



**EVALUATING THE SAFETY LEVEL OF PRESTRESSED
CONCRETE BRIDGE GIRDERS DESIGNED USING
DIFFERENT INTERNATIONAL CODES**

By

Ehab Mamdouh Hanna Riad

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
STRUCTURAL ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

GIZA, EGYPT

2017

**EVALUATING THE SAFETY LEVEL OF PRESTRESSED
CONCRETE BRIDGE GIRDERS DESIGNED USING
DIFFERENT INTERNATIONAL CODES**

By

Ehab Mamdouh Hanna Riad

**A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of**

**MASTER OF SCIENCE
IN
STRUCTURAL ENGINEERING**

Under the supervision of

Prof. Dr. Walid Abdel Latif Attia

Professor

Structural Engineering Department

Faculty of Engineering

Cairo University

Dr. Gamal Helmy Hanna

Head of Bridge Dept.

Dar al-Handasah

Cairo, Egypt

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

GIZA, EGYPT

2017

**EVALUATING THE SAFETY LEVEL OF PRESTRESSED
CONCRETE BRIDGE GIRDERS DESIGNED USING
DIFFERENT INTERNATIONAL CODES**

By

Ehab Mamdouh Hanna Riad

A Thesis Submitted to the

Faculty of Engineering at Cairo University

In Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

IN

STRUCTURAL ENGINEERING

Approved by the Examining Committee

Prof. Dr. Walid Abdel Latif Attia (Thesis Main Advisor)

Professor of Structural Analysis and Mechanics

Structural Engineering Department, Faculty of Engineering, Cairo University

Prof. Dr. Gamal Helmy Hanna (Thesis Advisor)

Head of Bridge Dept.,

Dar al-Handasah,

Prof. Dr. Ahmed Hassan Amer

Professor of Structural Analysis and Mechanics

Structural Engineering Department, Faculty of Engineering, Cairo University

Prof. Dr. Hatem Hamdy Ghaith

Professor of Reinforcement Concrete

Housing & Building National Research Center

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

GIZA, EGYPT

2017

Engineer's Name: Ehab Mamdouh Hanna Riad

Date of Birth: 06/05/1986

Nationality: Egyptian

E-mail: ehab.hanna@hotmail.com

Phone: +20 - 01090021202

Address: 4. Bni Amer Street, Giza - Egypt

Registration Date: 1/10/2011

Awarding Date: 2017

Degree: Master of Science

Department: Structural Engineering

Supervisors: Prof. Dr. Walid Abdel Latif Attia

Dr. Gamal Helmy Hanna (Dar al-handasa -cairo)



Examiners:

Prof. Dr. Ahmed Hassan Amer

Prof. Dr. Hatem Hamdy Ghaith (Housing & Building National Research Center)

Prof. Dr. Walid Abdel Latif Attia

Dr. Gamal Helmy Hanna (Dar al-handasa -cairo)

Title of Thesis:

Evaluating the Safety Level of Prestressed Concrete Bridge Girders Designed Using Different International Codes

Key Words: CSiBridge; Eurocode; AASHTO LRFD code; Egyptian code; Prestressed Bridges

Summary:

The main aim of this study is to evaluate the safety level of bridge designed with the same dimension according to AASHTO LRFD code, Eurocode, and Egyptian code also evaluate the quantity of Prestressing required by each code. Prestressed concrete structures are typically designed to ensure that the initial and final stresses at service load conditions are within the allowable limits, each code (AASHTO LRFD, Eurocode, and Egyptian code) has different Prestressing requirements because there are considerable differences in the values of design live load specified by the three codes. A CSiBridge model has been used to to determine the maximum deflections, forces, and stresses, Several case studies investigated based on the Evaluating the safety level of prestressed concrete bridge girders designed using the three codes: Typical post-tensioned prestressed concrete T-girders used with different spans ranging from 25 to 40 m and multi-span cast-in-place concrete box bridges with variable spans 62-100-62m, 80-100-80m, 100-100-100m, 62-80-62m and 62-60-62m



حساب معامل الامان للكباري الخرسانية سابقة الاجهاد باستخدام المواصفات العالمية المختلفة

