Mansoura Engineering Journal

Volume 28 | Issue 4 Article 2

1-21-2021

Influence of Connections between Towers and Floor Beans in Cable–Supported Bridges.

Mohamed Abou El-saad
Structural Engineering Department., Faculty of Engineering.,El- Mansoura University., Egypt.

Recommended Citation

Abou El-saad, Mohamed (2021) "Influence of Connections between Towers and Floor Beans in Cable–Supported Bridges.," *Mansoura Engineering Journal*: Vol. 28 : Iss. 4 , Article 2.
Available at: https://doi.org/10.21608/bfemu.2021.141904

INFLEUNCE OF CONNECTIONS BETWEEN TOWERS AND FLOOR BEAMS IN CABLE -SUPPORTED BRIDGES

By

Mohamed Naguib Abou El-saad
Associate Professor, Structural Engineering Department.
Faculty of Engineering.
Mansoura University - Egypt

"تأثير الوصلات بين الأبراج وكمرات أسطح الكباري ذات / لارتكاز بالكابلات"

الخلاصة: إن هدف هذا البحث يتناول التحليل الاستاتيكي للكباري ذات الارتكاز بالكابلات أخذا في الاعتبار تـأثير الوصلات بين الأبراج وكمرات سطح الكباري ولتقليل بعض أسباب اللاخطية في تحليل هذه المنشاءات تم هذا البحث لاختيار النوع المناسب من الوصلات وقد تم دراسة ثلاثة أنواع من الكباري ذات ثلاثـة واربعـة وخمسـة بحـور وتركزت أنواع الكباري في الكباري المعلقة والكباري ذات الشدات بالكابلات والتي تأخذ الأشكال المروحية والوترية حيث تم دراسة أربعة أنواع من الوصلات. وقد تم إجراء التحليل الاستاتيكي لهذه الكباري باستخدام طريقة الطاقة المبنية علي تصغير طاقة الوضع باستخدام طريقة الانحدارات المتبادلة وقد قام الباحـث بإنشـاء جميـع بـرامج الحسوب المستخدمة في هذا البحث مع تدوين أهم النتائج.

Abstract

The purpose of this paper is to present the static analysis of cable-supported bridges taking into considerations the influence of connections between pylons and floor beams. To reduce some causes of nonlinearities, this research has been done to choose a reasonable type of connection between towers and floor beams. Three types of bridges having three, four, and five spans have been analyzed. These bridges were suspension; cable stayed with radiating or harp shape of arrangement of cables. Four cases of connections between pylons and decks are considered. In the static analysis, the energy method, based on the minimization of the total potential energy of structural elements, via conjugate gradient technique is used. The procedure is carried out using the iterative steps to acquire the final configurations. The author constructed all computer programs used in the analysis. The major conclusions, which have been drawn from the present work, are outlined.

1- Introduction

Cable –supported bridges have their origins vine –supported footbridges constructed by ancient peoples. They have been known since the beginning of the 18h century [1 and 2]. but they have been widely used only in the last 45 years. A rapid progress in the analysis and construction of these types of bridges has been made over last 40 years. This progress is mainly due to high strength steel cables and box-girders with orthotropic steel deck [3].

Cable bridges may be classified to cable-suspended or cable-stayed bridges. depending on whether the cables suspended between towers or nearly straight and extending from only one tower. Cable-bridges consist of three principal components. namely girders. towers. and cables. Inclined cable stays in cable-stayed bridges and suspensors in suspension bridges support the girder elastically at points along its length. Since the spans are large and the cable stays are long and under high pretension force action, the nonlinearities due to cable sag, compression effect in towers and girders and large deflections have to taken into account. Thus, it is imperative to utilize three-dimensional nonlinear analysis.

To reduce some causes of nonlinearities, this research has been done to choose a reasonable type of connection between towers and floor beams. Many parameters play significant rule in the analysis and design of cable-supported bridges. Most of these parameters are the arrangements of cables, height of tower to central span ratios, ratio of exterior spans to

Accepted December 31, 2003.

interior span in continuous bridges, influence of support fixation on the analysis and sag to span ratio in suspension bridges. To fix some of these parameters for choosing the reasonable dimensions in this study, we seek after the experience in this filed represented in [4]. The optimum ratio of L/LT is 0.55 [5], where LT is total length of three span bridges with two equal exterior spans and L is the length of interior span. The most economic range of tower height to central span of the bridges occurs between 0.16 and 0.2 [6 and 7]. The study is carried out on three types of bridges having three, four and five spans with four types of connections between towers and floor beams.

2. Geometry and Loading

Cable-stayed with radiating shape, cable- stayed with harp shape and suspension bridges as shown in Figs. (1-a), (1-b), and (1-c), respectively are the three studied cases in this paper. They have all interior spans of 240 m length and two exterior spans of 100 m. The deck girders have a total span of 440, 680, and 920 m, for bridges having continuous three, four and five spans, respectively. All types of bridges are symmetric and are composed of three major elements: (a) the deck girder, (b) number of pylons equals to number of spans excluding one, and (c) the cables [8]. The suspension bridge has sag of 10% of interior span (24 m) and two inclined stay cables. The pylon height above and down floor level in all types of bridges was taken as 50 m and 25 m, respectively The cables were 6x37 class IWRC of zinc-coated bridge rope. The towers are designed as reinforced concrete with rectangular uniform section, while the decks were taken as steel box-girder in orthotropic plate shape. All properties of cables, pylons and decks are given in Tables (1 and 2).

In order to take into account the influence of connections types between towers and floor beams; four cases are considered viz.:

a) The connections between towers and deck are rigid ,while the tower bases are fixed and rest of supports are rollers (Fig. 2-a).
b) The intersection between floor beams and towers are pinned, while the tower bases are fixed and other supports are rollers (Fig. 2-b).
c) The lower parts of towers are released and the deck girders are continuous with rigid attachments with towers on roller supports while hinged only at second support from left side (Fig. 2-c)
d) This case is similar to case c except with pin connections of towers to deck girders (Fig. 2-d).

3. Analysis Considerations

The static analysis for all examples is carried out by the energy method. This method is based on the minimization of the total potential energy and structural elements, via conjugate gradient technique [9]. The procedure used the iterative steps to acquire the final configurations. The program used in the analysis and all programs used for generation of geometry and properties of bridges are constructed by the author. The bridges were analyzed as a space structure with global system of coordinates given in Figs. (1-a), (1-b), and (1-c). Number of cables and flexural elements, number of joints and number of degrees of freedom with considered mathematical models in cable stayed and suspension bridges are given in Tables (3-a) and (3-b), respectively. The cross section of the deck is box-girder in orthotropic shape. Many examples are solved considering the total dead weight and traffic load as uniformly distributed along all span lengths with intensity of 10 t/m^{*}. The initial tensions for all cable elements are taken as 10% of maximum fracture load for each type. The maximum normal forces and bending moments along tower height are presented in Table (4). Considering H is the height of tower above floor level, the maximum lateral displacements in towers tops are given in Table (5). Considering L is the interior span of the girder and W is the intensity of the uniform distributed loads along the decks. Tables (6,7and 8) are presented. These tables involve respectively maximum normal forces in decks, maximum bending moments in decks and deflections and bending moments at the eenter of the first interior span of the floor beam. In all tables contain normal forces, a sign (-) means a compression forces while no sign means a tension forces. Figs. (4, 5, and 6) show sway along tower height in suspension, stayed (harp), and stayed (radiating) bridges, respectively.

