STRUCTURAL BEHAVIOR OF PRESTRESSED PRETENSIONED CONCRETE COMPOSITE SECTION

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To

Whom was sent mercy for all people

Prophet Muhammad “Peace be upon him and his progeny”.

My late dad “God bless his soul”

Without him, this study would not have been possible

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ABSTRACT

Composite construction in prestressed concrete usually consists of precast, prestressed members acting in combination with a cast-in-situ concrete component. This study investigates the structural behavior of a JKR prestressed pretensioned precast concrete T-Beam (PRT) made composite by a cast-in-situ slab. The precast beam was scaled down by one half of the full-scale JKR PRT1 beam. The composite beam is constructed using the un-shored construction method and tested for flexural using two point loads. Load-deflection response, crack development, distribution of strain across the depth of the composite section, mode of failure and ultimate flexural strength capacity are measured and analyzed. The results show that the JKR Standard Beams (Pretensioned Concrete Composite T-Beam), and cast-in-situ slab has no significant difference in its structural behavior compared to the results from other research.

Keywords: Prestressed Pretensioned Concrete Composite Section, Scale-Down, Structural Behavior, Ultimate Flexural Strength Capacity, Load-Deflection Curve.

ABSTRAK

Pembinaan komposit bagi konkrit pra-tegasan kebiasanya terdiri daripada komponen pra-tuang, struktur pra-tegasan berfungsi sebagai kombinasi antara komponen konkrit tuang in-situ. Kajian eksperimen ini bertujuan untuk mengkaji kelakuan bagi struktur rasuk-T pra-tegasan pra-tegangan pra-tuang JKR (PRT) dibuat secara komposit dengan kaedah tuang in-situ. Skala bagi rasuk konkrit pra-tegasan adalah separuh daripada skala penuh Piawaian Rasuk JKR (Konkrit Komposit Pra-tegasan bagi Rasuk-T (PRT 1)), manakala rasuk pra-tuang dan papak tuang in-situ diperbuat daripada konkrit bertetulang biasa di uji bagi mendapatkan momen lentur, manakala kaedah bertupang (Un-Shored) digunakan bagi spesimen seksyen komposit. Reaksi beban-pesongan, serakan keretakan, taburan keregangan pada kedalaman seksyen komposit, jenis-jenis kegagalan dan kapasiti kekuatan lenturan muktamad telah diukur dan dianalisis. Hasil kajian menunjukkan bahawa Piawaian Rasuk JKR (Konkrit Komposit Pra-tegasan Rasuk-T), dan papak tuang in-situ tidak menunjukkan perbezaan yang ketara pada reaksi struktur mengikut perbandingan dengan hasil kajian yang lain.

Katakunci: Seksyen Konkrit Komposit Pra-tegasan, Scale-Down, Reaksi Struktur, Kapasiti Kekuatan Lenturan Muktamad, Lengkung Beban-Pesongan.

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A_c	-	Cross-sectional area of member
$A_{c, slab}$	-	Cross-sectional area of slab in composite section
$A_{c, beam}$	-	Cross-sectional area of beam in composite section
A_h	-	Area of shear reinforcement between slab and beam
A_{ps}	-	Area of prestressing steel
A_s	-	Area of reinforcing steel
A_{sv}	-	Cross-sectional area of two legs of link
b	-	Breadth of section
b_c	-	Breadth of interface of between beam and slab
d	-	Effective depth
d_n	-	Depth to centroid of compression block
e	-	Eccentricity
E_c	-	Secant modulus of elasticity of concrete
E_{ci}	-	Modulus of elasticity of concrete at transfer
E_{ct}	-	Modulus of elasticity of concrete at time *t*
E_{Ceff}	-	Effective modulus of elasticity of concrete
$E_{c, slab}$	-	Modulus of elasticity of slab concrete
E_s	-	Modulus of elasticity of steel
f_b	-	Stress at bottom of section
$f_{b, beam}$	-	Stress at bottom of composite beam

