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AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT

PUNCHING SHEAR STRENGTH OF ULTRA-HIGH PERFORMANCE CONCRETE FLAT SLABS

Thesis

Submitted in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE
in
CIVIL ENGINEERING (STRUCTURES)

by

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STATEMENT

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

The work included was carried out by the author.

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

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بسم الله الرحمن الرحيم

"وَقُل رَّبِّ زِدْنِي عِلْمًا"

صدق الله العظيم

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DEDICATION

I dedicate this thesis to my father, mother, brother “Eslam”, and all my family.

This thesis is dedicated to the soul of my dear grandfather.

ABSTRACT

PUNCHING SHEAR STRENGTH OF ULTRA-HIGH PERFORMANCE CONCRETE FLAT SLABS

Not for a long time, there is a growing interest in a new generation of concrete to make huge development in construction. A relatively new sophisticated construction material of cementations complex, ultra-high performance concrete (UHPC) was used. The mechanical property of UHPC is supreme of conventional concrete. The compressive strength is more than 124 MPa and tensile strength is greater than 5 MPa. The modulus of elasticity ranged between 42 to 55GPa, concrete density ranged between 2,400 to 2,500 kg/m^3, and tensile strength was more than 6.2MPa. In this thesis, the punching of flat slabs with UHPC was studied to increase the information of slab-column connections against punching shear failure.

Reinforced concrete flat slabs are commonly used today because of the preferences they offer; for example; decrease of floor height, simple formwork construction, and pleasant appearance. However, the critical problem of this system is the high-stress region slab-column connections resulting in a column is essentially pushed through the slab, (known as punching shear failure). To overcome this failure, there are many ways to increase the punching shear capacity of the reinforced concrete flat slabs such as; increasing slab thickness in the area adjacent to the column, increasing the dimension of a column which is always against the architectural desire, preparing a slab around columns with shear reinforcement, and finally development concrete strength.

The development of concrete strength is one of the most influential methods to avoid punching shear failure in a slab. Therefore, this research was aimed to examine slab-column connection with UHPC to increase punching shear

capacity. It should be noted that UHPC is a new material, it is still limited to a few structural applications due to its high cost, limited design codes, and the high factors of safety adopted in the design.

To investigate the advantages of UHPC in the highly stressed region of slab-column connections, four slabs specimens with dimensions 1350*1350*80mm were prepared. All specimens contain steel fibers which enable tension to be carried across opened cracks, give ductility and energy absorption for concrete. The average strength for the specimens test ranged between 193MPa to 164MPa for compression strength and 13.1MPa to 9.6MPa for tensile strength.

The experimental study and numerical analysis were used to examine the punching shear strength of four UHPC specimens which have been tested under concentrated vertical load, using various parameters such as concrete strength, column aspect ratio, column shape, and flexural reinforcement ratio. The experimental setup is a hydraulic jack acting at the center of the column stub. A steel I-beam frame supported the specimen at the edges. The load was applied gradually with a constant incremented rate of 10 KN. The numerical analysis was accomplished by a nonlinear finite element analysis (ABAQUS software) and performed with the concrete damaged plasticity model (CDPM), ABAQUS/Explicit. The compressive behavior and the tension behavior of the concrete were modeled by Hognestad Parabola and Bilinear tensile stress versus crack width respectively. The concrete was divided into brick elements (C3D8R) to avoid the shear local effect and hour glassing effect, while the reinforcement is modeled as a wire truss by (T3D2) embedded into the solid concrete elements. As a result, greater efficiency of UHPC was shown against punching shear failure. Provided the maximum load capacity for the four specimens which gives failure loads a 30% increase relative to the ACI punching formula. The average ultimate load for four specimens was increased by 81% relative to the load at the first crack. In addition, the average deflection value at the ultimate stage for the

four specimens at point “d/2” from columns face increased by 67.5% compared to the first crack deflection. Using micro steel fibers in UHPC changes the punching behavior to mostly ductile shear failure, which is represented in a ductility ratio of 2.77 to 3.57. The average punching cone angles for four specimens were 15.7^{o}. Furthermore, the presence of micro steel fibers in the mixture reduces the yield of flexure reinforcement as opposed to a high concrete strain value.

The outcome of this study leads to the continuous dissemination of a UHPC in building applications. If UHPC material was widely used in the construction application, the member cross-section would be minimized, and decrease the total weight of the structure that helps in earthquake resistance especially in the tall buildings located in earthquake zones. Besides, the UHPC structure will become economical compared with the HPC structure, which gives more rapid construction and amends durability over a lifetime.

Keywords

Flat slabs, Interior slab-column connection, Punching shear, Ultra-High Performance Concrete (UHPC), Finite element method, Cracking pattern, Deflection, Steel fibers, Cone Shape.

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