Figs. (7- a and 7-b) involve the values of horizontal and vertical displacements at cable joint for all considered types of connections. The tension forces in cables for all types of connections in suspension, stayed (harp) and stayed (radiating) bridges are presented in Figs. (8, 9-a and 9-b), respectively. Figs. (10), and (11) summarize the variations of deflections along floor beams for bridges having three and four spans, respectively.

A comparison containing the three considered types of bridges having four and five spans between deflections along floor beams is showed in Figs. (12 and 13), respectively. As example, the variations of moments along floor beam in suspension bridge are shown in Fig. (14). Normal forces along tower height in suspension, stayed (radiating), stayed (harp) bridges are given in Figs. (15-a, 15-b, and 15-c), respectively. Finally, Figs. (4, 5, and 6) show sway along tower height in suspension, stayed (harp), and stayed (radiating) bridges, respectively. Figures (16-a, 16-b, and 16-c) describe the bending moment along tower hcight in stayed (harp), stayed (radiating), and suspension bridges, respectively.

4. Analysis of Results

It may be concluded that:

1. Cables:

Displacements in cable joints (Figs. 7)

- ***a)*** All types of bridges had small variations in horizontal displacements.
- ***b)*** Case c had the smallest values of vertical and horizontal displacements.

Cables in suspension bridge (Figs. 8)

- ***a)*** Case b had the smallest values of cable tension in cable 1, while case c had the biggest value.
- ***b)*** Case c had the biggest values in sagging cable, while other cases were very close to each others and had the smaller values.
- ***c)*** The values of tensions in stayed cable are inversely proportional to the values of tensions in sagging cable.
- ***d)*** Cases b and d are very elose to each others.

Cables in stayed bridges (Figs. 9)

- ***a)*** Case b had the smallest values of tension in all cables.

Pylons (Figs. 4, 5, 6, 15, and 16)

- ***a)*** Cases b and d had the smallest values of lateral displacements for tower.
- ***b)*** The lateral displacements with increasing number of spans had a small variation.
- ***c)*** Comparison of the three types of bridges demonstrates that the suspension bridge had a relatively small normal force along tower height above the floor level.
- ***d)*** Case of connection type c had the smallest values of tension and bending moment along tower height.
- ***e)*** In case of bridges having a part of tower under floor level, case b had a bending moment along tower height smaller than that in case a.

3. Decks (Figs. 10,11,12,13, 14, and 17)

- ***a)*** Case b had the smallest values of deflections along floor beam in all types of bridges.
- ***b)*** The difference in deflection along floor beams in suspension bridge between case c and d is negligible.

c) Comparison of the three types of bridges demonstrates that the suspension bridge had big values of deflections along floor beams.

d) The biggest values of normal forces along floor beams are concentrated near to tower connection with the floor and decreases near the center of spans except in suspension bridge (case a).

e) Case b had the smaller values of bending moments in exterior and interior spans, while the other cases a, b, and d are very close to each other.

f) Case b is the best case with respect to the maximum deflection along the floor beams, while other cases are close to each other with a complete similarity between cases c and d.

5. Conclusions:

The major conclusions that have been drawn from the present work are:

1. The connection types between pylons and floor beams play an important rule on the final design of cable –supported bridges. They have influence on the final values of tension in cables, normal forces and bending moments in towers and decks as well as on the lateral sways in towers and vertical deflections in decks.

2. Cases b and c are the best choice confirming all phases of comparisons.

6-REFERENCES

1. .Leonhardt f, Brucken/Bridge: Architectural press, London , 1982
2. Fu-Kuei Chang and E. Cohen:" Long-span Bridges': State of the art. J.Struct. Div, ASCE, 1981.
3. Pao-Hsil Wang and Chiung-Guei Yang; " Parametric Studies on Cable-Stayed Bridges", Computers & Structures, Vol. 60, No.2, PP. 243-260, 1996.
4. Frederick S. Merritt: Structural Steel Designers' Handbook: Copyright by McGraw-Hill, Int., 1972.
5. Aly S.A.I.N. " The Stability of Cable –Stayed Bridges", Ms. Thesis , Ain Shams University, Cairo ,1982
6. Podolny W., Jr. Chmn., "Tentative Recommendations for Cable Stayed Bridges Structures", by the Task Committee on Cable-Suspended Structures of the Committee on Special Structures, of the Committee on Metals, of Structural Division, J. Strict. Div., ASCE, 1977.
7. F. Leonhardt and Zellner W., "Cable-Stayed Bridges', IABSE Proceedings, May, 1980.
8. J.Ch.Erhopoulos, A.S.Vcahinos, and Yang-Cheng Wang " Stability Analysis of Cable-Stayed Bridges', Computers & Structures Vol. 44,No. 5, PP. 1083-1089,1991.
9. Buchholdt H.A. " An Introduction to Cable Structures", Cambridge University, Press 1985.

Table (1): Properties of used cables.

Group No.	Diameter (cm)	Weight (t/m)	Area (m^2)	Modulus (t/cm^2)	Breaking load,(tons)	Initial tension (tons)
1	7.62	0.022	0.00274193	1584	412	41.2
2	10.16	0.0393442	0.00487741	1584	730	73

Table (2): Properties of pylons and deck sections.

Element	Area (m^2)	Polar inertia (m^4)	Inertia I-X (m^4)	Inertia I-Y (m^4)	Weight (t/m)	Modulus (t/cm^2)
Upper tower	9.116	17.135	31.19	6.306	22.791	200
Lower tower	14.047	21.261	36.848	7.395	35.185	200
Floor beams	0.4027	11.1821	10.7374	0.4447	3.49	2100

Table (3-a): Numbers of joints, members, and degrees of freedom in cable stayed bridges.

Item	3-spans		4-spans		5-spans	
Cases	(a and b)	(c and d)	(a and b)	(c and d)	(a and b)	(c and d)
Number of joints	91	87	136	130	181	173
Number of cables	64	64	96	96	128	128
Number of flexural members	46	42	69	63	92	84
Degrees of freedom	398	381	596	571	794	761

Table (3-b): Numbers of joints, members, and degrees of freedom in suspension bridges.

Item	3-spans		4-spans		5-spans	
Cases	(a and b)	(c and d)	(a and b)	(c and d)	(a and b)	(c and d)
Number of joints	72	68	110	104	148	140
Number of cables	43	43	74	74	105	105
Number of flexural members	46	42	69	63	92	84
Degrees of freedom	341	324	518	493	695	662

Table (4): Maximum normal forces and bending moments in pylons.

Response	Normal Force, ton			Bending Moment , t.m		
Spans No: and cases	Suspension bridge	Harp Bridge	Radiating bridge	Suspension bridge	Harp Bridge	Radiating Bridge
3-spans (a)	-3225	-3894	-3924	17052	12426	11369
3-span(b)	-3087	-3755	-3793	2964	2408	1951
3-spans (c)	-733	-1604	-1902	2733	1108	821
3-spans(d)	-957	-1586	-1878	2089	4851	5072
4-spans (a)	-3726	-4336	-4340	14690	8659	7894
4-spans(b)	-3639	-4248	-4259	1356	2018	1786
4-spans (c)	-940	-1709	-2052	1532	1002	741
4-spans(d)	-961	-1698	-2039	1706	4049	4218
5-spans (a)	-3680	-4279	-4282	14791	8091	7432
5-spans(b)	-3640	-4238	-4245	1374	2779	2441
5-spans (c)	-934	-1670	-1996	1795	1038	769
5-spans(d)	-957	-1669	-1955	1808	4228	4430

Table (5): The maximum lateral displacements in towers tops as a ratio of tower height, H.

