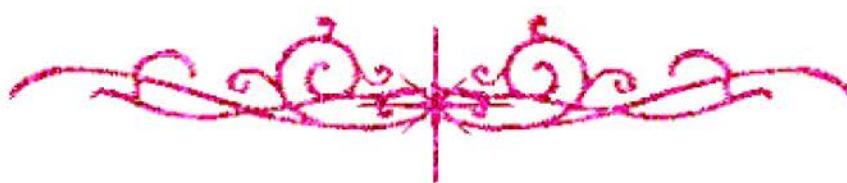


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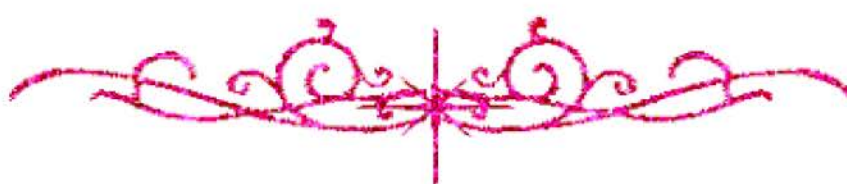
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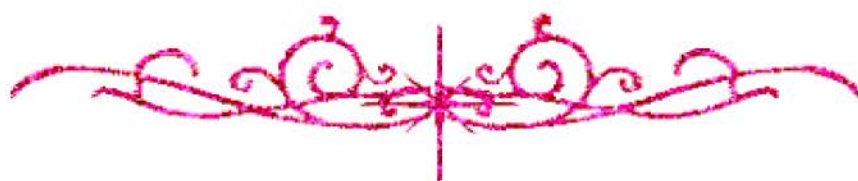
قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار



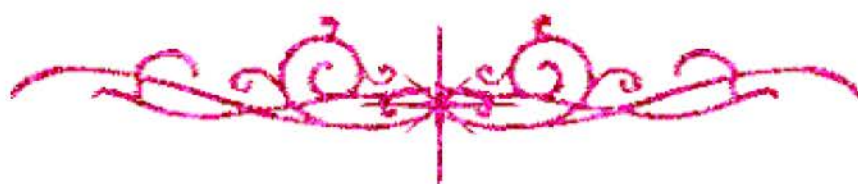
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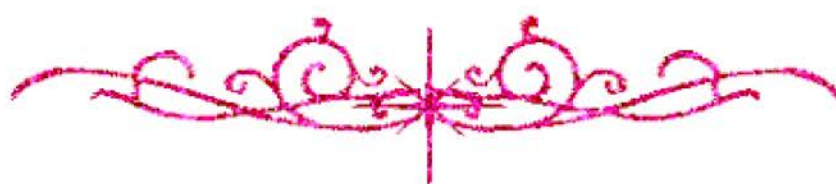
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بالرسالة صفحات لم ترد بالأصل



50/18

**Application of Equilibrium Truss Models to
Continuous Reinforced Concrete Solid Webbed
Deep beams and with web Openings**

By

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A Thesis

**Submitted for the Partial Fulfillment of the Requirements of
a Master Degree in Structural Engineering, Cairo University**