$f_{b,\ slab}$	-	Stress at bottom of composite slab
f_{ci}	-	Concrete strength at transfer
f_{co}	-	Concrete stress at level of tendons
f_{cp}	-	Prestress at level of member centroid
f_{cu}	-	Characteristic concrete cube strength
f_{k}	-	Characteristic strength
f_{max}	-	Maximum allowable concrete stress at service load
f'_{max}	-	Maximum allowable concrete stress at transfer
f_{min}	-	Minimum allowable concrete stress at service load
f'_{min}	-	Minimum allowable concrete stress at transfer
Δf_{p}	-	Reduction in tendon stress
f_{pi}	-	Initial stress in tendon
f_{pb}	-	Tensile stress in tendon at failure
f_{pe}	-	Effective prestress in tendons after all losses
f_{prt}	-	Allowable concrete principle tensile stress
f_{pu}	-	Characteristic strength of prestressing steel
f_{r}	-	Modulus of rupture
f_{s}	-	Shear stress
f_{st}	-	Stress in reinforcement
f_{t}	-	Concrete stress at top of section
$f_{t,\ beam}$	-	Stress at top beam
$f_{t,\ slab}$	-	Stress at top of slab
f_{y}	-	Characteristic strength of reinforcement
f_{yv}	-	Characteristic strength of shear reinforcement
F_{t}	-	Total tensile force in a section
h	-	Overall depth of section
h_{eff}	-	Effective depth of slab at drop panel

I	-	Second moment of area
I_b	-	Second moment of area of beam
I_{comp}	-	Second moment of area of composite section
I_{cr}	-	Second moment of area of cracked section
I_e	-	Effective second moment of area
I_g	-	Second moment of area of gross section
K	-	Wobble coefficient
K_t	-	Transmission length coefficient
L	-	Span
L_t	-	Transmission length
m	-	Modular ratio
M	-	Bending moment
M_{cr}	-	Bending moment to cause cracking
M_d	-	Dead load bending moment
M_i	-	Self weight bending moment
M_o	-	Bending moment to produce zero stress at tensile face
M_p	-	Prestress moment
M_{per}	-	Permanent load bending moment
M_s	-	Service load bending moment
M_u	-	Moment of resistance at failure
P	-	Prestress force
ΔP_A	-	Loss of prestress force due to anchorage draw-in
P_e	-	Effective prestress force after elastic shortening
P_i	-	Initial force in tendons
P_x	-	Prestress force in x direction
r	-	Radius of gyration
r_{ps}	-	Radius of curvature of tendons

$1/r$	-	Curvature
S_v	-	Spacing of links
T	-	Tension
t_{eff}	-	Effective thickness of section
v	-	Vertical shear stress
v_c	-	Allowable ultimate concrete shear stress
v_h	-	Horizontal shear stress
V	-	Shear force
V_c	-	Ultimate shear resistance of concrete
V_{cr}	-	Ultimate shear resistance of section cracked in flexural
V_{co}	-	Ultimate shear resistance of section un-cracked in flexural
V_{eff}	-	Effective shear force in slab
w	-	Distributed load
w_d	-	Dead load
w_i	-	Self weight
w_s	-	Service load
x	-	Neutral axis depth
x_A	-	Length of anchorage draw-in effect
y	-	Displacement
z	-	Lever arm
Z_b	-	Section modulus for bottom fiber
$Z_{b,\ beam}$	-	Section modulus for bottom of beam
$Z_{b,\ comp}$	-	Section modulus for bottom of composite section
Z_t	-	Section modulus for top fiber
α	-	Short-term prestress loss factor
β	-	Long-term prestress loss factor
γ_f	-	Partial factor of safety for load