Cases	Suspension bridge	Cable-stayed (harp shape)	Cable-stayed(radiating)
Case a	H/508	H/460	H/493
Case b	H/2390	H/868	H/976
Case c	H/325	H/385	H/415
Case d	H/770	H/670	H/614

Table (6): Maximum normal forces in decks as a percentage of WL^2, tons.

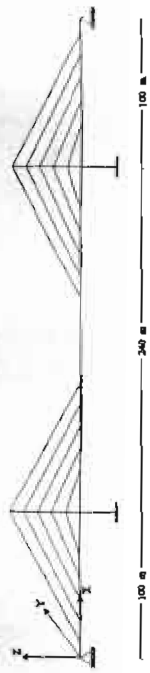
Bridge type	Suspension bridge		Cable stayed (harp)		Cable stayed (radiating)	
Cases	exterior	interior	Exterior	Interior	Exterior	Interior
Case a	-4.80	-26.50	-22.10	-35.50	-18.75	-39.03
Case b	5.40	-6.10	-20.20	-17.30	-16.66	-19 to 1.6
Case e	-6.10	14.16	-23.13	-18.75	-20.62	-20 to 1.5
Case d	-3.38	-5.6 to 9.4	-16.12	-26.00	-16.25	-27

Table (7): Maximum bending moments in decks as a percentage of WL^2, t.m.

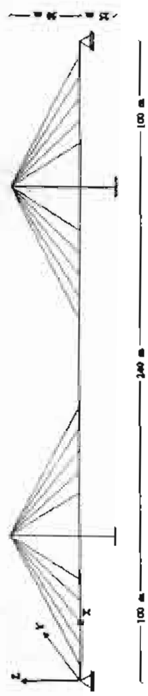
Bridge type	Suspension bridge		Cable stayed (harp)		Cable stayed (radiating)	
Cases	exterior	interior	Exterior	Interior	Exterior	Interior
Case a	4.34	7.47	3.61	5.65	3.00	4.86
Case b	1.21	5.20	0.88	4.03	0.67	3.60
Case c	6.44	6.91	4.99	5.19	4.22	4.38
Case d	6.67	6.51	4.81	4.81	4.10	4.30

Table (8): Deflections and bending moment at the center of first interior span of the floor beams.

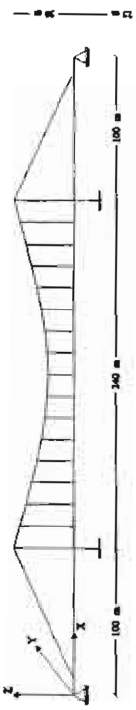
Response		Deflection multiplied by L/100			Moment multiplied by WL^2 /100		
No of spans	Cases	Suspension	Harp	Radiating	Suspension	Harp	Radiating
3	a	0.204	0.167	0.152	4.73	3.91	3.67
3	b	0.155	0.123	0.116	4.07	3.36	3.18
3	c	0.250	0.194	0.176	5.32	4.28	3.98
3	d	0.250	0.178	0.163	5.29	3.79	3.76
4	a	0.179	0.141	0.127	4.37	3.54	3.3
4	b	0.155	0.120	0.111	4.06	3.28	3.08
4	c	0.194	0.147	0.132	4.59	3.25	3.37
4	d	0.194	0.142	0.128	4.56	3.18	3.3
5	a	0.180	0.143	0.130	4.40	3.58	3.34
5	b	0.155	0.120	0.132	4.06	3.28	3.2
5	c	0.208	0.163	0.123	4.78	3.52	3.58
5	d	0.208	0.150	0.120	4.78	3.31	3.41



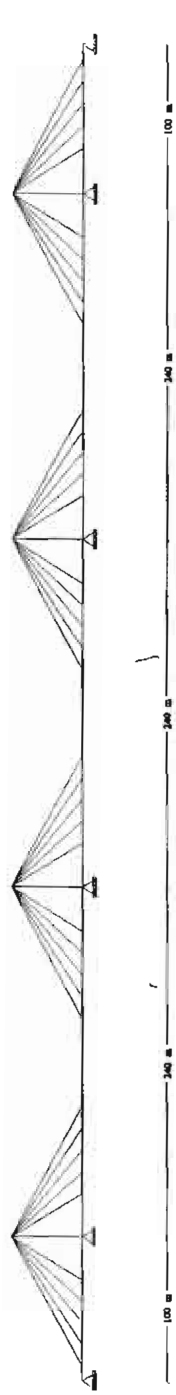
Fig(1-a) Cable stayed bridge(harp shap)



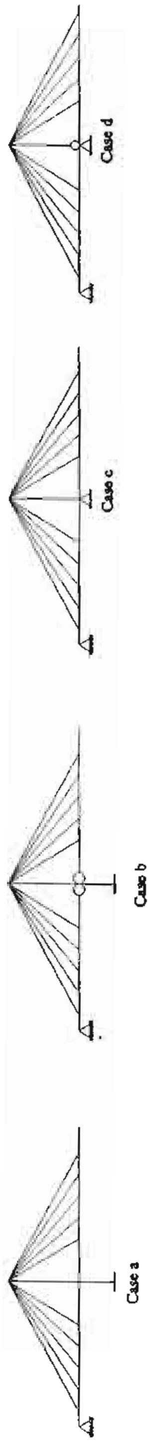
Fig(1-b) Cable stayed bridge(radiating shap)



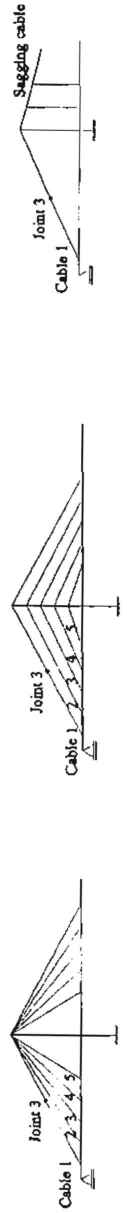
Fig(1-c) : suspension bridge.



Fig(1-d) : Five spans cable stayed bridge(radiating shap)



Fig(2) : Connection types between towers and floor beam.



Fig(3) : Numbering of some joints and cables.

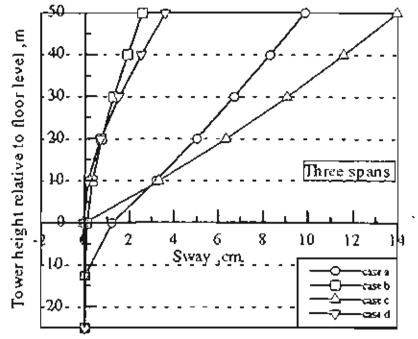


Fig.(4-a) :Sway along tower height in suspension bridge.

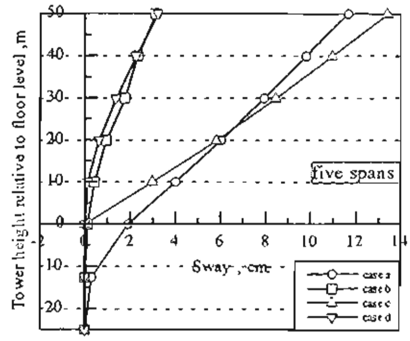


Fig.(4-b) :Sway along tower height in suspension bridge.

