Ain Shams University
Faculty of Engineering
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# Behavior of Rectangular Partially Prestressed High Strength Concrete Beams

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# STATEMENT

This thesis is submitted to Ain Shams University, Cairo, Egypt, in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Structural).

The work included in this thesis was carried out by the author at reinforced concrete laboratory of the faculty of Engineering, Ain Shams Uviversity.

No part of this thesis has been submitted for a degree or qualification at any other university or institute.

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## Dedication

I dedicate the work and accomplishment in this thesis to the people who devoted their lives for making me a successful person, my Father and Mother. Gratitude and appreciation words cannot describe my feelings towards them.

Special dedication to my grandparents for their continuous encouraging wishes. Specially my grandfather Ali Abdelrahman, who passed away during my thesis preparation for acting as my role model during my whole life.

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# Abstract

In the last few decades, prestressed concrete has been rapidly used in bridge engineering due to the enormous development in the construction techniques and the increasing need for long span bridges. High strength concrete has been also more widely spread than the past. It currently becomes more desirable as it has better mechanical properties and durability performance. Major defect of fully prestressed concrete is its low ductility; it may produce less alarming signs than ordinary reinforced concrete via smaller deflection and limited cracking. Therefore, partially prestressing is considered an intermediate design between the two extremes. So, combining high strength concrete with partial prestressing will result in a considerable development in the use of prestressed concrete structures regarding the economical and durability view points. This study presents the results of seven partially prestressed high strength concrete beams in flexure. The tested beams used to investigate the influence of concrete compressive strength, prestressing steel ratio and flange width on the behavior of partially prestressed beams.

The experimental program was conducted on seven partially prestressed concrete beams with total length of 4800mm.The beams were simply supported with 4500mm clear span and 150mm projection at each end. All the beams were 150mm wide and 250mm deep for all the five rectangular sections. The web of the T-section

specimens was similar to the rectangular ones while flange widths were 350 and 550mm. The experimentally observed behaviors of all beams were presented in terms of the cracking load, ultimate load, deflection, cracking behavior and failure modes. Strains at the bottom longitudinal reinforcement steel and concrete (top and reinforcement levels) were also measured so as to monitor the strain propagation across the concrete cross section

The research program developed an analytical approach to predict the behavior of the partially prestressed high strength beams under the studied parameters. The program based on rational and empirical methods available in the literature to model both deflection and crack width of partially prestressed high strength concrete. Failure modes and ultimate carrying capacity of the beams were predicted and then compared to the experimental values.

# Table of Contents

## List of symbols

| | |
|---|---|
| $a$ | Depth of the equivalent rectangular stress block in the compression zone of concrete section. |
| A | Effective concrete tension area divided by number of bars or wires. |
| $A_r$ | Concrete area in tension below neutral axis. |
| $A_{cr}$ | Cross sectional area of transformed cracked section. |
| $A_s$ | Area of longitudinal tension reinforcement within effective tension. |
| $A_{cef}$ | Area of effective concrete section in tension. |
| $A_{st}$ | Area of prestressing and equivalent conventional steel. |
| $A_{ps}$ | Area of prestressed reinforcement. |
| $A_g$ | Gross section area of concrete. |
| $A_{ns}$ | Area of non-prestressed reinforcement. |
| $c$ | Concrete cover |
| c | Neutral axis depth from the extreme compression fiber. |
| $C_s$ | center-to-center distance of tensile reinforcements (mm). |
| $d_c$ | Concrete cover to the center of reinforcement. |
| $d_p$ | Depth of the prestressing reinforcement from the extreme compression fiber. |
| e | Eccentricity of prestressing force based on gross section properties. |
| $e_{cr}$ | Eccentricity of prestressing reinforcement with respect to neural axis of the transformed cracked section. |
| $E_c$ | Concrete modulus of elasticity. |
| $E_{As}$ | Conventional reinforcement modulus of elasticity. |

| | |
|---|---|
| $E_{ps}$ | Prestressing steel modulus of elasticity. |
| $E_s$ | Average modulus of elasticity for conventional and prestressing steel reinforcement. |
| $E_{total}$ | Total energy. |
| $E_{elastic}$ | Elastic energy. |
| $f_{cu}$ | Concrete characteristic cube compressive strength at 28days. |
| $f_c'$ | Concrete specified cylinder compressive strength. |
| $f_{cm}$ | Mean value of concrete cylinder compressive strength. |
| $f_{ck}$ | Concrete characteristic cylinder compressive strength at 28days. |
| $f_{ctm}$ | Mean axial tensile strength. |
| $f_{ck,cube}$ | Concrete characteristic cube compressive strength at 28days. |
| $f_r$ | Concrete average modulus of rupture. |
| $f_{ctm,fl}$ | Concrete average modulus of rupture. |
| $f_{ct,sp}$ | Concrete indirect tensile splitting strength. |
| $f_{ctr}$ | Concrete tensile splitting strength. |
| $f_{ct,sp}$ | Concrete average modulus of rupture. |
| $f_{ps}$ | Stress in the prestressing reinforcement at the ultimate stage. |
| $f_c$ , | Stress at any level of loading. |
| $f_{ps}$ | Stress at the prestressing steel reinforcement. |
| $f_{ps}$ | Stress at the prestressing steel reinforcement. |
| $f_y$ | Yielding stress at prestressing and conventional reinforcement. |
| $f_c$ , | Stress at any level of loading. |
| $f_{sr}$ | Stress in longitudinal steel at the tension zone, based on the analysis of cracked section due to loads causing first cracking. |

| | |
|---|---|
| $f_s$ | Stress in longitudinal steel at the tension zone, based on the analysis of cracked section under permanent load. |
| h | Total member depth |
| $I_e$ | Effective moment of inertia. |
| $I_g$ | Gross moment of inertia. |
| $I_{cr}$ | Moment of inertia of the cracked section ignoring the concrete in tension. |
| $Ie_{L2}$ | Effective moment of inertia for moment corresponding to a downward (net positive) deflection. |
| $k$ | Factor to increase the decay of stresses. |
| $k_1$ | Ratio of the average compressive stress to the maximum compressive stress. |
| $k_2$ | Ratio of the depth of the resultant compressive force to the depth of neutral axis. |
| $k_3$ | Ratio of the maximum compressive stress to the compressive strength of concrete cylinder. |
| $k_1$ | Coefficient depending on reinforcement bond properties. |
| $k_2$ | Coefficient depending on strain distribution. |
| $k_1$ | Coefficient depending on the reinforcement geometry. |
| $k_2$ | Coefficient depending on the concrete quality. |
| $k_3$ | Coefficient depending on the arrangement of reinforcement. |
| $k_1$ | Coefficient depending on the reinforcement type. |
| K | coefficient depending on the support and loading conditions. |
| L | Effective length of the member. |