NUMERICAL MODELING AND EXPERIMENTAL INVESTIGATION ON ENHANCING PUNCHING SHEAR CAPACITY USING CARBON FIBER REINFORCED POLYMER ON FLAT SLABS

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Degree of Master of Philosophy

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The above candidate has carried out research for the Master of Philosophy under my supervision

Name of the supervisor: Dr. (Mrs.) J.C.P.H. Gamage

Signature of the supervisor: Date:

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ABSTRACT

Flat slabs are much vulnerable to shear failures because stress transferring between the column and the slab happens within a considerable small region. This creates high stress at the slab-column connection area result in punching shear failure. Shear failures are a little different from other failure modes such as flexural failure and excessive deflections because it shows a sudden nature while failing the member. Therefore, giving adequate shear capacity for the flat slabs is crucial. Carbon Fiber Reinforced Polymers (CFRP) is a new material which can be used for structural strengthening. Use of CFRP is promoted by its competitive advantages such as high strength and stiffness to weight ratio, corrosion resistance, low thermal expansion, non-magnetic properties, good fatigue properties and ease of handling.

The sudden punching shear failure tendency of flat slabs is a critical issue. Installation of CFRP flexural reinforcements and post installed CFRP shear reinforcements to enhance punching shear capacity are successful approaches. In this study, medium scale flat slab panels were prepared and strengthened with CFRP. Effects of seven alternative bonding arrangements of CFRP were studied. More than 120% punching shear gain was noted from the specimens strengthened with the combination of CFRP flexural and shear reinforcements. Further, the effects from end anchorage of external CFRP and the refilling material at drilled locations to install CFRP shear strengthening scheme were investigated in terms of the enhancement on punching shear performance.

A numerical investigation was also conducted to analyze bond behavior and stress behavior. The model predicted performances are in good agreement with the test results. A parametric study was also performed. The use of double-layered CFRP as external reinforcement was found to be the most effective multi-layered system. Further, the identification of the critical locations for the application of the external CFRP strengthening scheme was determined and the practical importance of providing end anchorage was quantified.

Keyword: ABAQUS, CFRP, deflection, flat-slab, punching, strengthening

LIST OF PUBLICATIONS

Conference Publications

1. Title: Experimental Investigation on Enhancing Punching Shear Capacity of Flat Slabs Using CFRP

   Conference: 8th International Conference on Structural Engineering and Construction Management- 2017

2. Title: Behavior of Reinforced Concrete Flat Slabs Retrofitted with Carbon Fiber Reinforced Polymer Sheets

   Conference: 6th International Symposium on Advances of Civil and Environmental Engineering Practices for sustainable Development- 2018

3. Title: Punching Shear Capacity Enhancement of Flat Slabs using End Anchored Externally Bonded CFRP Strips

   Chapter: Society of Structural Engineers in Sri Lanka- MODULUS

4. Title: Numerical Modeling of Reinforced Concrete Flat Plates Strengthened with Externally Bonded CFRP against Punching Shear

   Conference: 9th International Conference on Sustainable Built Environment- 2018

5. Title: Investigation on Flexural Performance of Heavily Cracked Concrete Beams Strengthened with CFRP

   Conference: 7th International Symposium on Advances of Civil and Environmental Engineering Practices for sustainable Development- 2019

Journal Publications

1. Case Studies in Construction Materials (Published)
   Title: Performance of Slab-Column Connections of Flat Slabs Strengthened with Carbon Fiber Reinforced Polymers
   DOI: https://doi.org/10.1016/j.cscm.2019.e00275

2. Lecture notes in Civil Engineering (Published)
   Title: Behavior of CFRP Retrofitted Reinforced Concrete Slab-Column Connections
   DOI: https://doi.org/10.1007/978-981-13-9749-3_40

3. Journal of Composite Structures (Revision requested, 04/09/2019)
   Title: Combined Effects of Carbon Fiber Reinforced Polymer Flexural Reinforcements and Post Installed Shear Dowels on the Performance of Flat Slabs

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