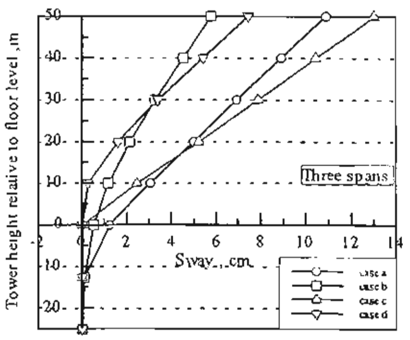


Fig.(5-a) :Sway along tower height in stayed bridge (harp)

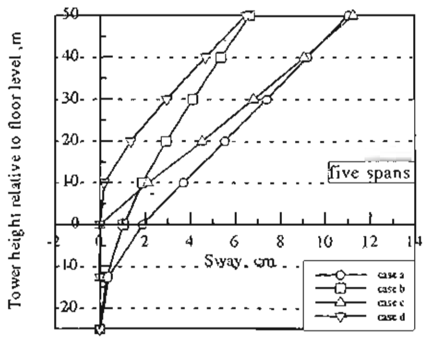


Fig.(5-b) .Sway along tower height in stayed bridge (harp)

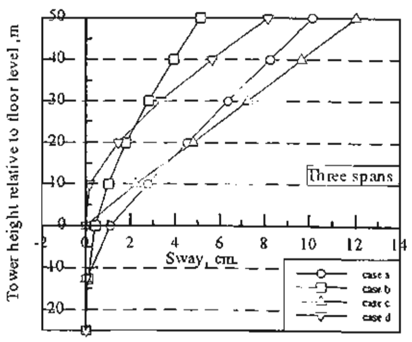


Fig.(6-a) ·Sway along tower height in stayed bridge (radiating)

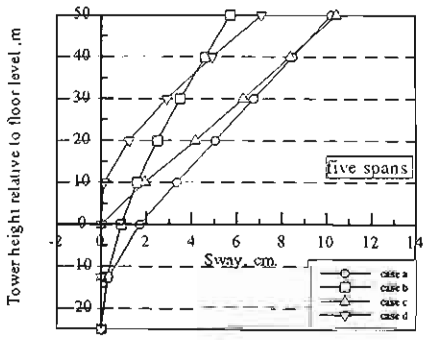


Fig.(6-b) .Sway along tower height in stayed bridge (radiating)

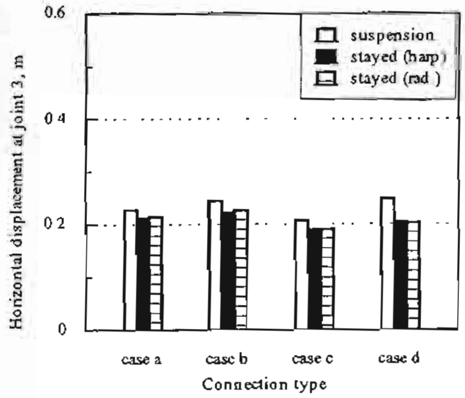


Fig (7-a). Variations of horizontal disp. along cable joint.

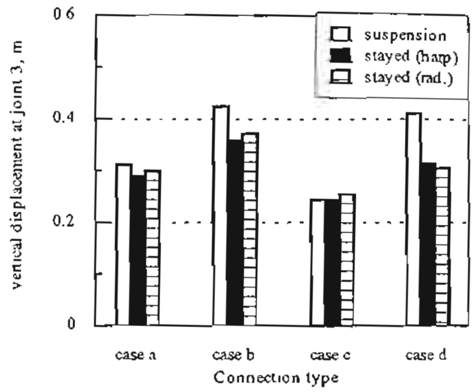


Fig (7-b) Variations of vertical disp along cable joint.

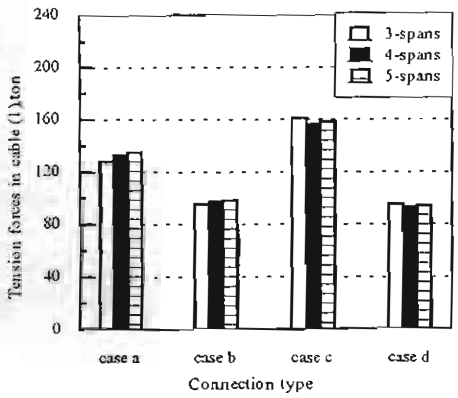


Fig.(8-a):Tension forces in cable (1) in suspension bridge

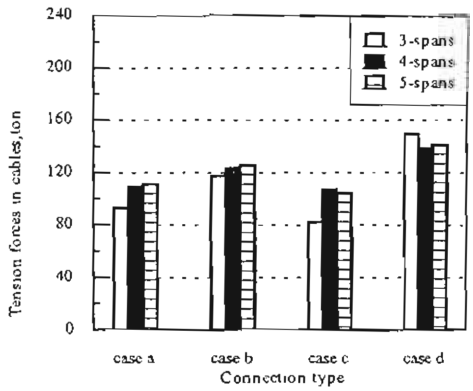


Fig.(8-b): Tension forces in sagging cables in suspension bridge.

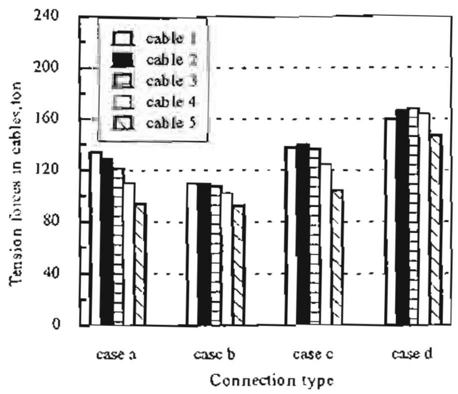


Fig.(9-a): Tension forces in cables (stayed harp) bridge

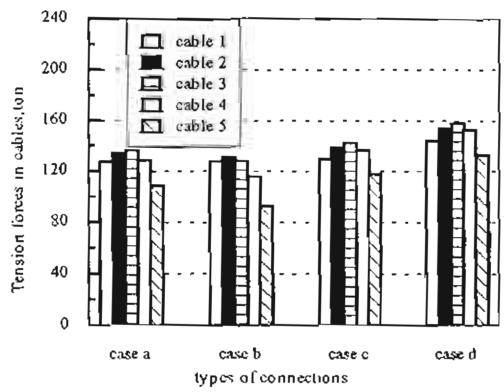


Fig.(9-b): Tension forces in cables (stayed radiating) bridge.

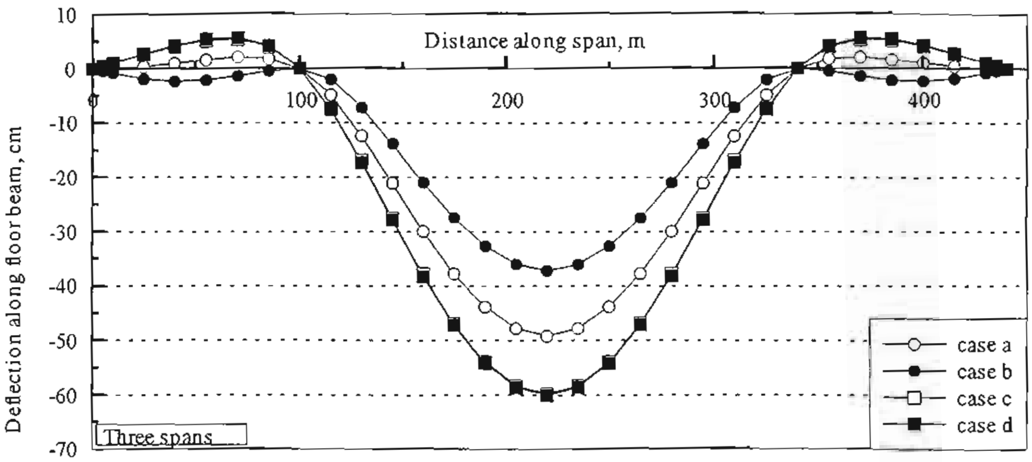


Fig.(10-a): Variations of deflections along floor beam in suspension bridge.