اعداد

ايهاب ممدوح حنا رياض

رسالة مقدمة إلى كلية الهندسة – جامعة القاهرة
كجزء من متطلبات الحصول على درجة ماجستير العلوم
في الهندسة الانشائية

كلية الهندسة، جامعة القاهرة
الجيزة – جمهورية مصر العربية
2017

حساب معامل الامان للكباري الخرسانية سابقة الاجهاد باستخدام المواصفات العالمية المختلفة

اعداد

ايهاب ممدوح حنا رياض

رسالة مقدمة إلى كلية الهندسة – جامعة القاهرة
كجزء من متطلبات الحصول على درجة ماجستير العلوم
في الهندسة الانشائية

تحت اشراف

أ.د. وليد عبد اللطيف عبد الجواد عطية

أستاذ تحليل و ميكانيكا الأنشاءات
قسم الهندسة الانشائية
كلية الهندسة – جامعة القاهرة

د. جمال حلمي حنا

رئيس قسم الكباري
شركة دار الهندسة

كلية الهندسة، جامعة القاهرة
الجيزة – جمهورية مصر العربية
2017

حساب معامل الامان للكباري الخرسانية سابقة الاجهاد باستخدام المواصفات
العالمية المختلفة

اعداد

ايهاب ممدوح حنا رياض

رسالة مقدمة إلى كلية الهندسة – جامعة القاهرة
كجزء من متطلبات الحصول على درجة ماجستير العلوم
في الهندسة الانشائية

يعتمد من لجنة الممتحنين:

أستاذ دكتور: وليد عبد اللطيف عبد الجواد عطية
أستاذ تحليل و ميكانيكا الإنشاءات
قسم الهندسة الانشائية، كلية الهندسة، جامعة القاهرة

أستاذ دكتور: جمال حلمي حنا
رئيس قسم الكباري
شركة دار الهندسة

أستاذ دكتور: احمد حسن عامر
أستاذ تحليل و ميكانيكا الإنشاءات
قسم الهندسة الانشائية كلية الهندسة، جامعة القاهرة

أستاذ دكتور: حاتم حمدي غيث
أستاذ الخرسانة المسلحة
المركز القومي لبحوث الاسكان و البناء

كلية الهندسة، جامعة القاهرة
الجيزة – جمهورية مصر العربية
2017



مهندس : ايهاب ممدوح حنا رياض

تاريخ الميلاد: 1986/05/06

الجنسية: مصري

تاريخ التسجيل: 2011/10/1

تاريخ المنح: 2017

القسم: الهندسة الإنشائية

الدرجة: ماجستير العلوم

المشرفون:

أ.د. وليد عبد اللطيف عبد الجواد عطية

د. جمال حلمي حنا (شركة دار الهندسة - القاهرة)

المتحنون:

أ.د. احمد حسن عامر

أ.د. حاتم حمدي غيث (المركز القومي لبحوث الاسكان و البناء)

أ.د. وليد عبد اللطيف عبد الجواد عطية

د. جمال حلمي حنا (شركة دار الهندسة - القاهرة)

عنوان الرسالة: حساب معامل الامان للكباري الخرسانية سابقة الاجهاد باستخدام المواصفات العالمية المختلفة

الكلمات الدالة:

CSiBridge ، الكود الاوروبي ، الكود الامريكي ، الكود المصري ، الكباري سابقة الاجهاد

ملخص الرسالة:

هذا البحث يسلط الضوء علي حساب معامل الامان للكباري الخرسانية سابقة الاجهاد باستخدام المواصفات العالمية المختلفة (الكود المصري والاوروبي والامريكي) من خلال حساب كمية الكبلات اللازمة لتحقيق معامل الامان طبقا لكل مواصفة. حيث يتم تصميم المنشآت الخرسانية سابقة الإجهاد للتأكد من أن الاجهادات الأولية والنهائية في ظروف التحميل هي ضمن الحدود المسموح بها طبقا لاشتراطات كل مواصفة. حيث تختلف اشتراطات معامل الامان باختلاف قيمة الاحمال الحية المحددة بواسطة كل كود. و قد تم استخدام برنامج التحليل الانشائي csi bridge للحصول علي الاجهادات و القوي المختلفة اللازمة لتصميم القطاعات المختلفة لكل كوبري و تحديد كمية الكبلات اللازمة فقد تم دراسة اكثر من نوع للكباري (الكباري بسيطة الارتكاز و الكباري المستمرة) فمن حيث دراسة الكباري بسيطة الارتكاز المكونة من الكمرات سابقة الاجهاد تم استخدام ببحور تتراوح من 25 م الي 40 م و من حيث دراسة الكباري المستمرة ذات القطاعات الصندوقية (box section تم تغيير البحور الخارجية مرة ثم تغيير البحر الداخلي مرة اخري 80-100-80م، 100-100-100م، 62-100-62-62م، 62-80-62م، 62-62-62م، و قد تم عمل مقارنة بين كمية الكبلات اللازم استخدامها لتحقيق معامل الامان لكل مواصفة من المواصفات الثلاثة

Acknowledgments

I would first like to thank my thesis advisors Prof.Dr Walid Abdel Lattif Attia and Dr gamal helmy for their great effort in this research

CHAPTER 1.....	1
INTRODUCTION.....	1
1.1 Topic overview.....	1
1.2 Objective.....	1
1.3 Scope of Work.....	1
1.4 Thesis organization.....	2
CHAPTER 2.....	3
LITERATURE REVIEW AND PREVIOUS WORK.....	3
2.1 Introduction.....	3
2.2 Issue and consideration for the development of AASHTO LRFD criteria	3
2.3 Development and implementation of Eurocode.....	5
2.4 Development and implementation of Egyptian Code	6
2.5 Literature review and previous work.....	6
CHAPTER 3.....	9
COMPARISON BETWEEN CODES.....	9
3.1 Live Load.....	9
3.1.1 Live Load according to AASHTO LRFD(2014) (HL-93 Loading).....	9
3.1.2 Live Load according to EUROCODE (EN1991-2:2003).....	11
3.1.3 Live Load according to Egyptian CODE (ECP-201:2012).....	14
3.2 Allowable concrete Stress.....	16
3.3 Losses of prestressing.....	18
3.3.1 Immediate losses	18
3.3.2 Time dependent losses.....	20
3.4 Ultimate moment capacity	25
3.4.1 Equivalent stress block	25
CHAPTER 4.....	26
CASE STUDIES AND THE DESCRIPTION OF THE FINITE ELEMENT MODELS	26
4.1 Introduction.....	26

4.1.1	Analysis Features	26
Case study 1		27
FINITE ELEMENT MODELS DESCRIPTION		29
4.2	Case study 2 (Khurais Main Bridge)	30
FINITE ELEMENT MODELS DESCRIPTION		32
CHAPTER 5.....		37
Comparisons and Discussion of Results.		37
5.1	Case study 1 (single span bridge).....	37
5.2.1	Span 25m	37
5.2.2	Span 30m	42
5.2.3	Span 35m	49
5.2.4	Span 40 m	55
5.2	Effect of span length changes	61
5.2.1	Comparison of moments.....	61
5.2.2	Number of prestress strand	64
5.3	Case study 2 (multi-span bridge)	65
5.3.1	Span 62-100-62m.....	65
5.3.2	Span 62-80-62m.....	74
5.3.3	Span 62-60-62m.....	78
5.3.4	Span 80-100-80m.....	82
5.3.5	Span 100-100-100m	86
5.4	Effect of span length changes	91
5.4.1	Comparison of moments.....	91
5.2.3	Number of prestress strand	93
CHAPTER 6.....		94
SUMMARY, CONCLUSION AND RECOMENDATIONS		94
6.1	Summary.	94
6.2	CONCLUSION.....	94
6.3	RECOMMENDATIONS FOR FUTURE STUDIES	95

