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SPLICE SYSTEM IN EXTENDING THE PRECAST PRESTRESSED CONCRETE BEAM SPAN

MOHD NASIR BIN KAMAROL ZAKI

A project report submitted in partial fulfilment of the
requirement for the award of the degree of
Master of Engineering (Civil – Structure)

Faculty of Civil Engineering
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NOVEMBER 2009

I declare that this project entitled "Splice System in Extending the Precast Prestressed Concrete Beam Span" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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“This study is especially dedicated to my beloved Mommy and Daddy
Brothers, Friends,
for everlasting love, care, and supports…..”

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ABSTRACT

This project focuses on the use of splicing precast concrete beams to extend their span length. Precast prestressed concrete beams are economical solutions for many bridges, due to various restrictions such as weight and hauling length they are rarely used for spans greater than 40 m. This project was initiated by collecting the information from internet and technical reports of some bridge projects that have used spliced beam system. The experimental work has been carried out on three beams of 2.5 m span with different location of splice loaded to fail. The type of splice beam system used consisted of precast pretensioned beam joint together by post-tensioned method. The experimental results show the development at shear failures inclined the depth opposed with initial prediction to fail in flexure. Both spliced beam has achieved the ultimate load capacity. On the other hand, the actual load capacity for controlled beam was twice times higher than calculated. From this research, base on ultimate load failure, the spliced system applied for double spliced beam has succeeded to perform as calculated nominal beam. However, since the actual controlled beam perform better, and the splice beam fail unexpectedly in shear, the future research should focusing on the materials, location and type of splice section to improve the present research.

ABSTRAK

Projek ini menfokuskan kepada penggunaan sistem sambungan kepada rasuk konkrit prategasan untuk memanjangkan rentangnya. Ketika rasuk prategasan menjadi penyelesaian ekonomikal untuk pelbagai projek jambatan, namun kerana halangan seperti had berat dan panjang maksima di atas jalan raya, sistem ini menghadapi masalah untuk rentang melebihi 40 m. Projek ini berasaskan kepada pengumpulan maklumat dari internet dan laporan teknikal beberapa projek jambatan yang menggunakan sistem sambungan. Eksperimen telah dijalankan ke atas tiga rasuk 2.5 m dengan berbeza bilangan bahagian sambungan yang dikenakan beban secara berkala sehingga gagal. Jenis sambungan yang diaplikasi pada spesimen rasuk dalam ujian makmal adalah sistem pratuang prategasan yang dicantumkan dengan kaedah tegangan. Keputusan eksperimen menunjukkan kegagalan ricih lebih ketara pada garisan sambungan bertentangan dengan jangkaan awal agar ia gagal dalam lenturan. Rasuk yang mempunyai dua sambungan melepasi kapasiti beban maksima. Pada masa yang sama, rasuk yang dikawal gagal pada nilai dua kali ganda daripada nilai jangkaan. Berdasarkan kiraan kegagalan beban maksima, adalah didapati, rasuk yang mengaplikasi sistem sambungan ini berjaya bertindak seperti rasuk monolitik biasa. Namun, memandangkan rasuk kawalan sebenar bertindak jauh lebih baik daripada segi nilai kegagalan dan rasuk bersambungan gagal pada jenis ricih, kajian pada masa depan perlu menumpukan pada bahan, lokasi dan jenis sambungan yang lebih baik berbanding kajian sedia ada.

TABLE OF CONTENT

2 LITERATURE REVIEW

3 RESEARCH METHODOLOGY

4 FINDINGS AND SURVEYS

5 RESULT FROM LABORATORY TESTING

6 CONCLUSION AND RECOMMENDATION

REFERENCES

APPENDIX

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

α - Coefficient of short term losses.

β - Coefficient of long term losses.

A_{ps} - Area prestressing tendon (mm^2)

A_s - Area of strands (mm^2)

b_v - Breadth of the member (mm)

d - Effective depth (mm)

d_n - Depth to the centroid of compression zone (mm)

e - Eccentricity of the prestressing steel (mm)

f_{ci} - Concrete strength at transfer (N/mm^2)

f_{cu} - Concrete strength at service (N/mm^2)

f_{ct} - Flexural compressive stresses (N/mm^2)

f_{tt} - Flexural tensile stresses (N/mm^2)

f_{cp} - Design compressive stress at the centroidal axis due to prestress (N/mm^2)

f_{pu} - Tensile strength of strand (N/mm^2)

f_t - Maximum design principal tensile stress (N/mm^2)

f_{cp} - Design compressive stress at the centroidal axis due to prestress (N/mm^2)

f_{pe} - Design effective prestress in the tendons after losses (N/mm^2)

F_{bst} - Bursting force (kN)

h - Height of section (mm)

h_f - Height of flange section (mm)

I - Moment of inertia of the section (mm^4)

L - Length (m)

M_o - Moment necessary to produce zero stress in the concrete at the extreme tension fibre. (kNm)

Mu - Ultimate moment (kNm)

n - Number of strand

P - Prestressing force (kN)

V_c - Shear resistance of the concrete (N/mm^2)