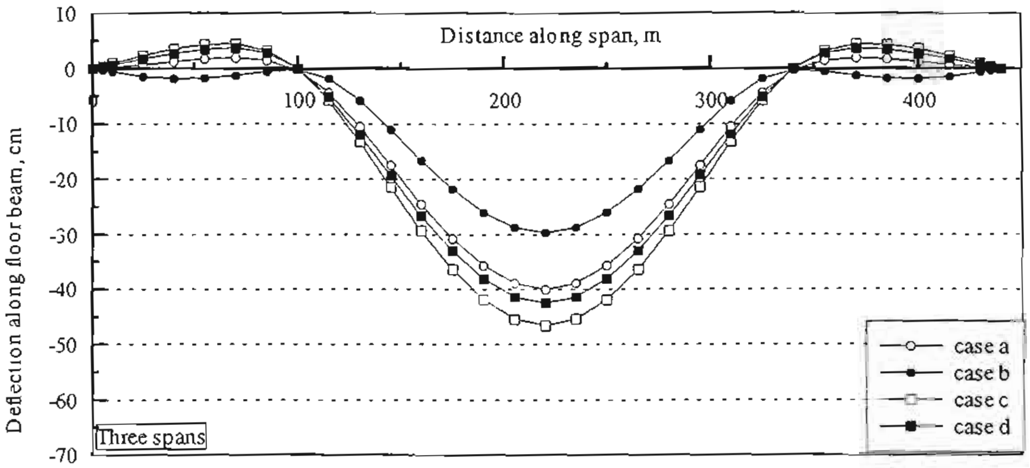


Fig.(10-b): Variations of deflections along floor beam in cable stayed (harp) bridge.

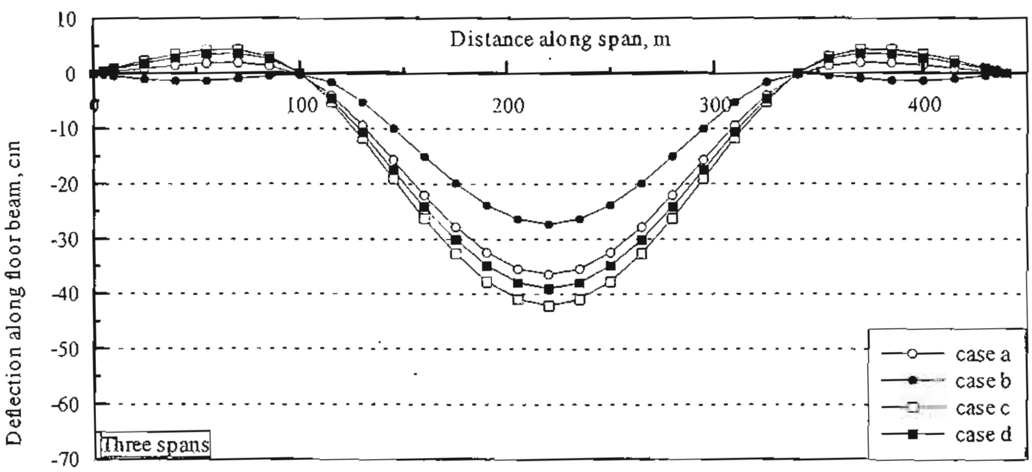


Fig.(10-c): Variations of deflections along floor beam in cable stayed(raditing)bridge.

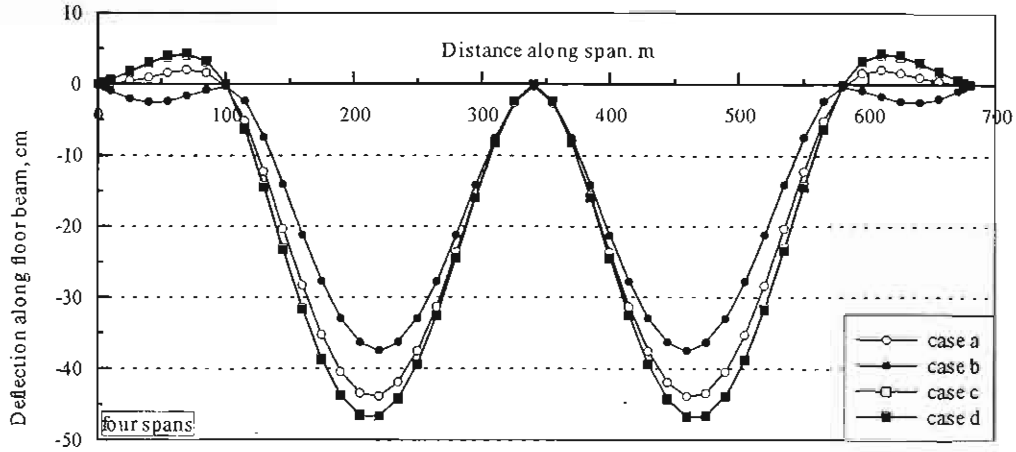


Fig.(11-a) Variations of deflections along floor beam in suspension bridge.

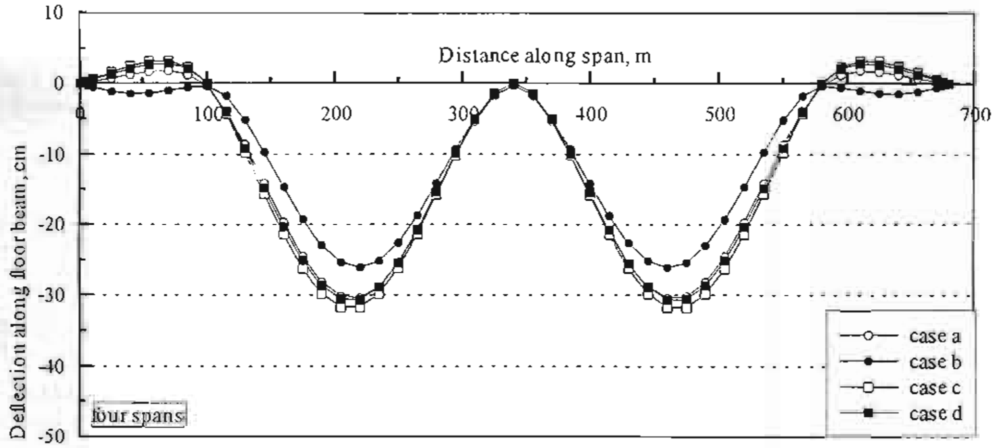


Fig.(11-b). Variations of deflections along floor beam in cable stayed(harp)bridge.

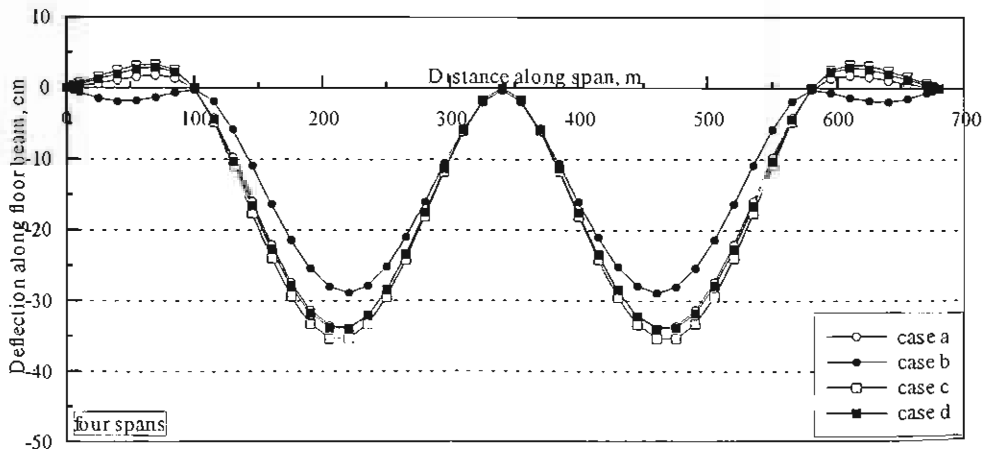


Fig.(11-c) Variations of deflections along floor beam in cable stayed(radiating)bridge.

