SEISMIC RESPONSE ANALYSIS OF CABLE STAYED BRIDGES

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SUMMARY

The detailed dynamic investigation of long span cable stayed bridges subjected to strong ground motion requires a study of the following combinations of earthquake motions, (i) Horizontal component in the direction of traffic combined with vertical component, and (ii) Horizontal component transverse to the direction of traffic combined with vertical component.

This paper presents the results of the above analysis wherein the bridge is modelled as a lumped mass system in two and three dimensional space with appropriate modelling of the foundation soil.

The results obtained indicate that the soil properties do not significantly affect the response of the system and that the dynamic forces in cables being small, the possibility of cable slackening during vibrations is prevented.

INTRODUCTION

The cable stayed bridge investigated has a "radiating" cable arrangement and consists of five spans as demarcated by the six piers, two of which support the steel towers. A general view of the bridge structure and components is shown in Fig. 1. Some of the salient dimensions are as follows:

Central span between the towers	457.20 m
End spans, each	91.44 m
Height of steel towers	104.00 m
Total width of bridge including footpaths	34.50 m
Centre to centre distance of main box girders	27.50 m
Spacing of cross girders	7.50 m
Size of box girders	3.0 mx2.0 m

In order to conduct a detailed study into the seismic response of the bridge system it was considered desirable to phase the analysis by considering the following combinations of earthquake motions.

i) Horizontal component of ground motion along the flow of traffic combined with vertical component, and

ii) Horizontal component of ground motion transverse to the traffic combined with vertical component.

The mathematical models adopted for the above studies were lumped mass systems with the foundation soil modelled as springs in two and three dimensional spaces respectively and subjected to assumptions amenable to the

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analysis. The free vibration characteristics were determined along with the spectral response parameters in the form of absolute dynamic displacements and member forces such as axial force, shears and moments. A parametric study with respect to variation in the modulus of subgrade reaction was also conducted to assess the nature of interaction and its extent between the long span cable stayed bridge and the soil.

MATHEMATICAL MODEL

Structure

The main assumptions involved in the formulation of the mathematical models are,

i) The well, pier and tower segments are represented by beam members, cables by truss members effective in tension as well as compression, and deck by a combination of both.

ii) The number of cables being large they are represented by ficticious cables whose equivalent area is obtained by lumping areas of actual cables.

iii) Links provided at the supports are idealised as truss members.

iv) The foundation soil was idealised by rotational springs at the base. The method of calculating spring constants is discussed subsequently.

Soil

The superstructure of the bridge is supported on piers and subsequently well foundations. The dimensions of the wells are large and loads are heavy so as to justify the assumption that the well behaves as a rigid body hinged at the base. The above is further substantiated by the fact that rotation of well is restrained by subgrade reaction activated at the sides and the base. The above condition is mathematically idealised by restraining the well base against horizontal and vertical translation and introducing a rotational spring at the base.

Based on the reactive moment transmitted from the soil to the foundation as given by Polshin (4), Barkan and Terenin (4) and the relationship between the coefficient of elastic non-uniform compression of soil (C_ϕ) and the coefficient of uniform elastic compression (C_u) as given by Barkan (4), the stiffness in pure rotation is,

$$K_{\theta 1} = 2.0 \, n_h \cdot I.H$$

the equivalent rotational spring due to horizontal reaction as indicated by Terzaghi (6) is,

$$K_{\theta 2} = 0.0833 n_h \, H^4 B$$

and the total stiffness of the rotational spring is,

$$K_\theta = K_{\theta 1} + K_{\theta 2} = n_h \cdot H \cdot (2I + 0.08333 \, BH^3)$$

where n_h is modulus of subgrade reaction, I is the moment of inertia of contact surface between well and soil about the axis of bending during vibrations and H and B are the height and weidth of the well.