γ_m	-	Partial factor of safety for materials
δ_a	-	Long-term deflection under permanent load
δ_{ad}	-	Anchorage draw-in
δ_b	-	Short-term deflection under total load
δ_c	-	Long-term deflection under permanent load
δ_d	-	Dead load deflection
δ_e	-	Expected elongation of tendons
δ_i	-	Deflection at transfer
ε	-	Strain
ε_c	-	Concrete strain
ε_{cu}	-	Ultimate concrete strain
ε_p	-	Strain in tendons due to flexural
ε_{pb}	-	Ultimate strain in tendons
ε_{pe}	-	Effective prestrain in tendons
ε_{sh}	-	Shrinkage strain
ε_{st}	-	Strain in reinforcement
μ	-	Coefficient of friction
φ	-	Creep coefficient

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CHAPTER 1

INTRODUCTION

1.1 Overview

Precast and prestressed concrete is the most recent major form of construction introduced in the structural engineering. It has become a well established method of construction where its technology is available in most developed and in many developing countries. Today, prestressed concrete are used in buildings, underground structures, communication towers, floating storage and offshore structures, power stations, nuclear reactor vessels, and numerous types of bridge systems including segmental and cable-stayed bridges.

In the field of bridge engineering, the introduction of prestressed concrete has aided the construction of long-span concrete bridges. These often comprise precast units, lifted into position and then tensioned against the units already in place, the process being continued until the span is complete. For smaller bridges, the use of simply supported precast pre-stressed concrete beams has proved an economical form of construction, particularly where there is restricted access beneath the bridge for construction. The introduction of ranges of standard beam section has also simplified the design and construction of bridges.

Prestressed concrete composite construction has many advantages over non composite construction. In many situations, a significant reduction in construction costs can be achieved, the concrete can be cast in the controlled environment of a pre-casting yard before construction ever begins. Reduction or total elimination of formwork and rapid execution of the construction. All of these factors offer a product of higher quality with decreased traffic interruptions.

Like ordinary reinforced concrete, prestressed concrete consists of concrete resisting compression and reinforcement resisting tension. Based on the concept that reinforced concrete’s tensile strength is limited while its compressive strength is extensive, consequently, pre-stressing become essential in many applications in order to fully utilize the compressive strength of reinforced concrete and through proper design, elimination or control of cracking and deflection can be achieved.

In order to benefit from the slab contribution to the flexural strength of composite beam section, the slab-web connection should be to transmit longitudinal shear stress. When the slab is cast in place over the precast pre-tension girders, the shear stresses can be transmitted a cross the connection by shear friction at the concrete interface and the dowel action of the reinforcing bars that cross the connections.

The success of composite action depends on the shear resistance at the interface between the precast element and cast-in-place element to allow full transfer of stresses. If no shear resistance exists and a load is applied to the composite beam shown in (fig. 1.1.a), the slab would slide with respect to beam (fig. 1.1.b), and the system would act as if two separate elements were used. However, if sufficient shear resistance is provided, the slip between the two elements can be prevented and composite action can be counted on (fig.1.1.c). Thus a good connection between the two components of the composite system is essential. (Naaman 2004)

