AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT

EFFECT OF HANGER STEEL REINFORCEMENT AND ITS LOCATION ON THE BEHAVIOUR OF LEDGE BEAM

A Thesis
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in
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by

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STATEMENT

This thesis is submitted as partial fulfillment of the requirements for the degree of Doctor of Philosophy in Civil Engineering (Structures), Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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EFFECT OF HANGER STEEL REINFORCEMENT AND ITS LOCATION ON THE BEHAVIOUR OF LEDGE BEAM

SUMMARY

Reinforced concrete L-shaped beams are frequently used in the precast concrete industry especially in bridge constructions to support a series of deck beams. The most common application is where L-shaped beams are used to support double-tee deck beams in a parking garage. The stems of the double-tee deck beams bear on the top surface of the spandrel ledge, loading the spandrel beam with a series of concentrated eccentric reactions. The contribution of the inner vertical branches of stirrups as a hanger for the ledge part is neglected. Therefore, the outer vertical stirrups have a great amount with respect to the internal stirrups.

This research introduces experimental and analytical study in order to investigate the load path of the concentrated loads on the ledge beams and study the effect of the inner vertical stirrups in the contribution of the hanging action of ledge part. The objective of this thesis is to find an efficient, easy and economic reinforcement arrangement under combined effect of bending moment, shear force and torsional moment.

The experimental program is designed to study the contribution of the internal vertical stirrups on the hanging action of the ledge. The test specimens consist of sixteen simply supported beams of 2.70m span subdivided into six groups. All beams had a total height of 380mm and a web width of 120mm or 250mm. The heights of the ledge part were chosen to be 140, 180 & 220mm and their projection was 250mm. The study considers the following variables, the distribution of internal vertical stirrups, thickness of ledge part, the web width of specimens and eccentricity of vertical loads. The specimens were designed to ensure that the ultimate failure load of the ledge part is due to yielding of the vertical hanger outer stirrups based on the ACI assumptions. The specimens were tested under single vertical concentrated load at mid-span acting on the ledge part with eccentricity of 150, 100 & 70mm to the inner edge of the web.

An additional study using finite element method has been carried out to introduce a design model for the ledge beams. The commercial finite element program Ansys has been adapted in which the experimental tests has been analyzed. Additional parametric study can be done to investigate more variables. A verification of the adapted model has been run the experimental tested specimens.

An analysis using strut and tie method has been performed. Different strut and tie models had been built to simulate the behavior of the ledge beams and can be easily used into design.

Key Words: Shear friction, Shear reinforcement, Ledge beam.

To fulfill the previously mentioned objectives, this research is divided into the following chapters:

- Chapter (1) is an introduction to this research. This chapter discusses the importance of the research and the scope of the research program.

- Chapter (2) presents a brief review of the available literature, research findings, performance data and current practices relative to the behavior and design of reinforced concrete ledge beams.
- Chapter (3) presents the experimental program. This chapter describes the formwork, material properties, fabrication, test specimens, test setup, measurement devices, and loading scheme.

- Chapter (4) discusses and analyses the test results and observations. The results include load–deflection and load-rotation curves, crack patterns and strain in both steel and concrete.

- Chapter (5) discusses the methodology adopted in the analytical study along with the description of the analysis technique adopted by the finite element computer program (**ANSYS**) used and presents details of the analyzed models, material properties and main analysis results. Also, a parametric study had been established to take other variables which are not taken in the experimental program.

- Chapter (6) introduces analytical study using the **strut and tie** method. The methodology of the model creation has been introduced in details. Different strut and tie models have been constructed for different tested specimens that simulate the behavior. Based on these strut and tie models, the failure loads of the tested specimens have been predicted. These models have been verified. Finally, a rational design tool using strut and tie method for those ledge beams has been conducted, that can be easily used by the designer of those elements.

- Chapter (7) includes the general conclusions of the study alongside with recommendations for future research and developments in the subject.

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