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Aerodynamic Stability of Twin Suspension Bridge Concept

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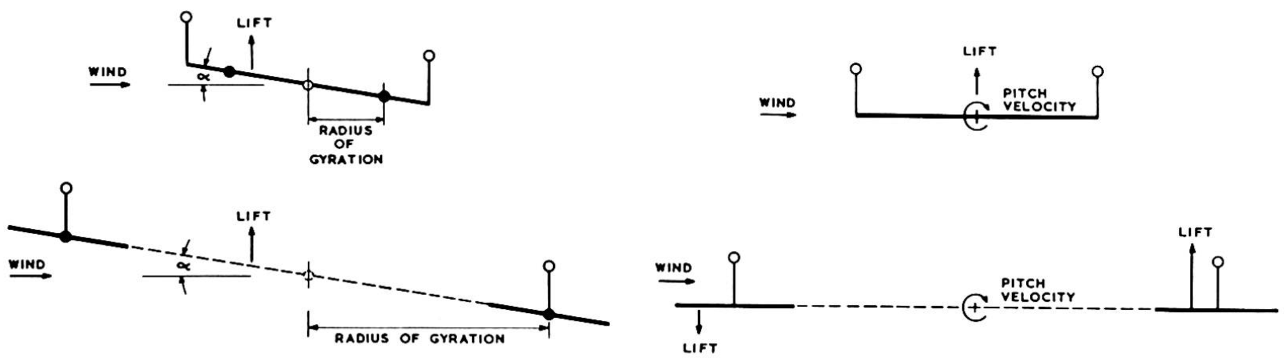
THEORY

When a conventional road deck is twisted the wind causes a negative aerodynamic moment, which reduces the torsional stiffness and frequency as the wind speed increases. At some critical wind speed this frequency coincides with that of bending, and the two modes couple together in an unstable oscillation called "flutter". This speed can be raised by increasing the torsional stiffness with a lattice-truss or steel box. Unfortunately this increases the dead load carried by the cables, and becomes uneconomic for very long spans.

If the still-air torsion frequency could be reduced to that of bending the two frequencies would never coincide in high winds, and flutter would be avoided. However, high torsional stiffness would still be needed because the torsion frequency would reduce to zero at some wind speed, leading to another instability called "static divergence". Such a solution could therefore be achieved only by increasing the torsional inertia of the deck. Even if this was practically possible, the torsional damping would be nearly zero because the aerodynamic lift due to pitch <u>velocity</u> acts at the centre of the deck, and so gives no damping moment.



LIFT DUE TO PITCH ANGLE

LIFT DUE TO PITCH VELOCITY

Torsional stiffness can be achieved, without weight penalty, by spacing the cables much further apart. If at the same time, the two deck halves are also separated to hang directly under each cable leaving a huge "slot" between them, three phenomena occur. With the understanding that the two decks are constrained to move as a single body by rigid transverse beams at intervals along the span, then

i) the destabilising aerodynamic moment remains exactly the same, so that no increase in torsional stiffness is needed,
ii) the still-air torsional frequency is reduced to that of bending by the increased radius of gyration

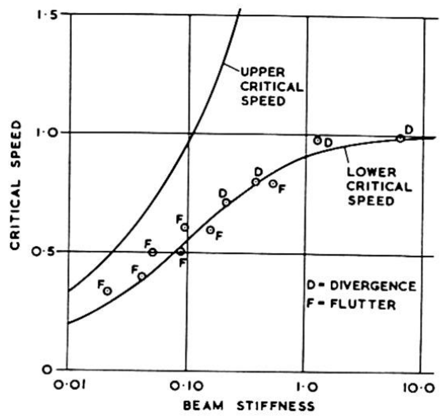
and iii) the aerodynamic damping in the torsion mode becomes highly positive.

Such a bridge will not "flutter" at any speed, and has high aerodynamic damping in both bending and torsion modes. It can only become unstable in a static divergence mode, whose critical wind speed can be raised to any value by increasing the distance between the decks.

EXPERIMENT

The theoretical predictions of the aerodynamic forces on twin decks have been confirmed by tests on wind-tunnel models. Further tests on an aeroelastic section model with a wide range of transverse beam stiffnesses were then conducted. Very rigid beams gave the predicted divergence speed with high subcritical damping and no flutter. More flexible beams reduced the divergence speed, and very flexible beams led to independent flutter of the two decks as would be expected. These results are shown below.

The weight of beams sufficiently stiff to avoid significant reduction of the critical divergence speed can, however, be shown to be only a few percent of that of the superstructure.



REDUCTION OF DIVERGENCE SPEED DUE TO TRANSVERSE BEAM FLEXIBILITY AND COMPARISON WITH EXPERIMENT

PRACTICE

Various practical forms of twin bridge can be envisaged. A pair of supporting cables for each deck is the most likely configuration, with the transverse beams attached directly below the deck or connecting the four cables above it. Precise equality of the still-air bending and torsion frequencies has been shown by experiment to be unnecessary.

TRANSVERSE BEAM