Abstract

The main aim of this study is to evaluate the safety level of bridge designed with the same dimension according to AASHTO LRFD code, Eurocode, and Egyptian code also evaluate the quantity of Prestressing required by each code. Prestressed concrete structures are typically designed to ensure that the initial and final stresses at service load conditions are within the allowable limits, each code (AASHTO LRFD, Eurocode, and Egyptian code) has different Prestressing requirements because there are considerable differences in the values of design live load specified by the three codes. A CSiBridge model has been used to to determine the maximum deflections, forces, and stresses, Several case studies investigated based on the Evaluating the safety level of prestressed concrete bridge girders designed using the three codes: Typical post-tensioned prestressed concrete T-girders used with different spans ranging from 25 to 40 m and multi-span cast-in-place concrete box bridges with variable spans 62-100-62m, 80-100-80m, 100-100-100m, 62-80-62m and 62-60-62m

List of Figures

Figure 3.1 Characteristics of Design Truck, HL-93-AASHTO LRFD (2014)

Figure 3.2 Design Live Load in AASHTO LRFD (2014) HL-93

Figure 3.3 - Application of load Model 1

Figure 3.4 - Application of tandem systems for local verifications

Figure 3.5 Load Model 1 of vehicular live load according to ECP-201:2012 (dimensions are in m).

Figure. 4.1. Dimensions of typical T-girder sections studied.

Figure. 4.2. Cross-section of bridge deck studied

Figure 4-3 3D finite element model for the concrete bridge girders used in the present

Fig (4-4): photography of main Khurais Bridge during construction

Fig (4-5): Typical carriageway Main Bridge deck cross sections

Fig (4-7): 3D finite element model for the Khurais bridge used in the present study

List of Tabels

Table 3.1 Load model 1: characteristic values

Table5-1 Unfactored moment per girder due to dead load (D1), superimposed dead load (D2) and live load (D3) (t.m/m)

Table 5-2 Results of Design According to service limit state for span 25m

Table 5-3 Results of Design According to service limit state for span 30m

Table 5-4 Results of Design According to service limit state for span 35m

Table 5-4 Results of Design According to service limit state for span 40m

Table5-6 Un-factored moment due to live load according to AASHTO, Egyptian and Eurocode span 62-100-62

Table5-7 Un-factored moment due to live load according to AASHTO, Egyptian and Eurocode span 62-80-62

Table5-8Un-factored moment due to live load according to AASHTO, Egyptian and Eurocode span 62-60-62

Table5-9 Un-factored moment due to live load according to AASHTO, Egyptian and Eurocode span 80-100-80

Table5-10 Un-factored moment due to live load according to AASHTO, Egyptian and Eurocode span 100-100-100

CHAPTER 1

INTRODUCTION

1.1 Topic overview

One of the particular forms of reinforced concrete is the prestressed concrete. Prestressing includes applying an initial compressive axial load on a structure to reduce or eliminate the internal tensile forces and thereby control or minimize cracks. The initial compressive force is applied and sustained via using highly tensioned steel strands applied on the concrete. A prestressed concrete section is considerably stiffer with cracking reduced or eliminated than the equivalent (usually cracked) reinforced section.

In the modern transportation system highway bridges have a crucial role and the safety of their designs and overall quality of construction is ensured by certain design specifications. There are many specifications all over the world that the bridge engineers can use, where as some countries have their own bridge design specifications such as American Association of State Highway and Transportation Officials Load and Resistance Factor Design (AASHTO LRFD) code in United States, Eurocode in Europe, and Egyptian code in Egypt.

1.2 Objective

The main aim of this study is to evaluate the safety level of bridge designed with the same dimension according to AASHTO LRFD code, Eurocode, and Egyptian code also evaluate the quantity of Prestressing required by each code. Prestressed concrete structures are typically designed to ensure that the initial and final stresses at service load conditions are within the allowable limits, each code (AASHTO LRFD, Eurocode, and Egyptian code) has different Prestressing requirements because there are considerable differences in the values of design live load specified by the three codes.

1.3 Scope of Work

Evaluating the safety level of prestressed concrete bridge girders designed using three codes: AASHTO LRFD Code, BS EN1992-2:2005 Code and the Egyptian Code through a comparison of the required number of Prestressing strands. Typical post-tensioned prestressed concrete T-girders used with different spans and a three-span, cast-in-place concrete box Girder are considered. Both the service limit state and the strength limit state are taken into account in the study