UNIVERSITI PUTRA MALAYSIA

EFFECT OF TORSION ON EXTERNALLY PRESTRESSED SEGMENTED BOX BRIDGE GIRDER

MOHAMMED ABDULLA ISMAIL AL-GORAFI

FK 2011 158

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By
MOHAMMED ABDULLA ISMAIL AL-GORAFI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

January 2011

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DEDICATION

To My God

My country and

Family

I Dedicate This Work

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Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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MOHAMMED ABDULLA ISMAIL AL-GORAFI

January 2011

Chairman: Professor Ir. Abang Abdullah Abang Ali

Faculty : Engineering

Externally Prestressed Segmented (EPS) concrete box bridges are widely used in the construction of bridge structures today. EPS has also become an attractive tool for rehabilitation and strengthening of existing structures with insufficient strength and/or excessive deflection and cracking.

The behaviour of externally prestressed segmented bridge has been studied under either shear force or combined bending moment and shear forces only. No extensive research work has been carried out so far to study the effect of combined bending, shear force, normal force and torsion on the structural behaviour of these bridges. Therefore, there is a need to focus on this area; and hence, both analytical and experimental investigation need to be carried out to study the behaviour of EPS box bridge under combined bending, shear, normal force and torsion.

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The key objective of the research was to obtain a better understanding of the behaviour of externally prestressed segmented box bridge girders under combined loading, and to study the significance of torsion in the overall response. The research was also intended to study the effect of joint opening on the overall response of the bridge. In addition, this research aims at proposing a formula to estimate the failure load of EPS bridge girders under combined loading, since no design code provides a formula to estimate the load capacity of EPS bridges under such loading condition.

The scope of this study was limited to determining deformation characteristics, strain variation, onset point of nonlinearity load, failure load and failure mechanism. The effect of different parameters studied include joint type (flat and with shear key) and tendon layout (harp and straight). There were three different load cases: without torsion, and with torsion imposed by different load eccentricities.

To achieve these objectives, 12 specimens of externally prestressed segmented box bridge girders were tested. In addition, Finite Element (FE) analysis was conducted on a some of these girders using ANSYS finite element package. Three different types of elements (cube element, interface element and link element) were used in the FE analyses. Both geometric and contact nonlinearities were incorporated. The result of adopted Finite Element analysis was verified twice, once with the result of real bridge (in Bangkok), and another with the results of adopted experiments. So, the result of FE shown that the FE modelling can be used to simulated.

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This research was conducted for a better understanding of the behaviour of externally prestressed segmented bridges under combined loading. The results indicated that torsion has a significant effect on EPS bridges. Torsion not only reduces the value of failure load but also affects the failure mechanism. It was concluded that the contact nonlinearity due to joint opening affected the behaviour of EPS bridges. Finally, a formula was proposed to estimate the failure load of EPS beams.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN PUNTIRAN KE ATAS RASUK PRATEGASAN LUARAN JAMBATAN KOTAK BERSEGMEN

Oleh

MOHAMMED ABDULLA ISMAIL AL-GORAFI

Januari 2011

Pengerusi: Profesor Ir. Abang Abdullah Abang Ali

Fakulti : Kejuruteraan

Jambatan konkrit kotak bersegmen prategasan luaran (EPS) banyak digunakan di dalam pembinaan struktur jambatan hari ini. EPS juga menjadi alat yang diminati untuk memelihara dan memperkuatkan struktur sedia ada yang mempunyai kekuatan yang kurang dan/atau ubahbentuk berlebihan dan keretakan.

Sifat jambatan bersegmen berprategasan luaran di bawah samada daya ricih atau momen lenturan dan daya ricih sahaja sudah diselidiki. Setakat ini tiada kerja penyelidikan lanjutan dijalankan untuk mengkaji kesan kombinasi lenturan, daya ricih, daya paksi dan puntiran ke atas kelakuan struktur jambatan begini. Oleh sebab itu, adalah perlu untuk fokus ke arah bidang ini dan dengan itu kedua-dua penyiasatan analitikal dan ujikaji hendaklah dijalankan untuk mengkaji kelakuan jambatan kotak EPS di bawah kombinasi lenturan. ricih, daya normal dan puntiran.