RESULTS AND CONCLUSIONS

For the mathematical models as shown in Figs. 2a and 2b the free vibration characteristics are as shown in Table I and the mode shapes are as shown in Figs 3 and 4. The results of the parametric study involving variation of the modulus of subgrade reaction are as shown in Fig. 5. The obtained results indicate that

i)   In the practical range of n_h values the soil does not significantly influence the seismic response of the cable stayed bridge. This conclusion corroborates earlier studies on two span systems (1) and (5).

ii) In long span systems it is the predominant behaviour of individual spans which determines the dynamic behaviour of the system and these should be appropriately designed.

iii) The dynamic forces in cables being small as compared to dead load tension, there is no possibility of cable slackening during vibrations (2 and 3).

ACKNOWLEDGEMENTS

REFERENCES

1.   Ahmad S., Oct. 1977, Influence of Horizontal Subgrade Reaction on the Dynamic Behaviour of Cable Stayed Bridges, M.E. Dissertation, SRTEE, University of Roorkee, Roorkee.

2.   Arya A.S., Krishna, Prem, Thakkar S.K., Gupta, Pratima Rani, Pandey Ashok D., 1975, Second Report on Seismic Investigations of Second Hooghly Bridge, Earthquake Engg. Studies EQ 75-17, SRTEE, University of Roorkee, Roorkee.

3.   Arya, A.S., Krishna, Prem, Thakkar S.K., Gupta, Pratima Rani, Pandey Ashok D., 1979, Third Report on Seismic Investigations of Second Hooghly Bridge, Earthquake Engg. Studies EQ 79-1, SRTEE, University of Roorkee, Roorkee.

4.   Barkan, D.D., 1962, Dynamics of Bases and Foundations, McGraw Hill Book Co.

5.   Krishna, Prem, Nandakumaran, P., Pandey Ashok D., Ahmad, Suhail, Oct. 1978, Influence of Soil Structure Interaction on the Dynamic Behaviour of Cable Stayed Bridges, VI Symp. of Earthquake Engg., Vol. I, pp, 247-252.

6. Terzaghi, K., Dec. 1955, Evaluation of Coefficient of Subgrade Reaction, Geotechnique, Vol. V, No. 4.

TABLE I - SUMMARY OF DYNAMIC ANALYSIS

MODE	2D ANALYSIS			3D ANALYSIS			
	T	CRL	CRV	T	CRL	CRV	CRT
1	3.433	1.225	0.299	2.408	-0.078	0.497	1.152
2	3.151	1.372	-1.039	1.913	-0.068	1.024	-0.775
3	2.357	0.303	-0.012	1.311	0.101	0.049	1.210
4	1.622	-0.238	0.525	1.000	-0.120	0.505	0.053
5	1.261	-0.140	0.623	0.736	-0.061	1.069	0.250
6	1.237	0.128	0.386	0.675	1.058	0.371	0.024

T = Time period in secs.

CRL = Mode participation factor in traffic direction.

CRV = Mode participation factor in vertical direction.

CRT = Mode participation factor in direction transverse to the traffic direction.
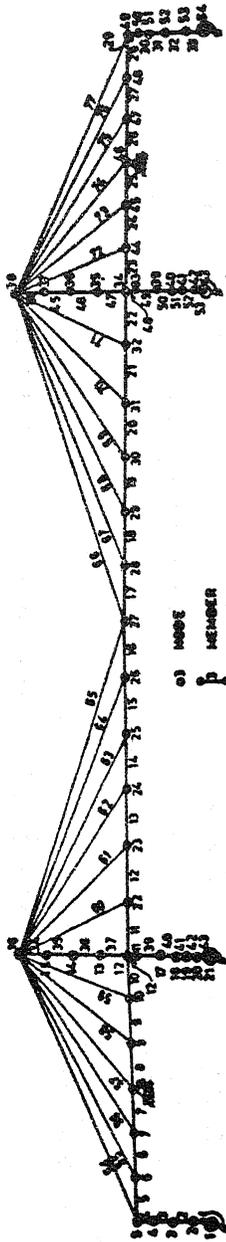
Cross section of Deck