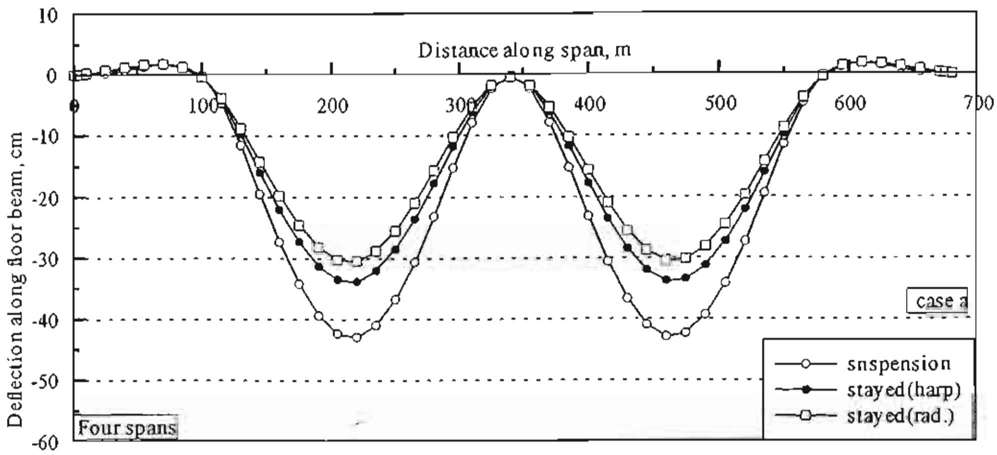


Fig.(12-a): Variations of deflections along floor beams in cable bridges.

