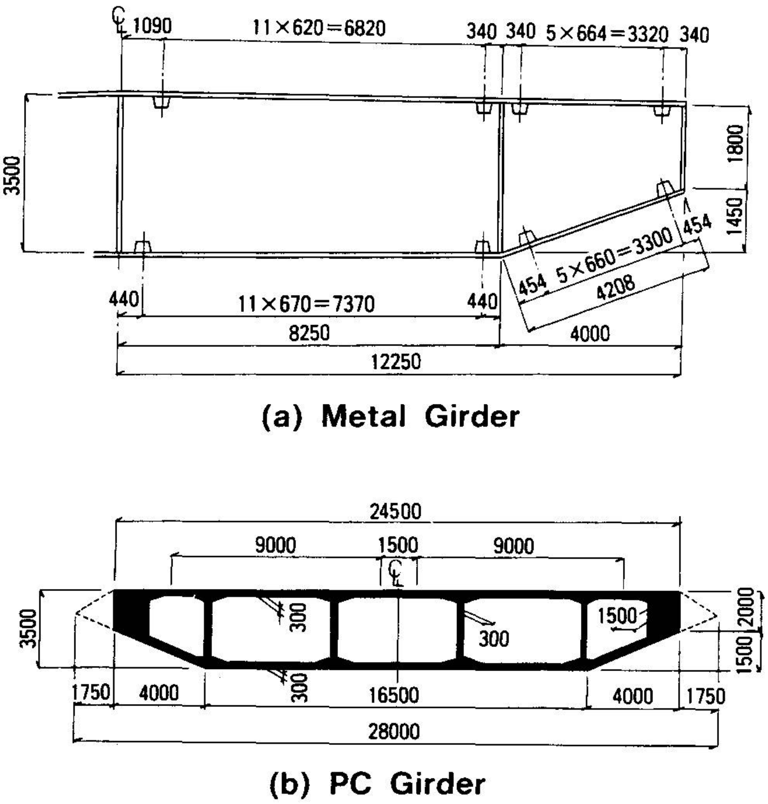

Fig.3 Cross Sections

This paper shows one design example of a composite cable-stayed bridge with a 900 m center span and 300 m side spans. These numerical results are compared to those of a self anchored cable-stayed bridge. The two types of partially anchored cable-stayed bridges considered here (i.e. hinge type and continuous girder type) are compared from the viewpoint of constructing method.

2. STRUCTURAL MODEL

Figs. 1, 2, and 3 show a general view of the hinge type bridge, towers, and cross sections, respectively, of the composite cable-stayed bridge treated in this paper. Typical cross-section properties and load values are listed in Table 1. Steel main girders are used between two hinges. The cable-stayed bridges are idealized as plane structures and analyzed using matrix structural theory.

3. ANALYSIS RESULTS

Fig.4 shows bending moments and axial forces in the main girders for the self and partially anchored systems caused by both dead loads and prestressing forces in cables. Bending moments are almost same for both anchoring systems_ but axial compression in the partially anchored system is about 53 % less than that of the self anchored system. Variations of bending moments from D+L(-) to D+L(+) in the partially anchored system are smaller than those of the self anchored system as shown in Fig.5. On the other hand, the corresponding variation of axial force in the partially and self anchored systems is almost same and small as shown in Fig.6.

Table 2 shows internal forces and longitudinal movements at the hinges. To dampen the longitudinal movements produced by earthquakes, oil dampers will be inserted at the hinge locations. Axial forces at hinges are caused by the special links inserted for analysis in this example, but in actual structures these values are almost zero. Hinge design for partially anchored systems is relatively easy.

Reacting forces at the anchorages are shown in Table 3. By optimizing the shape of anchorages constructed for partially anchored cable-stayed bridges, the cost of anchorages may be decreased compared to the conventional type used for suspension bridges.

Table 1 Characteristics of Cross Sections & Dead Load

Members		A(m^2)	Iz(m^4)	Iy(m^4)	D(tf/m)
Main Girders	Steel	1.13	2.52	62.2	18
	PC	20.0	30.0	800.0	60
Towers	1	1.32	9.1*	2.9**	22
	2	2.08	15.9*	4.6**	34
	3	2.24	18.8*	5.0**	34
	4	2.58	23.3*	5.8**	42
	5	0.70	2.9	2.9	21
Cables	I	0.024	–	–	0.019
	II	0.022	–	–	0.017
	III	0.020	–	–	0.016

A : Area of cross section
Iz, Iy : Moment of Inertia in and out of plane, respectively
* for two columns, ** for one column, 1 tf = 9.81 kN

