CHAPTER - 1

INTRODUCTION

1.1 General

The rapid development of the present day highway system together with the modernization and extension of urban motorways have led to the construction of a large number of bridges at complex interchanges and grade separations. The choice of a particular type of bridge for a fixed span is governed by varieties of factors, such as, functional, aesthetic , environmental and many more.

Box beam, both straight and curved in plan as a structural element, appears to have come into its own recently in many types of bridges. A box combines the advantages of lightness and stiffness in both bending and torsion. As a result, it has largely superceded the I-section, whether steel or concrete for long span bridges. Box section bridges have a strong aesthetic appeal with their closed form and pleasing contour. The search for bridge structures where the supporting piers of elevated highways could be unobstrusive in an urban environment has induced a large scale adoption of spine beam bridges. These are frequently referred to as cellular bridge decks and in practice, any number of cells may be used. A multicell deck is distinguished from a voided slab or pseudo slab in analysis in that, the local bending of the flanges should be considered in the cellular deck. The structural action of a box section is complex in nature and so also its analysis and design.

Another important class of bridges is the arch bridge that has come to be used from early times. Arches are used to support bridge decks in all types of span ranges, small as well as large, but often under conditions where there is required to be a large difference of level between the bridge deck and the land or water surface lying below it. In appearance, these bridges can be made graceful and pleasing to a degree unrivalled by any other form of bridge. The axial thrust, developed by reason of the resistance to spread offered by the abutments, reduces the bending moment. Owing to the reduction in bending moment for a particular span a comparatively shallower depth is required than with the more elementary type of bridges. If the width of the arch is considerable in transverse direction, it seems logical to treat it as a part of shell. The normal component of the external load is resisted by transverse forces (normal stresses) on the radial section, whereas the tangential component is resisted by shearing forces on the transverse section. The presence of these shearing forces distinguishes shell action from arch action. It is because of them, that the shell, regardless of its shape, can support any type of loading by direct stresses whereas an arch can carry, by direct stresses, only one type of loading.

1.2 Scope of the Present Investigation

This thesis presents an investigation into the use of closely associated finite difference technique for the analysis of bridge deck structures as a feasible alternative to the widely publicised finite element method. The analysis of box girder bridges with single cell and multicells, and an arch-slab bridge where the vault is treated as a cylindrical shell are taken up.

The principal contributions made in the thesis may be studied under the following major sections,

(a) Extension and application of Discrete Energy Method for the analysis of structures with particular reference to box girder and arch bridges.

(b) Experimental investigations of arch bridges through models.

1.2.1 Discrete Energy Method or Discrete Element Method

This method proposed by Buragohain (6)* is a modification of finite difference energy method which is found to be boundary dependent. Using Chuang's modified finite difference scheme (21) and introducing additional degrees of freedom in the form of slope of the normal to the boundary, to make the formulation independent of the boundary conditions, a systematic method known as Discrete Energy Method or Discrete Element Method (DEM) for the analysis of various structures is proposed.

The above method discretizes the total energy of the structures into energy due to extension and bending, and that due to shear and twisting, contributed by two separate sets of elements formed by a suitable finite difference network. The

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* Number in the parentheses indicates the reference given at the end.

derivatives in the corresponding energy expressions are replaced by their finite difference forms and the nodal displacements then constitute the undetermined parameters in the variational formulations. It is possible to join two adjacent panels of a plate by the use of displacement compatibility. To facilitate a systematic formulation and solution by the computer, a set of 'element matrices' are formed which are assembled in a manner similar to direct stiffness approach. Rest of the procedure follows the same steps as that of the conventional finite element displacement approach (97).

The formulation is extended to a cylindrical shell element of rectangular planform and some of the results of arch bridge analysis have also been checked by the use of the latter. In spite of thefact that this shell element has a stiffness matrix of size 9 x 9 only, it gives reasonably good results.

In order to test the degree of accuracy and workability of the method and the computer program developed in its connection, it was applied to a wide variety of problems which are appended below.

(i) Isotropic square plate for in-plane forces as shown in Fig.1.1 .

(ii) Isotropic square plate for concentrated and uniformly distributed load for various boundary conditions.

(iii) Orthotropic square plate for concentrated and uniformly distributed load.

(iv) Cylindrical shell (Fig.1.2) with

  - (a) circular directrix, with and without edge beams,
  - (b) parabolic directrix,
  - (c) elliplic directrix.

In the present investigation, the inherent potentiality of this method is fully exploited by its application to the analysis of a few box girder bridges and a broad arch bridge shown in Fig.1.3 and Fig.1.4 respectively.

1.2.2 Experimental Investigation

A search for relevant literature revealed an absence of full scale or small scale tests on arch slab bridges which would form a basis for comparison of the proposed method of analysis. On the other hand, several model tests on box girder bridges have been reported. It has therefore been decided to conduct additional experiments for broad arch bridges only. Since in actual practice, the broad arch bridges are generally made of reinforced concrete, mild steel mesh reinforced concrete models are used for experimental investigation.

The analysis of a broad arch bridge by finite element method is reported by Sabir (74). The same bridge was scaled down to approximately 18 : 1 ratio and models were cast accordingly.

Two models, one with the connection at crown between the deck slab and the vault, and the other without any connection between them, were tested within elastic limit to provide