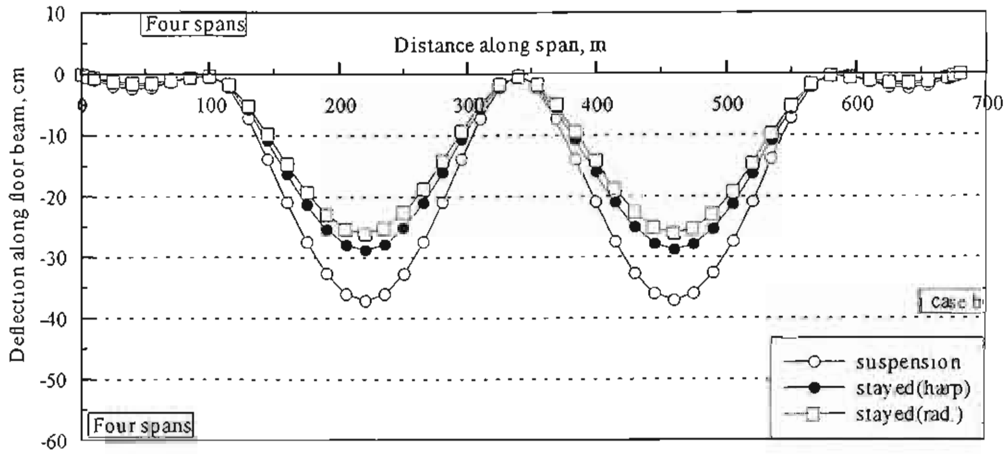


Fig.(12-b): Variations of deflections along floor beams in cable bridges

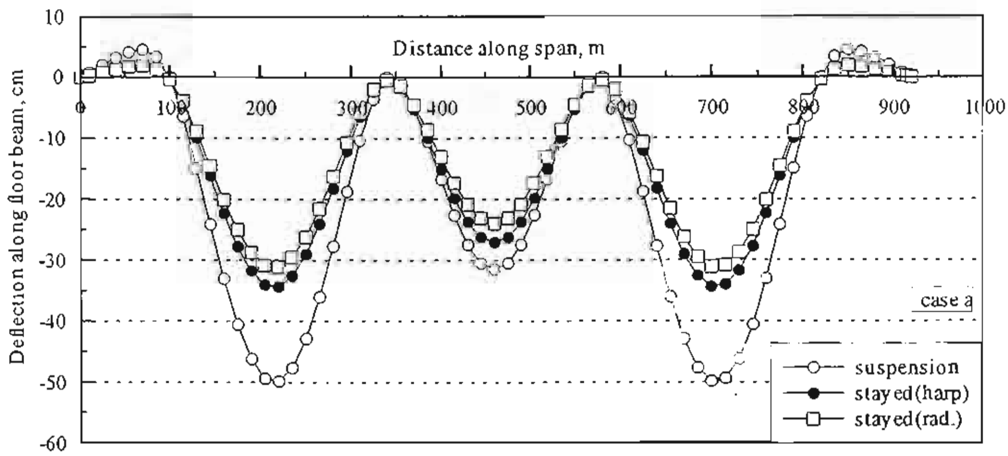


Fig (13-a): Variations of deflections along floor beams in cable bridges

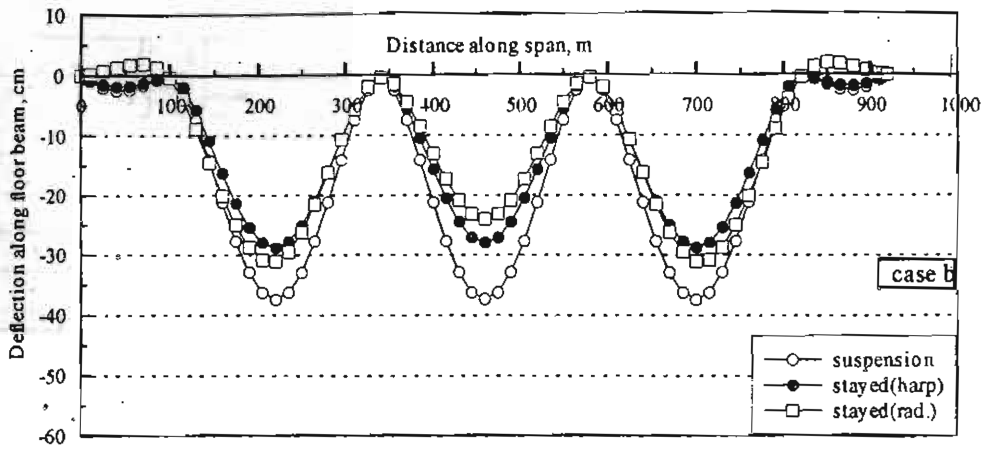


Fig.(13-b): Variations ofdeflections along floor beams in cable bridges

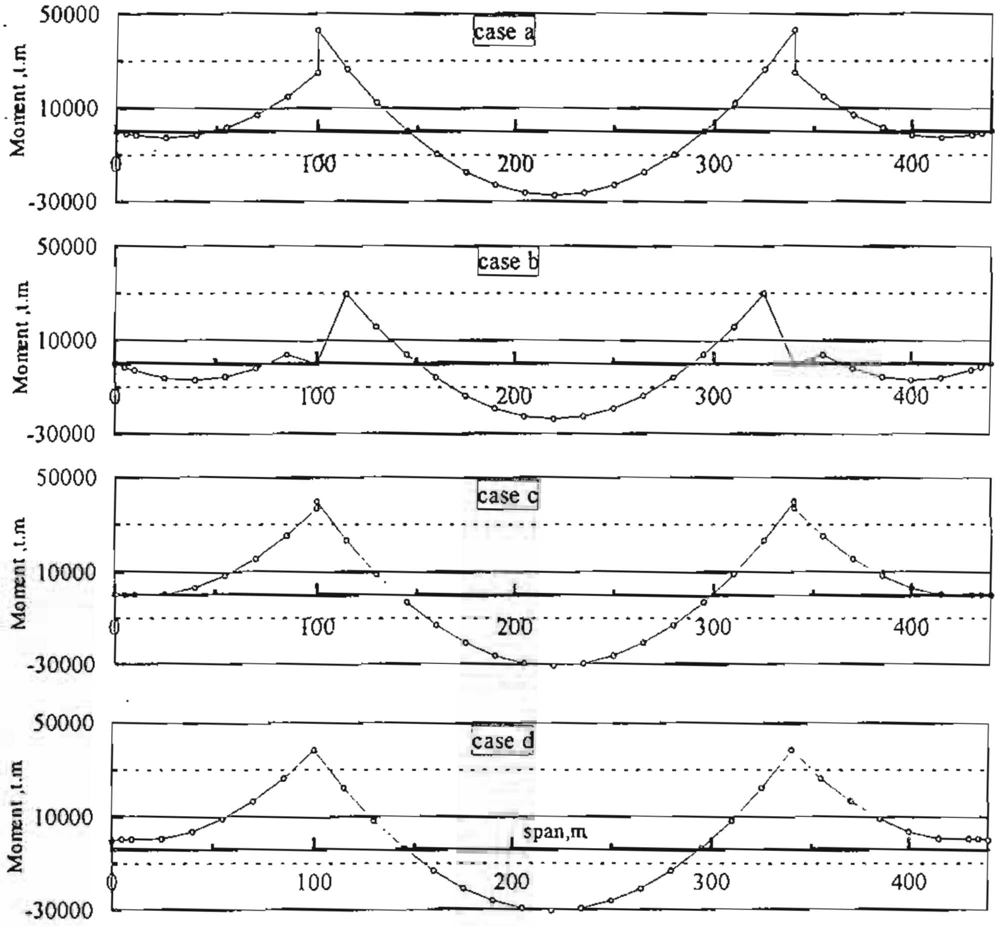
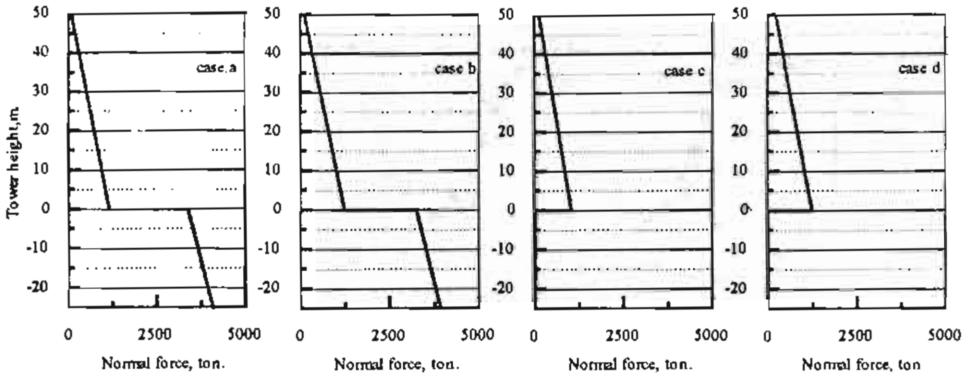
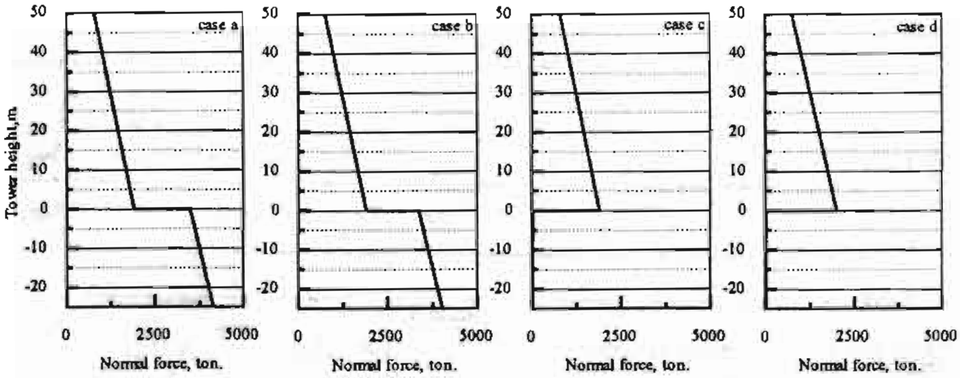


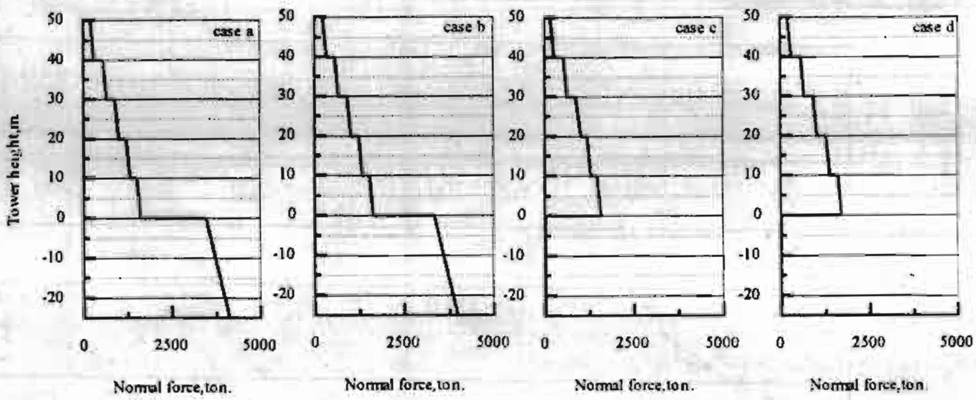
Fig (14): variations of moments along floor beam in suspension bridge.



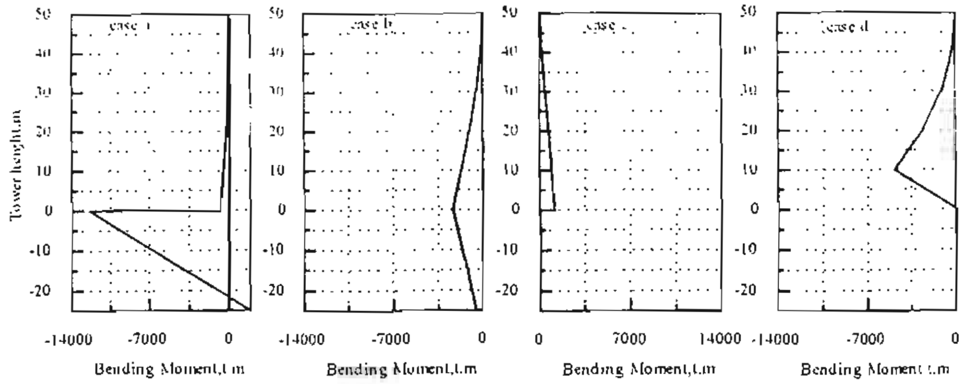
Fig(15-a): Normal force along tower height in suspension bridge.



