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Anchorages of stirrups under transverse tension in concrete - development of a design model

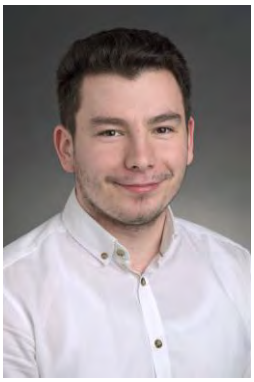
Mirhat MEDZITI

Civil engineer, MSc

Vincent Becker ingénieurs (VBI) Fribourg sàrl Switzerland

Fribourg, Switzerland
mirhat.medziti@vbisa.ch

Mirhat Medziti, born 1992, received his MSc degree in civil engineering from the HES-SO, Switzerland in 2018.



Daia ZWICKY

Professor, PhD, MSc

HES-SO University of Applied Sciences and Arts Western Switzerland

Fribourg, Switzerland
daia.zwicky@hefr.ch

Daia Zwicky, born 1971, received his MSc and PhD degrees from ETH Zurich, Switzerland in 1996 and 2002.

Contact: mirhatmedziti@gmail.com

1 Abstract

According to Swiss code SIA 262 "Concrete structures", stirrups of reinforced concrete beams must "surround the tensile longitudinal reinforcement" and must "be anchored to mobilize the static height of internal forces". For existing concrete structures, Swiss code SIA 269/2 provides stirrup detailing requirements while limiting these directives for stirrup anchorage to the compression zone. In zones of negative bending, these requirements are often not satisfied for execution reasons. This question is addressed in a largely experimental Ra&D project. Anchorage tests were performed and analyzed, with a total of 144 tests on 9 concrete beams. These underwent a longitudinal tensile force up to 1'000 kN to simulate transverse cracking at stirrup anchorages in negative flexure zones. The study parameters are crack width (0, 0.4 and 0.9 mm), stirrup diameter (10 and 14 mm), bar ribbing (smooth and ribbed) and hook angle (90°, 135°, 180° and straight bars). A design model based on the "tension chord model" (TCM) developed at ETH Zurich is proposed. This simple and practical design model has proved its effectiveness to consider bond effects. Reduction factors for bar diameter ($k_{ø}$), relative bar ribbing (k_{fR}), hook effect (k_{θ}) and crack width (k_w) were taken into account for calibration. Results of analytical calculations are coherent with experimental tests.

Keywords: reinforced concrete; shear; stirrups; anchorage; bond; construction details; experimental study; empirical analysis; modelling; calibration.

2 Introduction

Verification of existing reinforced concrete (RC) structures is of increasing importance.

According to Swiss codes SIA 262 and 269/2 [1, 2], the stirrups in the webs of beams must "surround the tensile longitudinal reinforcement" and "be anchored so that they can be mobilized on the height of the lever arm of the internal forces". In areas of negative flexure, these requirements are often not satisfied for construction reasons. For the dimensioning of new beams as well as the verification of existing beams, there is a lack of knowledge for the modeling of stirrup anchorage in flexural tension zones, Figure 1.

The main objective of this largely experimental study [3, 4, 5] is to establish an empirical evaluation of test results and ultimately, to provide a proposal for anchorage design under transverse tension,

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