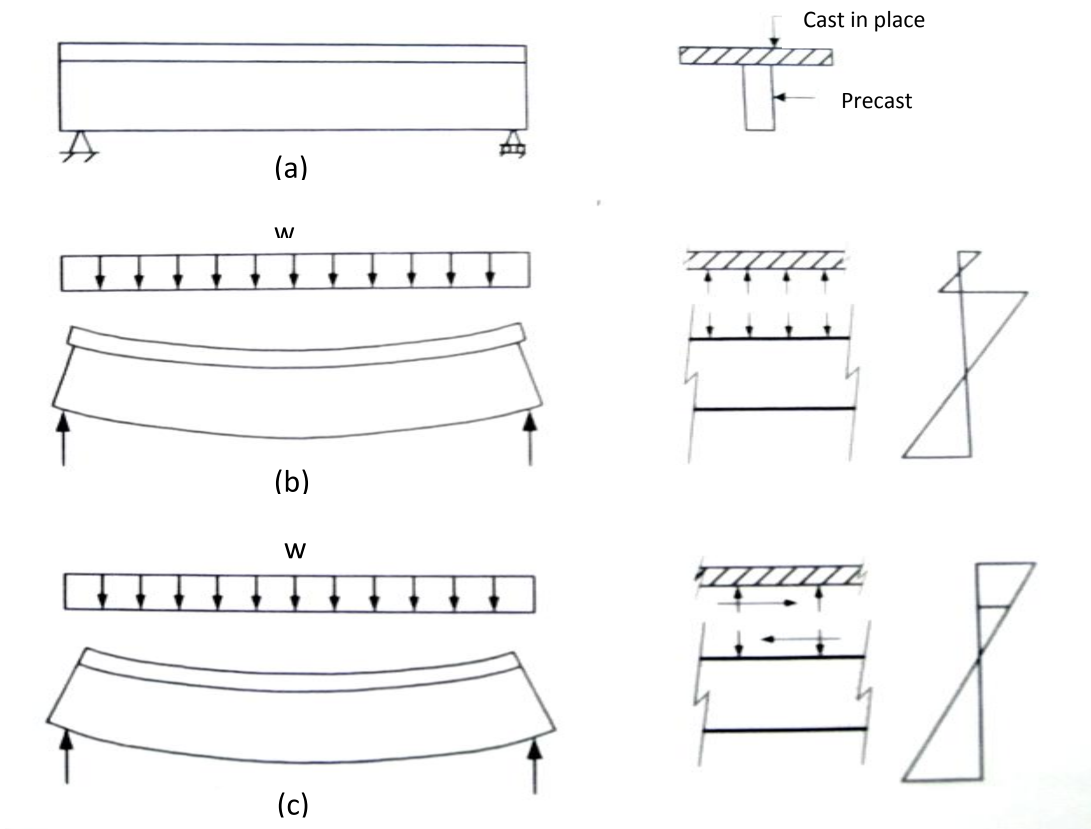

Figure 1.1: (a) Typical precast beam and cast-in-place slab. (b) Non-composite action (zero interface shears). (c) Composite action (full interface shear).

1.2 Need for Research

The need for this research is due to lack of test data on structural behavior of a composite section made of the JKR Standard Beams (PRT) and cast in-situ slab.

1.3 Research Objective

The primary objective of this study is to investigate the structural behavior of prestressed pretensioned concrete composite section made of JKR Standard Beams (PRT) and cast-in-situ slab, the structural behavior that are observed are:

1. Load-deflection response.
2. Crack propagation and distribution.
3. Variation of strain on concrete over the depth of the specimen.
4. Mode of failure.
5. The ultimate flexural strength capacity.

1.4 Scope of Research

This study will be concentrated on the beam with T-shaped cross section (JKR Standard Beams (PRT)) and the dimensions were scaled down from the full-scale JKR Standard Beams (Pretensioned Concrete Composite T-Beam (PRT 1)), with ratio basis of 1:2, and in-situ slab was tested under bending moment, to investigate the structural behavior. The specimen span 8 meter in length was designed and constructed by using un-shored construction method in accordance with the BS 8110.

The possible parameters that may affect the structural performance of pretensioned composite section such as strength of concrete, modulus of elasticity and modulus of rapture of concrete will be carried out. In-situ concrete specimens such as concrete cubes and concrete cylinders will be collected and laboratory testing will also carried out.

1.5 Outline of thesis

Chapter 2 gives a background on prestressed concrete composite section. Chapter 2 also covers composite section behavior. Chapter 3 discusses the design and construction process for the specimen, including its composite deck. Chapter 4 discusses all of the concrete material specimen testing and results. Chapter 5 discusses the structural test set-up and procedures, followed by a presentation and discussion of the results in Chapter 6. Finally, Chapter 7 presents conclusions and recommendations drawn from this study.