Longitudinal section of Deck

ALL DIMENSIONS IN METRES

Elevation at Tower
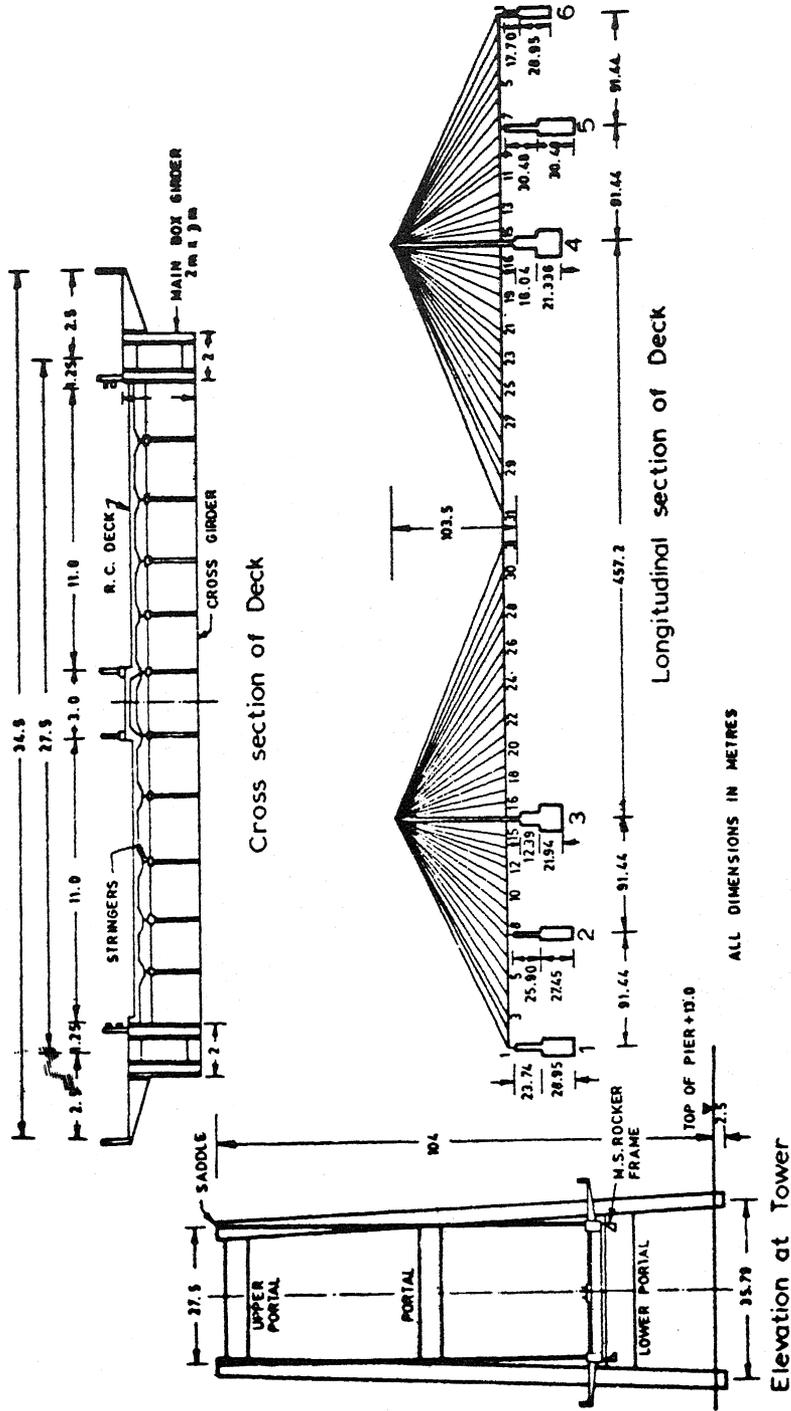
FIG. 1 – GENERAL VIEW OF BRIDGE