1994

Under the Supervision of

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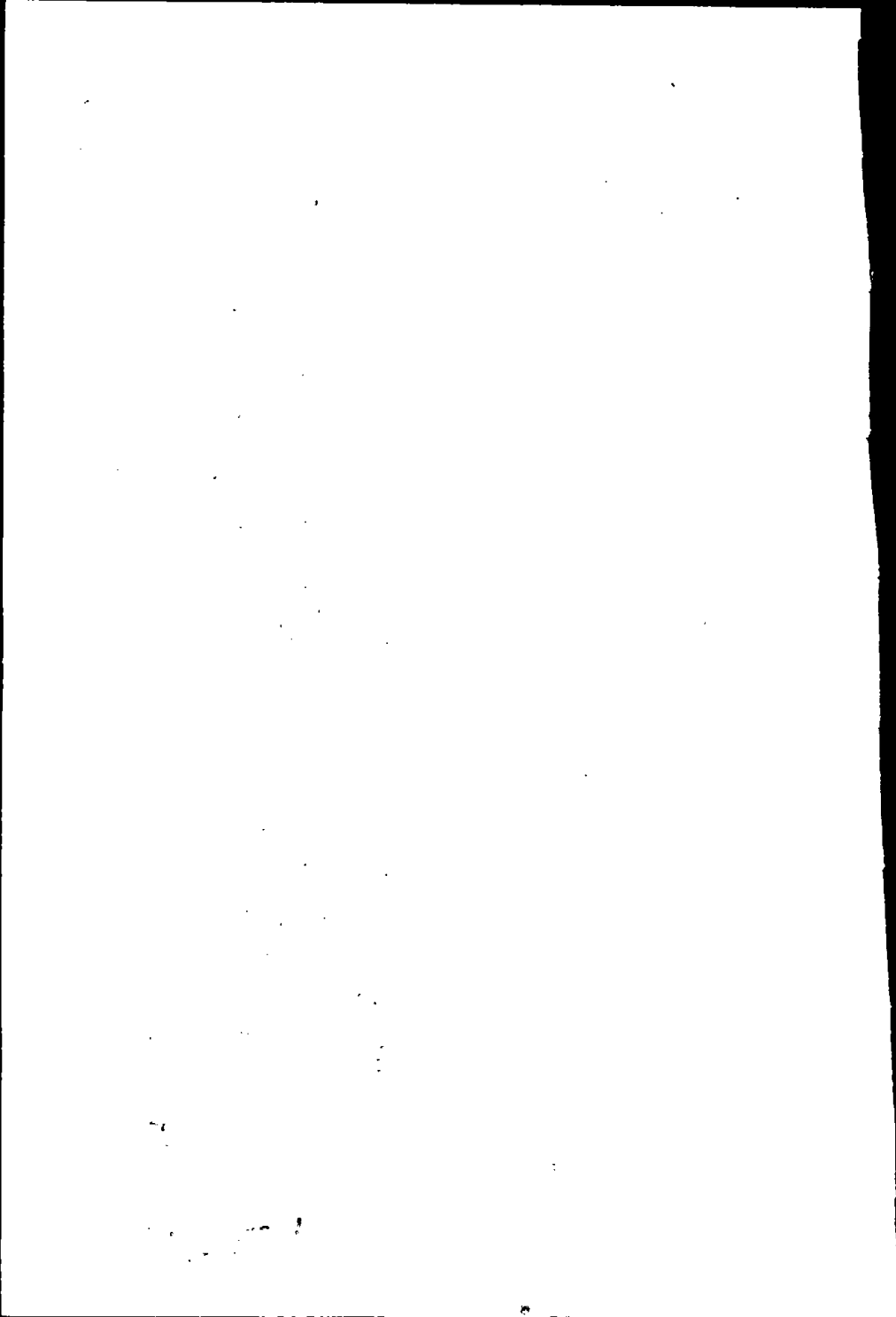
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ACKNOWLEDGMENT

I would like to express my gratitude to Dr. A. Abd El-Rahman and Dr. Adel Galal El-Attar for their guidance, appreciated encouragement, wonderful support, faithful opinion and sincere efforts.

I would never forget the great encouragement from the staff of concrete research laboratory of Cairo University during the testing program time.

No wonder that the full support provided by Dr. T.,M.,Moustafa is deeply appreciated.

The ever greatest support and encouragement provided by my superiors in Ferrometalco is deeply appreciated. Especially Mr. Eikmeier, Mr. Cordes and Mr. k. Tantawy.

I want also to thank all my colleagues especially Eng. M.,A.,Aly. for their great cooperation in accomplishing an application of the truss analogy method for deep beams.

Finally, I am not gonna say any thing to my family where words can never express their effort and my sincere feelings.

Abstract

The purpose of the current research is to investigate the possibility of applying the so called 'Equilibrium Truss Models' to the design of continuous reinforced concrete deep beams with or without web openings. The proposed method provides a simple and easy-to-apply technique to analyze such beams as compared to more complicated numerical methods such as the 'Non-Linear Finite Elements'. The power of the method lies in the fact that it is a design method, where the designer can decide the force path (truss) and consequently provides the necessary dimensions and reinforcement to enable the suggested truss, while other numerical methods can only check the stresses in an already designed element where the concrete dimensions and steel reinforcement are already known.

