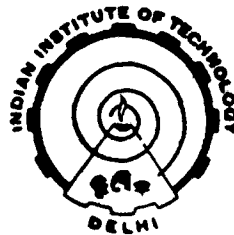


# **A NEW FINITE ELEMENT FOR NONPRISMATIC BOX GIRDER BRIDGES**

**By**  
**ARADHANA DHAWAN**  
**Department of Civil Engineering**

**THESIS SUBMITTED  
IN FULFILMENT OF THE REQUIREMENTS  
OF THE DEGREE OF  
DOCTOR OF PHILOSOPHY**

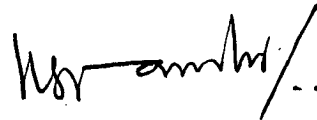


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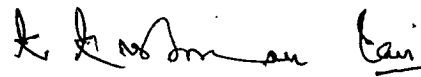
**CERTIFICATE**

This is to certify that the thesis entitled, "A NEW FINITE ELEMENT FOR NONPRISMATIC BOX GIRDER BRIDGES" being submitted by Ms. Aradhana Dhawan to the Indian Institute of Technology, Delhi for the award of Degree of Doctor of Philosophy in Civil Engineering is a record of bonafide research carried out by her. She has worked under my guidance and supervision and has fulfilled the requirements for the submission of the thesis.

The results contained in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any Degree or Diploma.



(K .Seetharamulu)  
Professor,  
Civil Engineering Department  
Indian Institute of Technology,  
Hauz Khas, New Delhi-110016



(K.K.Nayar)  
Professor,  
Civil Engineering Department,  
Indian Institute of Technology,  
Hauz Khas, New Delhi-110016.

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(Aradhana Dhawan)  
I.I.T., Delhi

## ABSTRACT

For straight bridges with prismatic crosssections, efficient methods have been developed both for simple and continuous bridges. Long span box girder bridges require a variation of depth to be economical. Although extensive literature is available for theoretical investigation of prismatic box girders, study concerning nonprismatic box girders use finite elements involving large degrees of freedom. Main objective of present investigation is to develop a method of analysis for deep nonprismatic box girder bridges. The matrix displacement method developed for general elastic analysis of nonprismatic box girder bridges uses a dedicated finite element with considerably reduced degrees of freedom. Because of the dedicated nature of finite element conforming to thin walled plate behaviour, the method requires reduced number of elements. Design of box girder bridge decks requires analysis for various load cases and a chosen train loading is moved laterally and longitudinally for arriving at envelope of critical stress resultants. In order to account for a large number of load cases, coefficient method is used. The coefficient method is illustrated by applying it to prismatic box girders based on harmonic analysis.

Coefficient Method, using harmonic analysis is developed which is based on idealising box girder as a folded plate. The

analytic solution is obtained by formulating a stiffness matrix considering 'slab action' and 'membrane action' independent of each other at member level. The applied train loading is substituted by harmonic loading to take into account three dimensional behaviour of the structure. Using stiffness method for analysis of box girders by harmonics, the values of deflections and stress resultants are calculated at various sections, for each load position at fold line only and for each harmonic individually. For a particular IRC loading, the loads on each wheel and coordinates of all wheels are specified. The amplitude of harmonic loading is calculated corresponding to each line of wheel loadings and is converted into harmonic loading. Plane frame analysis is done for transverse distribution of loading to nodal points (Fold lines) of the structure. Reactions are stored in an array. For every load position and different harmonics and number of sections, the values of stress resultant coefficients are multiplied by corresponding reactions from plane frame analysis to get deflections and stresses. Final deflections and stresses are obtained by superposition of various harmonics. Critical values of deflections and stress resultants are obtained as each IRC loading is moved transversely and longitudinally along the span.

A new 'inplane' finite element, is developed for the analysis of nonprismatic box girders. The new finite element represents a frame element with the addition of shear flow acting along its longitudinal edges. Accordingly, behaviour of new

finite element has been described by means of eight degrees of freedom. The inplane deformations are represented by the finite element, while a conventional folded plate slab element stiffness matrix (Scordelis,1964) is used to determine transverse deformations. The 'out of plane' elements used for slab degrees of freedom are separate and delinked from the ones used for inplane actions. The transverse degrees of freedom are placed on line of division between the nodes of the inplane finite element while the axis of slab element considered is coincident with the nodes of the new finite element. The slab nodes are thus considered to be coincident with the corner nodes of the new finite element used. The axial and inplane rotational degrees of freedom at the end nodes are transformed into two axial degrees of freedom 1 and 2 at the end corners of element to achieve compatibility between webs and flanges of the box girder.

Transfer matrix method is another method applied to prismatic box girder bridge analysis, (Seetharamulu,1970). It is particularly suitable for reinforced box girder bridges. With very small thickness of box girder, as adopted in steel box girders, this method is vulnerable to numerical instability. Number of unknowns are small as compared to even the stiffness method.

BEF analogy is another method applied to analyse single cell box girder bridges (Robinson, 1968 and Trikha, 1979). In this method, least amount of computational effort is required. BEF analogy is used for assessing nature of warping stresses

caused by distortional component of loading. The manual effort and computational effort are minimal. Numerical results obtained are used for validating the results obtained by the proposed approach.

The results from standard finite element software , ANSYS, have been used for validating the results of proposed new finite element method for nonprismatic box girders.

A knowledge base expert system is developed for a preliminary design of small to medium span bridge superstructures. Design decisions are primarily governed by Ministry of Surface Transport (1983) and Indian Roads Congress recommendations (1987). The information base from span and loading conditions is derived from bridges built in India (Madhya Pradesh Bridges, 1986). Based on span, number of traffic lanes, need for sidewalks or clearances, geometric configuration of bridge is decided by heuristic rules.

New finite element is proposed for the analysis of nonprismatic box girder bridges. Because of the dedicated nature of the element, the method requires lesser number of sections to analyse the structure. Method requires lesser input data. Coefficient method is recommended while using harmonic analysis for prismatic box girders. Typical design problems are solved to illustrate the method. The method is applicable for single as well as multicell box girder bridges. Transfer matrix method is reasonably satisfactory method for the analysis of reinforced concrete box girder bridges. This method can be used instead of

Direct Stiffness Method with considerable saving in execution time and effort for prismatic box girders. However for thin box girders, this method gives numerical instability.

BEF analogy is used for assessing the nature of warping stresses produced due to distortion. The Expert System presented assists the designer in the choice of bridge deck system and preliminary structural design of the chosen deck.

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