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LONGITUDINAL VIBRATIONS
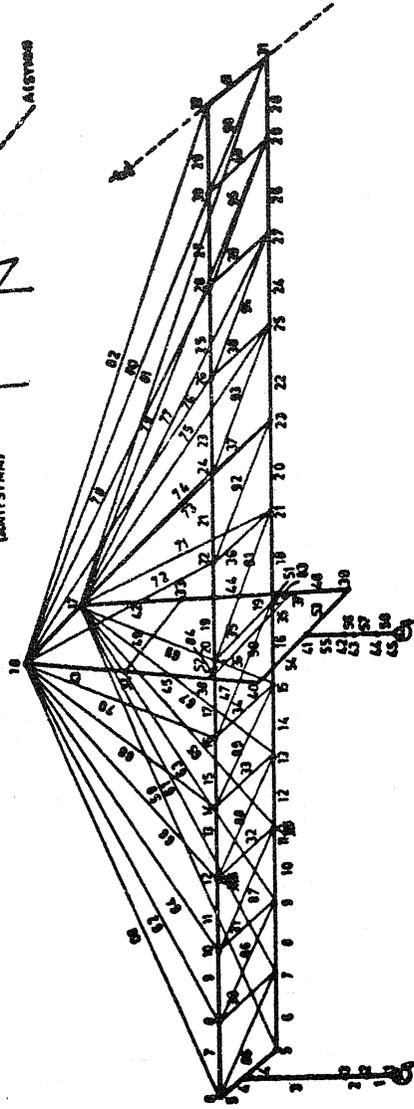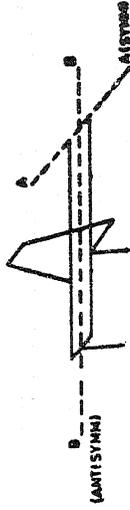
FIG. 2 _ MATHEMATICAL MODEL FOR TRANSVERSE VIBRATIONS

