

Ain Shams University
Faculty of Engineering

**EFFECT OF DIAPHRAGMS LOCATION
ON THE TORSIONAL AND DISTORTIONAL BEHAVIOR
OF R.C. CURVED BOX GIRDER BRIDGES**

By

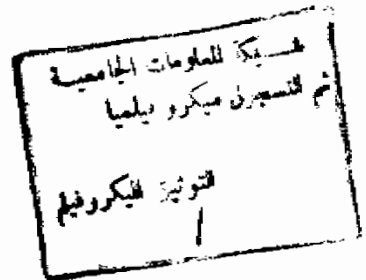
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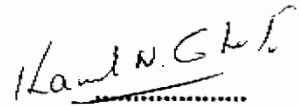
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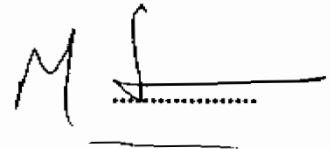
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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of PHILOSOPHY OF DOCTORAL in structural engineering.

The work included in this thesis was carried out by the author in the department of civil engineering (structural division), Ain Shams University, from January, 1989 to may 1994.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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To my Dear Prof. Dr. ***M.I. SOLIMAN***

MY FATHER

MY WIFE

AND MY DAUGHTER

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Abstract of the Ph.D. Thesis submitted by : Eng. Osama Hamdy Abdel-Wahed

**Title: EFFECT OF DIAPHRAGMS LOCATION ON THE TORSIONAL AND
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ABSTRACT

Because of its well-known structural advantages of torsional stiffness, the box girder has become a popular solution for short, medium and long span bridges. Dictated by the highway alignment layout and the site conditions, these bridges are usually curved in plan. If the radius of curvature is large compared with the span, a curved deck may be placed on a series of straight girders, and the design is essentially the same as that for the straight span. However, in cases where the radius of curvature is small, it will be more economical to have a curved structural system in which both the flanges and webs are curved horizontally.

Till recently, it has been the practice of designers to provide diaphragms in these box girders to improve the load distribution between girders, but often the position of the diaphragms has been determined arbitrarily rather than on any well-founded basis. The influence and behavior of these diaphragms in the curved reinforced concrete box girder bridges seem to have been misunderstood.

Therefore, the main purpose of the present research work is to investigate, experimentally and theoretically, the effect of the diaphragm locations on the torsional and distortional behavior of reinforced concrete curved box girder bridges. Also, the present work aims to investigate the effect of the warping restraint at the supports on the general deformational behavior, and the cracking of reinforced concrete curved box girder bridges from zero up to the failure load. A non linear F.E.A. will be formulated to consider the actual response of R.C. curved box girder bridges with different diaphragm locations. This will lead to a more realistic and economic design for this type of structures.

The results of this experimental - theoretical investigation are combined with other available information to formulate some recommendations for the analysis and design of this type of bridges.

Keywords: Diaphragms, Torsional, Distorsional, Box girder, Bridges, Warping, F.E.A

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INTRODUCTION

INTRODUCTION

General

Because of its well-known structural advantages of torsional stiffness, the box girder has become a popular solution for short, medium and long span bridges.

Reinforced concrete box girders or hollow girder type bridges were first used in Europe and North America forty years ago in an effort to develop new economical design and construction techniques in comparison with other types of concrete bridges.

Dictated by the highway alignment layout and the site conditions, these bridges are usually curved in plan. If the radius of curvature is large compared with the span, a curved deck may be placed on a series of straight girders, and the design is essentially the same as that for the straight span. However, in cases where the radius of curvature is small, it is more economical to have a curved structural system in which both the flanges and webs are curved horizontally.

It has been the practice of designers to provide transverse stiffeners, diaphragms, in these girders to improve the load distribution between girders, but often the position of the diaphragms has been determined arbitrarily rather than on any well-founded basis. The presence of diaphragms causes some additional dead load, but this effect is not likely to be a serious factor in the design. A more serious influence is the delay that arises in the casting cycle when the diaphragms have to be introduced.

The influence and behavior of these diaphragms in the curved reinforced concrete box girder bridges seems to have been misunderstood till recently.

Therefore, the main purpose of the present research work is to investigate the effect of the diaphragm locations on the torsional and distortional behavior of reinforced concrete curved box girder bridges. Also, the present work aims to investigate the effect of the warping restraint at the supports on the general deformational behavior, and cracking of R.C. curved box girder bridges from zero up to the failure load. A non linear F.E.A. is formulated to consider the actual response of R.C. curved box girder bridges with different diaphragm locations. This will lead to a more realistic and economic design for this type of structures.

The Specific Objectives of This Research Work are as Follows:

- 1- Investigate the effect of diaphragms location, on the following:
 - a) The general deformational behavior of the box section curved girders.
 - b) The cracking pattern and the crack propagation under the combined bending, shear, and torsion at different stages of loading up to the failure.
- 2- Study the effect of diaphragms locations on the torsional and distortional behavior of the box section curved girders.
- 3- Develop a nonlinear Finite Element Model which can define the complete nonlinear behavior of R.C. box curved girder through the load history, (from zero up to failure).

- 4- Compare the results of the Finite Element analysis with those obtained experimentally.

The Scope and Contents

The present study consists of seven chapters as follows :

Chapter (1) : Review of Previous Works.

This chapter includes the historical review of the development of the box girder bridge analysis, and a review of the most important previous research done in this field.

Chapter (2) : Experimental Work.

This chapter presents the experimental phase of the study which consisted of testing four horizontally curved reinforced concrete box girders of medium scale direct model. The overall external dimensions of these curved girders were 4.0 ms in radius and 3.08 ms arc length measured at the center line. The four curved girders had the same box dimensions and the same steel reinforcement. The girder box was taken 0.4 * 0.3 ms, while the thickness of the webs and the top and bottom slabs were 0.07ms. All these curved girders were loaded with an eccentric concentrated load at mid span sections, upon the outer web to provided the eccentric load which cause combined bending, shear, and torsion state of stresses.

All the experimental items including preparing, construction and testing, of the four models and the control specimens, and locations of measuring both the concrete and the steel strains and stresses are presented in this chapter.

Chapter (3) : Description of the Experimental Results.

In this chapter the results of the experimental work are presented as follows; The crack pattern of the tested girders, the cracking load, failure load, vertical deflections of top and bottom slabs, lateral deflections of loaded and unloaded webs, and the distribution of longitudinal and transverse concrete and steel stresses. Comparison between the results of the four curved R.C. box girders was also made.

Chapter (4) : Finite Element Modeling of Box Section Girder.

In this chapter the nonlinear finite element method which is used in analyzing the tested reinforced concrete box girders curved bridges is presented. Material non-linearity is introduced, such as; the nonlinear stress strain curve for concrete under multiaxial state of stress; cracking of concrete; and yielding of steel. The nonlinear finite element analysis is performed in an incremental manner.

Chapter (5) : Results of the Finite Element Analysis.

The analysis of the tested box section curved girders are carried out using the finite element program and the results are presented in this chapter. Comparisons are made between the results of the different box section curved girders to study the effect of changing the diaphragms location on the general deformational behavior of these curved girders.