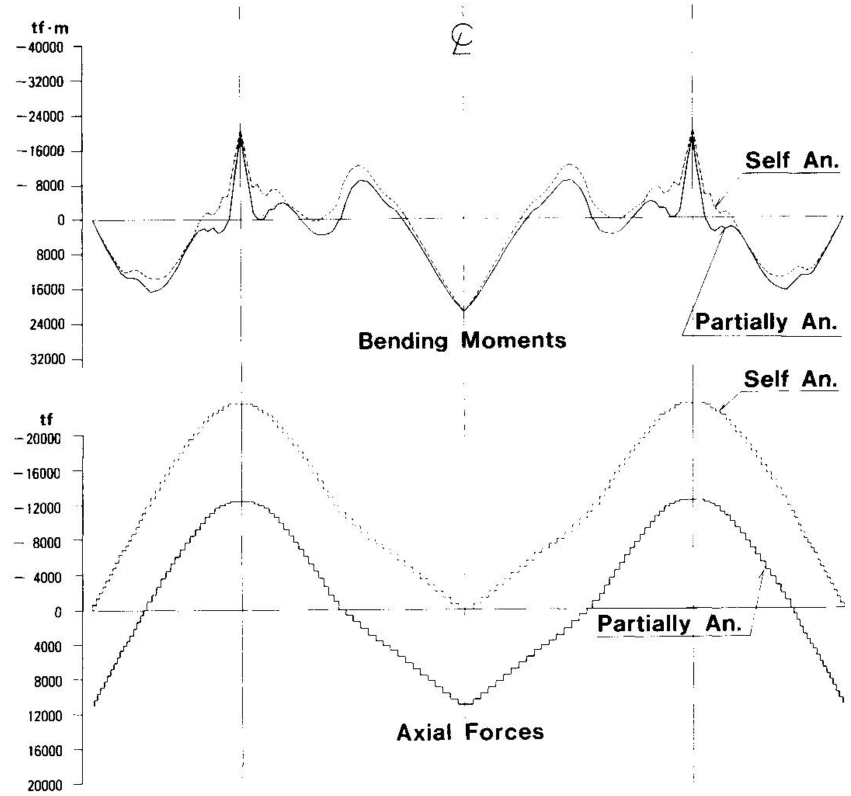

Fig.4 Bending Moments and Axial Forces (1 tf·m = 9.81 kN.m)

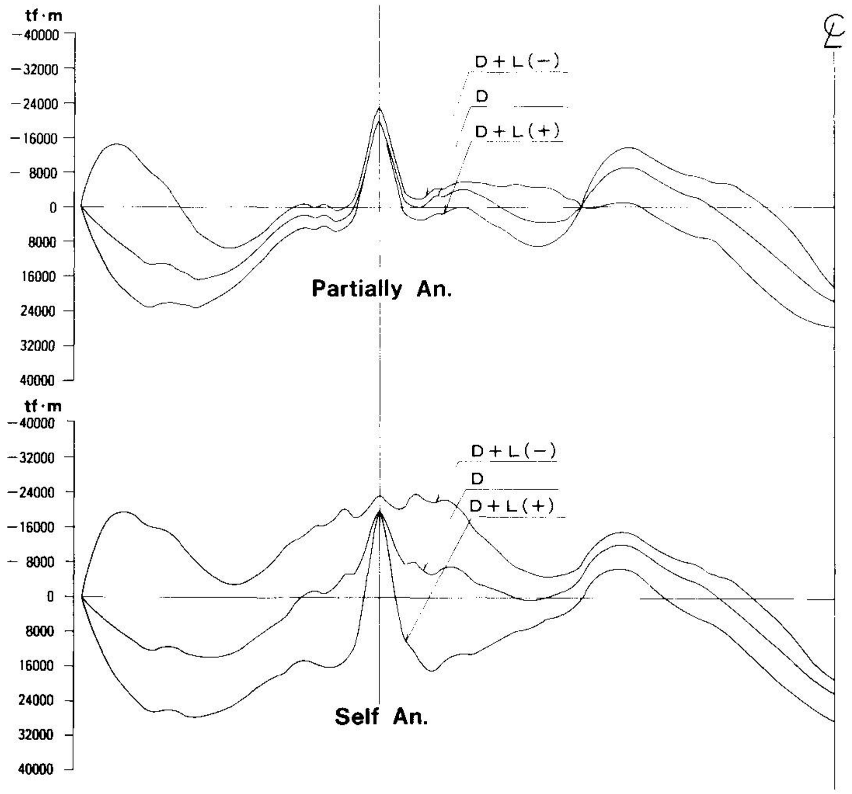

Fig.5 Variations of Bending Moments (1 tf·m = 9.81 kN·m)