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FIRST MODE

SECOND MODE

THIRD MODE

FOURTH MODE
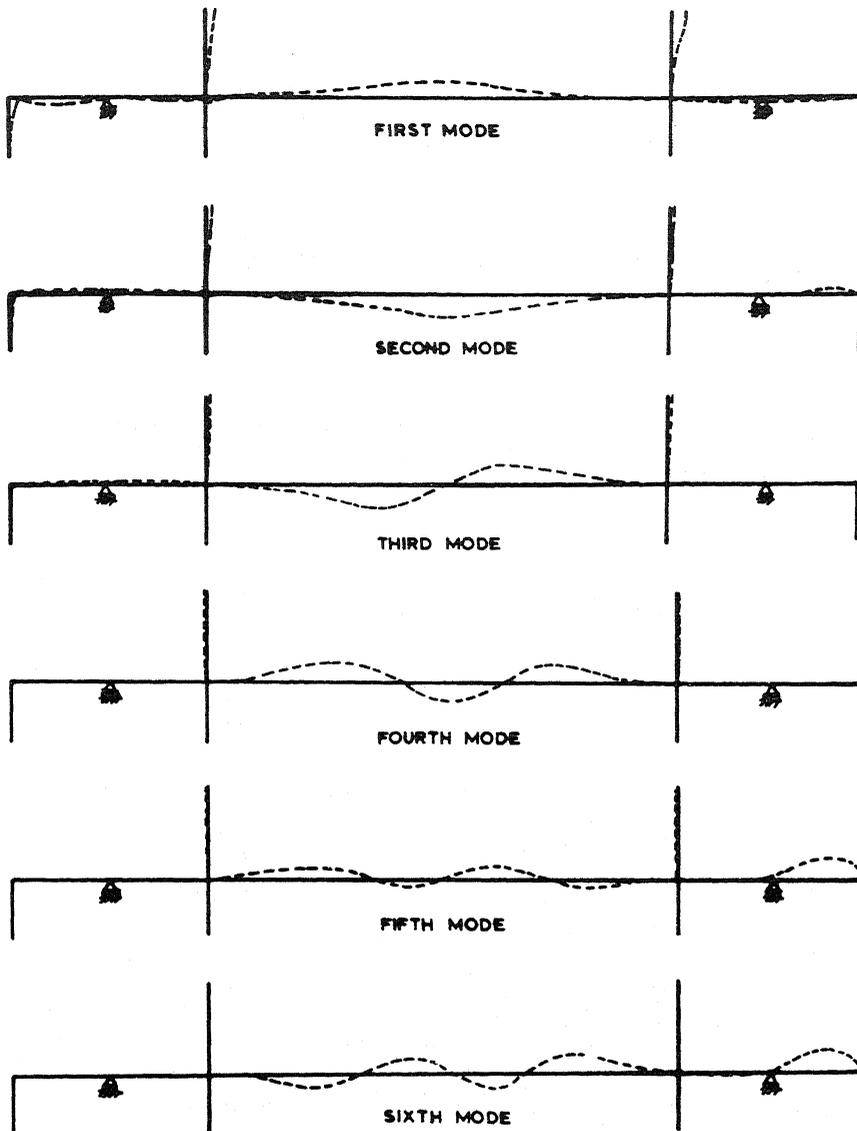
FIFTH MODE

SIXTH MODE
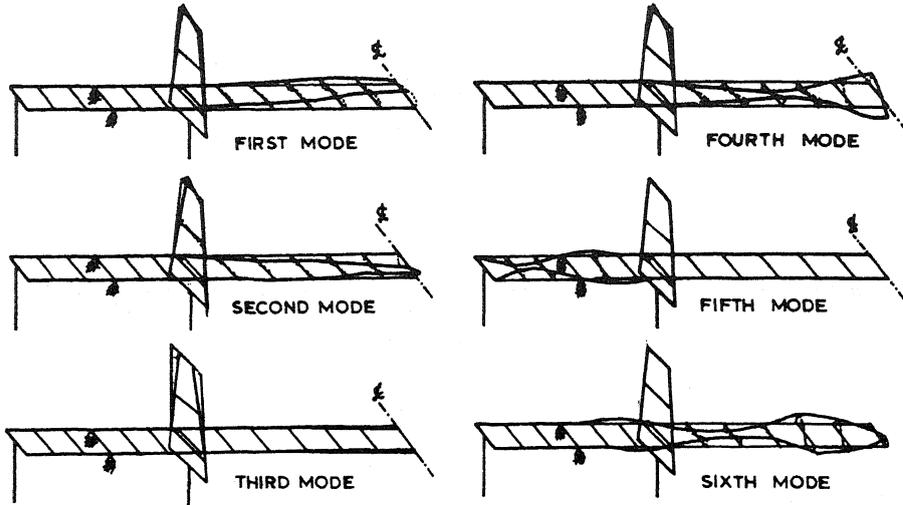
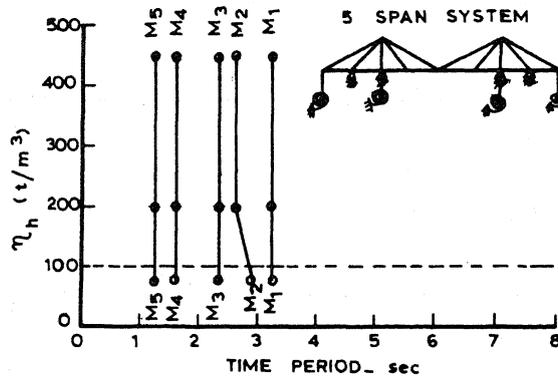FIG. 3 _ FREE VIBRATION MODES (LONGITUDINAL)

FIG. 4 _ TORSIONAL FLEXURAL MODES I TO VI

FIG. 5 _ VARIATION OF TIME PERIOD WITH η_h