EXTENDING INTEGRAL CONCEPTS TO CURVED BRIDGE SYSTEMS

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The behavior of integral abutment systems and the extension of their application to curved bridges are investigated. First, the stresses in the elements of a typical integral abutment are studied by conducting nonlinear finite element analysis using the software package Abaqus. The results are design recommendations for the details of such abutments. The effect of integral abutments on the responses of bridges is also investigated. Steel and concrete bridge systems are studied separately.

The studied steel bridge systems are composed of composite I-girder superstructures and integral abutments supported on steel H-piles. A series of finite element studies for different bridge lengths and radii are conducted and the effects of several load cases on the bridges are studied. In these bridges, the stresses in the abutment piles are of critical importance from the design standpoint. The results show that horizontal curvature mitigates these stresses. The bridge movement is also studied and a procedure to find the end displacements of curved bridges is presented. Pile orientation is another significant design factor that is studied elaborately. The results indicate that, for straight bridges, the strong-axis pile bending yields lower levels of stress. A method for finding the optimum pile orientation in curved integral bridges is developed. The effect of different bearing types is also investigated. This investigation reveals the superior structural performance of elastomeric bearings compared to other bearing types.

The concrete bridge systems that are studied consist of voided slab superstructures, integral abutments and concrete drilled shafts. A matrix of finite element studies is performed for different lengths and curvatures. Similar to steel I-girder bridges, it is concluded that horizontal curvature mitigates the internal forces of the abutment elements. The orientation of the concrete shafts is also examined which again shows the advantage of strong-axis orientation. Integral abutment bridges can have flexible piers integrally connected to the superstructure to eliminate all the bridge bearings. The effect of such integral piers on the internal forces of integral abutments is also examined. In these flexible piers, moment magnification can be of crucial significance. It is shown that choosing the integral abutment system reduces the magnification effects in the slender pier columns compared to jointed bridge systems.

Dedication

To

My wife Golboo

and

My daughter Taraneh

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Chapter 1

Introduction, Background and Objectives

1.1 Introduction

Bridges have been built since thousands of years ago by human beings. From prehistoric times to the Renaissance bridges had two main characteristics: The main construction materials were stone and natural cement and the spans were less than 100 feet. Despite the limitations that the architects and engineers of those times had, long bridges up to a total length of 1000 feet can be found among ancient bridges. After the Renaissance, modern bridges came into existence in the seventeen and eighteen century. The greatest differences of these modern bridges and the old ones were the material and span length. The material changed to iron (or steel) and later concrete. The span length gradually increased up to 3000 feet in the early twentieth century. So, the engineers were in charge of designing longer and longer bridges.

This trend in building bridges caused new approaches to appear in bridge industry. To accommodate the movements of long bridges, the designers adopted new techniques in

their designs. Moveable expansion joints and bearings were among those techniques. These devices have been used in bridges for more than 200 years. But, their performance has affected the long term performance of new bridges. Expansion joints have different designs which all of them have some sort of dysfunction. Even though they have high quality in the first months or years of service, after a longer time, most of them have problems such as leakage and poor ride quality due to wear or fracture. Bearings also have shown their intrinsic problems. In most bearing types, elastomeric layers are used. These elastomers lose their original properties in time. Ozone can damage the elastomer, even if there is no load or movement applied to the elastomer. That's why most of bearings should be replaced after some years.

The deficiencies of expansion joints and bearings drew the bridge designers to some new concepts of bridge design in the past years. Elimination of joints and bearings was the new target. This led to the introduction of a new type of structural system known as *Integral bridges*. These bridges are composed of:

- Abutments at the two ends
- Approach slabs that rest on abutments and their backfill
- Intermediate piers
- And finally a "*jointless"* superstructures built integral to the abutments

Note that there are no joints from the end to end of approach slabs. This bridge system is an ideal one which has no bearings and no joints. But, based on the needs, some other structural systems have also developed. First is an integral bridge that has rigid piers with movable and/or fixed bearings. In this type of bridges, all expansion joints and also the

abutment bearings are eliminated. But, piers still have bearings. If the durability of the pier bearings is guaranteed, these bridges can survive for a long time without any major deterioration. The second system has integral piers, but it has bearings in the abutments. In these bridges, the piers are flexible to be able to accommodate the movements, and the abutments are rigid, so they are isolated from the superstructure. A third system is a jointless bridge that has bearings both in the abutments and piers. Those jointless structural systems that have bearings in the abutments are called *semi-integral*. Table 1.1-1 shows different types of jointless bridges.

Bridge Type	Joint	Bearing over Piers	Bearing in Abutments
Integral with Flexible Piers	No	No	No
Integral with Rigid Piers	No	Yes	No
Semi-integral with Flexible Piers	No	No	Yes
Semi-integral with Rigid Piers	No	Yes	Yes

Table 1.1-1. Different Types of Jointless Bridges

As described before, integral bridges do not have joints whether they have bearings or not. Therefore, a better name for these bridges is "Jointless". These two terms have been used interchangeably in the literature and also in the present study. The integral bridges with no bearing in the abutments are sometimes called "integral Abutment Bridges". Figure 1.1-1 illustrates typical integral and semi-integral abutment details.