V_{cr} - Shear resistance of a section cracked in flexure (N/mm^2)

y_o - Half side of the end block (mm)

y_{po} - Half side of the loaded area (mm)

z_1 - Section modulus of top fibre (mm^3)

z_2 - Section modulus of bottom fibre (mm^3)

LIST OF APPENDICES

APPENDICE	TITLE
A	Questionnaire for the Thesis
B	Bridge Detailing for Railway Overpass Bridge, Kg Aur Lipis, Pahang
C	Specimens Design Calculation
D	Detailing of Specimens
E	Ultimate Load Test Result

CHAPTER 1

INTRODUCTION

1.1 Introduction

A prestressed concrete structure has many advantages, such as delaying cracks, saving materials, reducing deflection, and has been widely or increasingly used in long span structures (Lin and Burns, 1982). However, these beams are still used infrequently for spans in excess of 40 meters. This upper limit of practical application exists for several reasons, including material limitations, structural considerations, size and weight limitations on beam shipping and handling and a general lack of information and design aids necessary to design longer spans using concrete beams.

Some designers, fabricators and contractors, however have successfully collaborated to extend span lengths for precast prestressed concrete beams to distances greater than 40 meters and expand their use to other applications not normally associated with precast prestressed concrete beam construction. Unfortunately, the methods used only for specific job, and the knowledge gained has not made widely available to use in similar projects.

1.2 Problem Statements

Among the issues faced by the engineers on design stages such as the needs to eliminate piers for safety, reducing the number of substructure unit to avoid certain unstable soil foundation, improve the aesthetics and minimize the structure depth

During construction, there are various issues especially for long span beam and involving large full-span beam. These will resulting problems in fabrication and handling, transportation, erection, access to the site, fabricator`s facility and contractor`s equipment.

Economical issues are priority in all construction. The issues on reduction of construction costs, reduction of fabrication time and also cost for temporary support system on the nominal structures are among the challenges for the engineers.

Figure 1.1: Length and weight limits on precast beams lead to splicing for longer spans

1.3 Objectives

The main focus of this research was to address issues related to the design and construction of spliced precast prestressed concrete beam. The products of this research project include the following:

a) To investigate the options used for extending span ranges of precast prestressed concrete beam current projects and data.

b) To demonstrate the effectiveness of spliced beam method through the smaller scale laboratory work.

c) To examine the cracking type and failure occur in spliced beam system.

1.4 Research Scopes

The literature review and information address the full spectrum of possible approaches for extending the span ranges of precast prestressed concrete beams. Although this wide focus was retained for portions of the research, it was determined that narrowing the focus of the study would provide the greatest benefit. This decision was based on the following findings from the early stages of the research:

a) Most of the techniques and approaches for extending span ranges involve incremental changes in conventional design methods and materials. These changes generally result in relatively small increases in the span range for precast prestressed concrete beams. Information required to implement these techniques is generally available in the literature or from commercial sources.

b) One technique, the splicing of beams, was found to allow significantly increased span ranges for precast prestressed concrete beams bridges. This technique involves the fabrication of the beams in segments that are then assembled into the final structure. Although many spliced beam bridges have been constructed, the use of this technique is not widespread. Use of this technology also requires consideration of various issues with which the designer of conventional precast prestressed concrete beams typically is not familiar. Furthermore, the information available in the literature regarding the implementation of spliced beam construction is limited.

c) The laboratory work consist smaller scale precast prestressed concrete beams with a splice section.

d) The issues regarding this research were from Public Work Department (PWD), fabricator and main player of precast prestressed concrete industry, Hume Engineering Sdn. Bhd and ACPI Sdn. Bhd.

Based on these findings, it was determined that the main focus of this study would be to address issues related to splicing method in extending span for prestressed concrete beam.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Design options for extending span ranges of precast prestressed concrete beams are summarized in this section. Several of research also been carried out regarding this matter and enhancing the strength of beam`s flexural resistance itself.

Fu and Kudsi (2000), have come with a survey and approach in enhancing the joint on the piers to make a simply supported beam as continuous. It concluded that many engineers think that positive moment connections are needed to control cracking in the diaphragm and to provide continuity. However, this method was not eliminating the existence of piers besides extending the existing span.

2.2 Design Options for Extending Spans

There are wide variety of design options were identified that can be used to extend span ranges of precast prestressed concrete beams. The variety of identified design options is the result of differences in experience, equipment, site constraints, and other conditions. The design options identified for extending spans vary significantly in degree of complexity, effectiveness, and practicality. It was found that combining several design options may prove more effective than using the design options alone. Some design options listed may not be feasible in all areas or they may fail to produce a significant economical advantage for a particular set of circumstances. Therefore, designers are encouraged to consult with owners, fabricators, and contractors before implementing extended-span design options to ensure that the use of a selected option will offer the potential for greater economy without introducing unmanageable risk, uncertainty, or adverse effects. The design options identified are divided into four groups (Rigoberto, 2001):

a) Material-related options,
b) Design enhancements,
c) Methods utilizing post-tensioning, and
d) Spliced beam construction.