In the first chapter of this thesis, 'Strut-and-Tie Models', or 'Truss Model' are reviewed, with special attention paid to the application to disturbed regions in the structure. Elements of truss models including struts, ties, and nodal zones are introduced and discussed.

In the second chapter, a literature survey of the design of deep beams is introduced. Some important experimental tests on such elements are discussed, with special emphasis on the difference in behavior between deep and shallow beam elements. The proposed truss modeling technique was used to analyze 12 deep beams (3 simply supported and 9 continuous beams).

In chapter three, the experimental program is introduced, where 4 quarter scale continuous deep beams were tested to failure. Details of the test set-up, loading devices and specimen instrumentation can be found in this chapter. Special strut reinforcement were used in the tested beams to increase the strut capacity, and to enhance the overall beam ductility by preventing brittle modes of failure. It was found that all tested beams failed at a load higher than that predicted using truss models. The calculated truss capacity was about 90% of the recorded failure load in all tested beams, indicating that the method provides a consistent lower-bound solution.

In chapter four, 16 deep beams, including the four tested beams were analyzed using a non-linear finite element program (NLFEA90) and the program results were compared to the experimental data.

NOTATION

- a = Shear span, distance between concentrated load and face of support.
 A_b = Area of individual bar (cm^2).
 A_c = Area of core of reinforced compression member measured to outside edge (cm^2).
 A_s = Area of non prestressed tension reinforcement (cm^2).
 A'_s = Area of compression reinforcement (cm^2).
 A_v = Area of shear reinforcement within a distance (s) (cm^2).
 A_l = Loaded area in bearing (cm^2).
 b_w = Web width of the concrete cross section (cm).
 d = Effective depth = distance from extreme compression fiber to centroid of tension reinforcement (cm).
 d_b = Nominal diameter of steel bars (cm).
 d_c = Thickness of concrete cover measured from extreme tension fiber to center of the closest bar (cm).
 C = Diagonal compression force in the web of a beam or in a compression strut located in a D-region (t.).
 E_c = Modulus of elasticity of concrete (t/cm^2).
 E_s = Modulus of elasticity of reinforcement (t/cm^2).
 f'_c = Specified compressive strength of concrete (kg/cm^2).
 f_{ce} = Effective compressive strength of concrete = $v f'_c$ (kg/cm^2).
 f_s = Calculated stress in reinforcement at service loads (kg/cm^2).
 f_y = Specified yield strength of reinforcement bars (kg/cm^2).
 h = Overall depth of the cross section (cm).
 I = Moment of inertia of a section, subscript: b = beam, (cm^4).
 I_{cr} = Moment of inertia of cracked section transformed to concrete (cm^4).
 I_g = Moment of inertia of gross concrete section (cm^4).
 j_d = Distance between the resultants of internal compressive and tensile forces.
 k = Effective length factor for compression members.
 K = Flexural stiffness: moment per unit rotation.
 l_d = Development length (cm).
 l_n = Clear span of a beam measured from face to face of supports:
 = average of adjacent clear spans for continuous beams. (m).
 l_u = Unsupported length of compression members (m).
 n = Modular ratio = E_s / E_c .

P_u = Ultimate load due to factored loads (t.).

s = Standard deviation (kg/cm^2).

s = Spacing of shear reinforcement measured along the longitudinal axis of the structural member (cm).

v = Shear stress (kg/cm^2).

v_c = Nominal shear stress carried by concrete (kg/cm^2).

V_c = Nominal shear force carried by concrete (t.).

V_n = Nominal shear strength.

V_s = Nominal shear strength provided by shear reinforcement.

V_u = Factored shear force at section (t.).

α = Angle between inclined stirrups and longitudinal axis of member.

ϵ_c = Strain in concrete (dimensionless).

ϵ_s = Strain in steel (dimensionless).

ϵ_{cu} = Compressive strain at crushing of concrete (dimensionless).

v = Ratio of effective concrete strength in a web of beam or compression strut relative to f'_c .

ρ = Ratio of nonprestressed tension reinforcement = A_s / bd .

ρ' = Ratio of nonprestressed tension reinforcement = A_s' / bd .

ϕ = Strength reduction factor.

ω = Mechanical reinforcement ratio = $\rho f_y / f'_c$.

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