Table 3 Reacting Forces at Anchorages

Load Case	Reacting Forces
Dead Load + Prestressing	Rx = 10998 tf, Ry = 174 tf
Temperture(±35℃)	Rx = ±466 tf, Ry = ±13 tf
Live Load	Rx = 2107 tf(max), 519 tf(min) Ry = 519 tf(max), -1032 tf(min)
Wind Load (Trans.)	Rz = -256 tf, Mx = -2641 tf·m My = 43747 tf·m
Earthquake (Trans.)	Rz = -2501 tf, Mx = -17588 tf·m My = 260428 tf·m
Earthquake (Longi.)	Rx = ±4932 tf, Ry = ± 948 tf

x : longitudinal direction, z : transverse direction
y : vertical direction, 1 tf = 9.81 kN

4. ALTERNATIVE DESIGN

The hinges inserted in partially anchored systems would be rather expensive and would disturb the smooth driving of vehicles. Furthermore, from the viewpoint of constructing the girder, it may be difficult to expand the main girders beyond the hinges.

Partially anchored cable-stayed bridges without hinges can be accomplished by pulling the main girders from anchorage side after completing the continuous main girders. According to the Specifications for Japanese Highway Bridges, allowable stresses can be increased 25 % during the construction stages. Furthermore, it is easy to change prestressing values in PC main girders. Therefore , this type of partially anchored system becomes an attractive alternative design plan. After pulling main girders , total system behaves like a self anchored system due to the continuity of main girders. However, since bending stresses due to live loads are small compared to axial stresses , the advantages of the partially anchored system are realized in this system.

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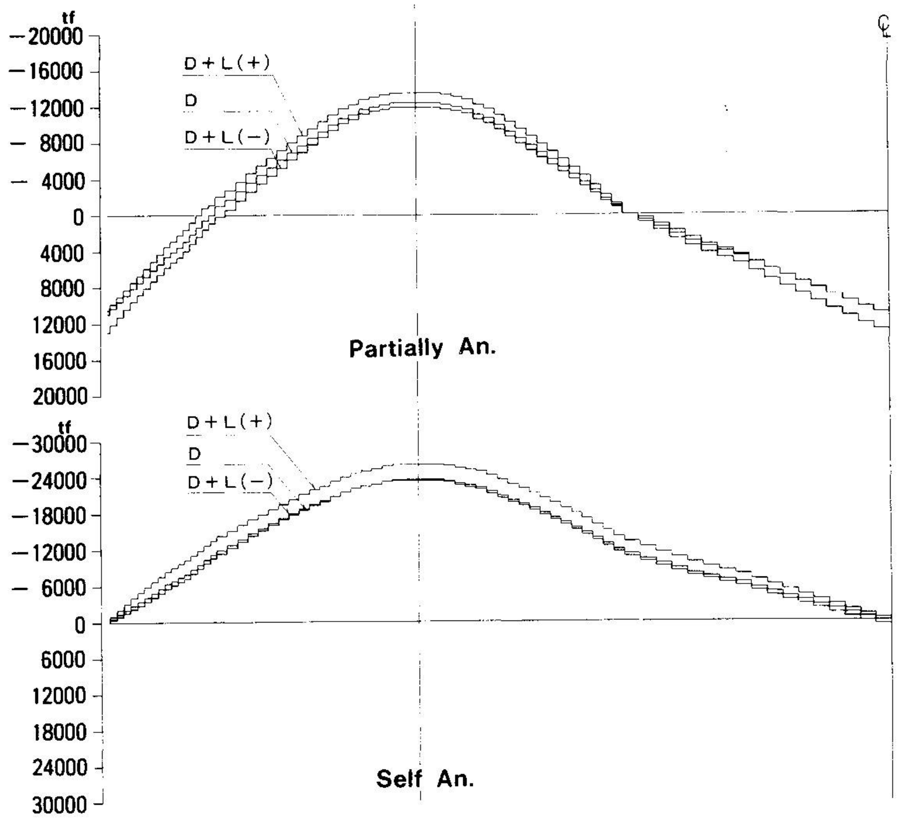

Fig.6 Variations of Axial Forces (1 tf = 9.81 kN)

Table 2 Internal Forces & Longitudinal Movements at Hinges

Load Case	Internal Forces	Movements (mm)
Dead Load + Prestressing	S = 267 tf	22
Temperture(±35℃)	S = 231 tf	±308
Live Load	S = 95 tf	±273
Wind Load (Transverse Direction)	S = 530 tf T = 1887 tf·m M = -781 tf·m	0
Earthquake (Trans.)	S = 2755 tf T = -3746 tf·m M = -24632 tf·m	0
Earthquake (Longi.)	N = ±771 tf	±1024

S = Shearing Force, T = Torque, M = Bending Moments,
N = Axial Forces, 1 tf = 9.81 kN