2.2.1 Material-Related Options

Design options for extending span ranges related to material properties can usually be implemented with standard design procedures and software. The enhancements should be prior to prevent cracks and improve the properties of the span. For instance, field inspections and a recent study report (Shing and Abu Hejleh ,1999) showed that the cracking problem of bridge decks in Colorado has not been completely resolved, and therefore, there is a pressing need for further improvement of the concrete mix designs to concrete bridge decks.

a) **High-Strength Concrete -** High-strength concrete (HSC) has been used successfully to extend the span ranges of precast prestressed concrete bridge beam bridges. It is generally used to the greatest advantage in beams, but may also be used in decks. Through adopting high strength concrete, prestressed concrete bridge can increase span, decrease self-weight, reduce prestress loss, and so on (Frenzh C ,2008).

Haibo Liu et al. (2007) applying the high strength concrete and fiber reinforced concrete into prestressed concrete continuous beam. From the results of mid-span deflection, it concluded that the presence of steel fiber in the negative moment zone can improve the structural stiffness after cracking for the fully prestressed high strength concrete beam. With the increment of amount of reinforcement bars, this effect decreases gradually.

b) **Specified Density Concrete -** Specified density concrete (SDC) has been used to reduce design loads to extend span ranges of precast prestressed concrete bridge beam bridges, but has also been used to reduce the shipping weights to facilitate use of longer beams. SDC may be traditional lightweight concrete, or it may be used to reduce the unit weight of the concrete as required for shipping.

Wahid Omar (2002) have come out with a test results show that lightweight concrete using clinker exhibit an almost similar pattern in cracking behaviour and failure modes. The test results show that the prestressed lightweight concrete beams can resist loading up to 90 percent of the normal prestressed concrete beams.

c) **Increased Strand Size -** The use of a larger strand size at the same strand spacing improves the efficiency of pre-tensioned beams. This design option frequently is combined with HSC to obtain a significant increase in beam spans. Standard strand sizes must still be used.

d) **Increased Strand Strength -** Strand producers have been developing strands with strengths of 300 ksi or greater. Increased strand strength, accompanied with a proportional increase in initial strand stress, will increase span ranges for precast prestressed concrete beams.

e) **Decks of Composite Materials -** In recent years, several concepts have been introduced for using composite materials, typically developed in the defense industry, for the construction of highway bridge decks. Although several important issues remain to be addressed, bridge decks, constructed using composite materials may be used to extend span ranges of precast prestressed concrete beams by significantly reducing the weight of the deck structure.

2.2.2 Design Enhancements

Several design options for extending span ranges are related to modifications or enhancements of design parameters or procedures. In most cases, these methods can be implemented with standard design procedures and software.

a) Modified Standard Beam Sections - A wide variety of options exist for modifying existing beam cross sections to extend span ranges of precast prestressed concrete beams. These include the following:

i) Moving side forms in or out to reduce section weight or increase section properties;

ii) Increasing the depth of the bottom flange to add a row of strands;

iii) Increasing the depth of a beam section for increased section properties;

iv) Increasing the width of the top flange to reduce deck forming, improve lateral stability of the beam for handling and increase section properties;

v) Casting some or all of the deck with the beam, this improves efficiency of prestressing and allows for more rapid construction by eliminating deck forming. This type of section is called a "decked bulb tee."

Megally et al. (2002) investigated two precast segmental bulb tee beams. The joint of the first beam was epoxy-bonded with no reinforcement other than prestressed tendons. The second beam had reinforced in situ deck closure joints. Both tested beams experienced significant seismic displacement under reversed cyclic loading without failure, and no shear failure in the joints was observed in the test.

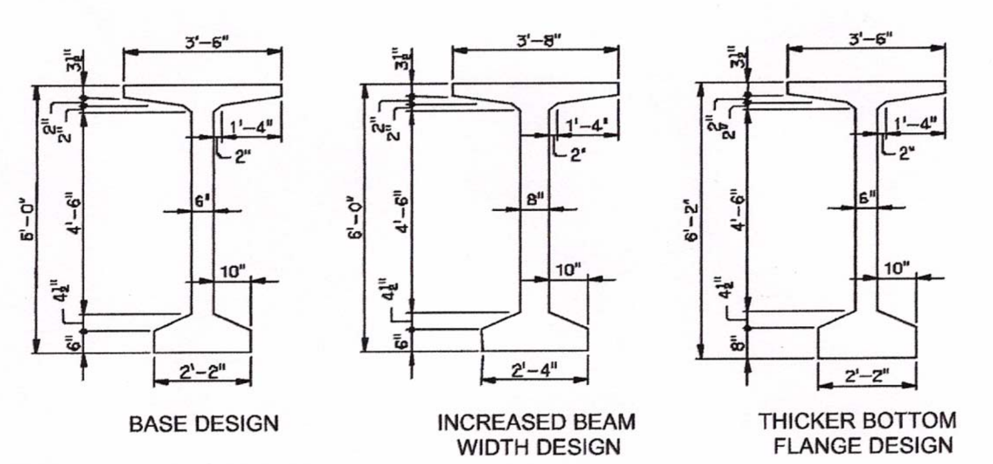

Figure 2.1: Beam Dimensions for PCI BT-72 Modifications