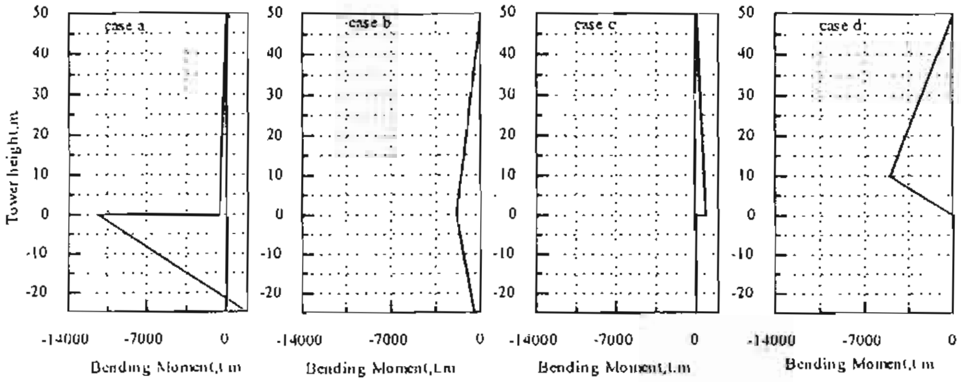
Fig(15-b): Normal force along tower height in cable stayed (radiating) bridge.



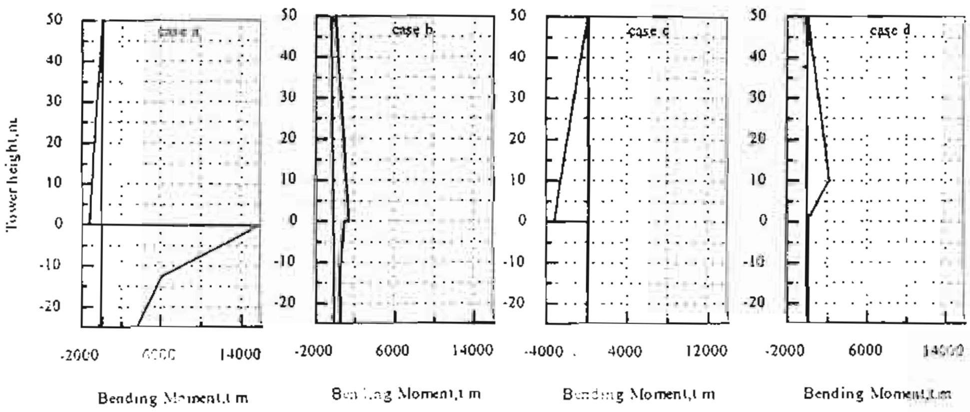
Fig(15-c): Normal force along tower height in cable stayed (harp) bridge.



Fig(16-a): Bending moment along tower height in cable stayed(harp) bridge.



Fig(16-b): Bending moment along tower height in cable stayed(radiating) bridge.



Fig(16-c): Bending moment along tower height in suspension bridge

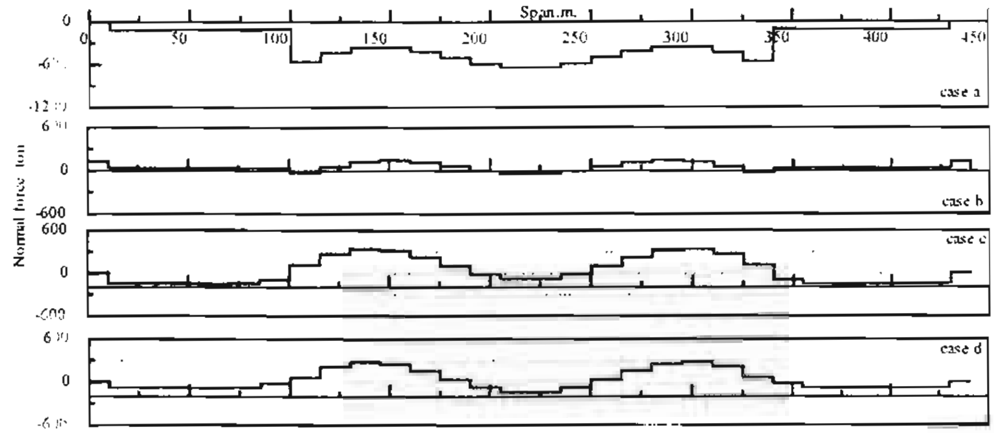


Fig.(17-a). Normal force along floor beam in suspension bridge.

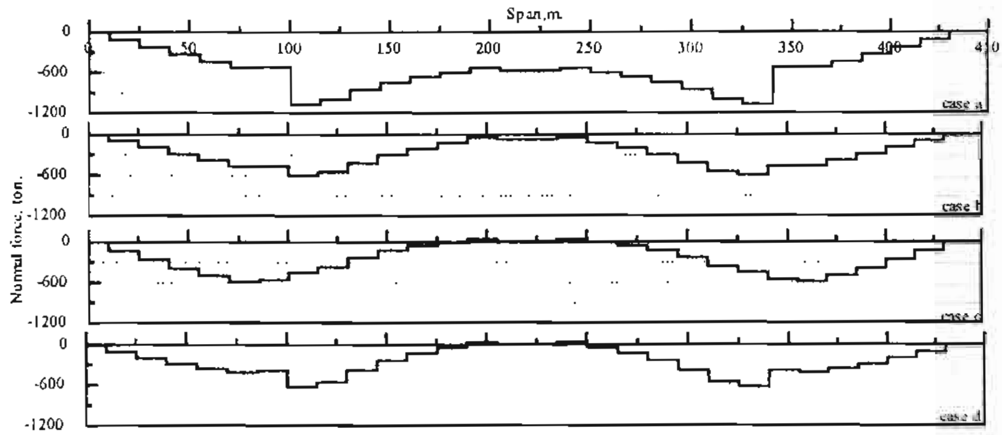


Fig (17-b): Normal force along floor beam in cable stayed (harp) bridge

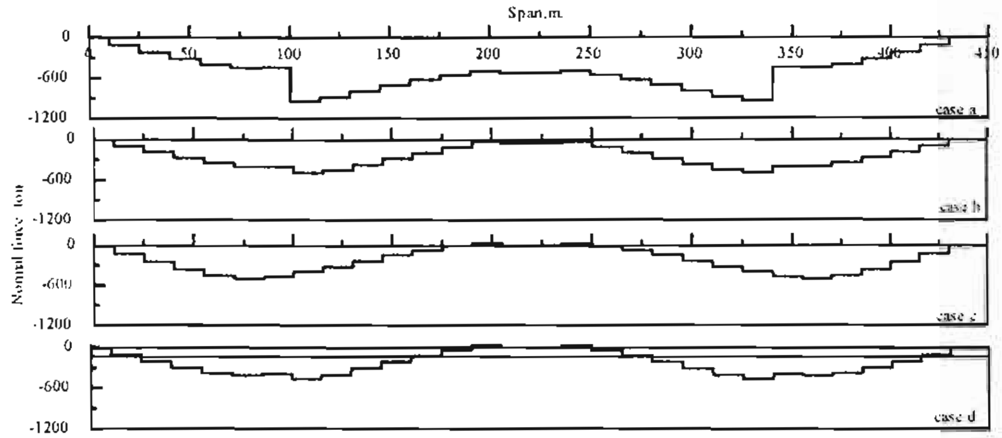


Fig (17-c). Normal force along floor beam in cable stayed (radiating) bridge.