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Objektif utama kajian ini adalah untuk mendapatkan pemahaman yang lebih baik tentang kelakuan rasuk jambatan bersegmen berprategasan luaran di bawah beban kombinasi dan untuk mengkaji pentingnya puntiran terhadap atas tindakbalas keseluruhan. Kajian ini juga bertujuan untuk mencadangkan formula untuk menganggarkan beban gagal rasuk jambatan EPS di bawah kombinasi beban, disebabkan tiada lagi sebarang kod rekabentuk menyediakan formula untuk menganggarkan kapasiti beban jambatan EPS di bawah keadaaan beban ini.

Skop kajian ini dihadkan dalam menentukan ciri ubahbentuk pembezaan terikan, titik onset bagi beban tidak linear, beban gagal dan mekanisme kegagalam. Kesan parameter berlainan juga diselidiki termasuk jenis sambungan (rata atau dengan kunci ricih) dan hamparan tendon (melengkung dan lurus). Ianya mempunyai tiga kes beban berlainan: dengan tiada puntiran dan dengan puntiran dikenakan melalui kesipian beban berlainan. Untuk mencapai objektif ini, 12 rasuk jambatan kotak bersegmen berprategasan luaran telah diuji. Sebagai tambahan, analisis unsur terhingga rasuk ini juga dijalankan menggunakan pakej unsur terhingga ANSYS untuk mengesahkan keputusan. Tiga jenis unsur (unsur kiub, unsur antaramuka dan unsur pengikat) telah digunakan di dalam analisis unsur terhingga. Kedua-dua geometrik dan ketidaklinearan persentuhan digunakan dan keputusan dibandingkan dengan keputusan eksperimen.

Kajian ini dijalankan untuk memahami dengan lebih baik kelakuan jambatan bersegmen prategasan luaran di bawah beban kombinasi. Hasil kajiam menunjukkan bahawa puntiran mempunyai kesan yang signifikan kepada jambatan EPS. Puntiran bukan

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sahaja mengubah nilai beban gagal tetapi juga memberi kesan kepada mekanisme kegagalan. Dapat dirumus bahawa ketidaklinearan persentuhan yang disebabkan pembukaan membawa kesan kepada kelakuan jambatan EPS. Akhir sekali, satu formula dicadangkan untuk menganggar beban gagal rasuk EPS.

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ACKNOWLEDGEMENTS

The author would like to express his deepest gratitude to his supervisor Dato. Prof. Abang Abdullah Abang Ali for his kind supervision, guidance, support and valuable suggestions.

Many thanks go to. Prof. Dr. Mohd. Saleh Jaafar for his encouragement and the great facilities he has provided to complete this work in a proper and convenient manner.

Furthermore, great deal of thanks and sincere appreciation goes to Assoc. Prof. Dr. Ismail Othman for his support, encouragement, constitute comments and criticisms towards this project and most importantly for his patience.

Many thanks go to Dr. Mohammed Parvez Anwar for his encouragement and the great facilities he has provided to complete this work in a proper and convenient manner.

To all his colleagues, friends and Mr. Halem and all technicians , the author would like to express his gratitude for their assistance and support throughout the duration in completing this study.

Finally, special and immense thanks goes to the author's wife, for being very patient and for sharing the frustrating moments with him.

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I certify that an Examination Committee has met on 25th May 2009 of viva to conduct the final examination of Mohammad Abdulla Ismail Al-Gorafi on his Doctor of Philosophy thesis entitled " Effect of Torsion on Externally Prestressed Segmented Box Bridge Girder" in accordance with Universiti Pertanian Malaysia (Higher degree) Act 1980 and Universiti Pertanian Malaysia (Higher degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Bujang Bin Kim Huat, PhD
Professor
Faculty of Engineering,
Universiti Putra Malaysia
(Chairman)

Jamalodin Noorzaei, PhD
Associate Professor
Faculty of Engineering,
Universiti Putra Malaysia
(Internal Examiner)

Ratnasamy Muniandy, PhD
Associate Professor
Faculty of Engineering,
Universiti Putra Malaysia
(Internal Examiner)

Wan Hamidon Hj. Wan Badaruzzaman, PhD
Professor
Faculty of Engineering,
(Independent Examiner)

_____
SHAMSUDDIN SULAIMAN, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the supervisory committee were as follows:

Abang Abdullah Abang Ali, Prof
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohd Saleh Jaafar, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Ismail Othman, PhD
Associate Professor
Faculty of Engineering
University Of Malaya
(Member)

_____
HASANAH MOHD GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or any other institution.

_____

MOHAMMED A. AL-GORAFI

Date: 26 January 2011

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