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An experimental investigation of shear-transfer strength of normal and high strength self compacting concrete

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ABSTRACT

Fifteen non-precracked pushoff specimens were tested to investigate the shear-transfer behavior of normal strength and high strength self-compacting concrete (SCC). The reported results include the cracking stresses, the yielding stresses, the ultimate strengths and the post-ultimate residual strengths. It is shown that the specimens resisted significant post-ultimate residual strengths and shear slip values reaching 20 mm. It is also shown that increasing the compressive strength of the concrete significantly increased the ultimate shear strength but had a limited effect on the cracking and the residual strengths. The calculations of four existing models are compared with the observed ultimate strengths, and the calculated strengths are generally conservative. The AASHTO shear-friction and the SMCS models provide the best correlation with the experimental results. The possibility of using existing models to calculate the residual strength is also investigated. The shear transfer planes are assumed to be precracked, and the roughness conditions are selected based on the expected path of the cracks relative to the coarse aggregates. Eurocode 2 (EC2) provides the best correlations while the ACI calculations are generally conservative. The residual strengths from 30 pushoff specimens are analyzed. A shear friction equation with a coefficient of cohesion equal to zero, a coefficient of friction equal to 1.0, and an upper limit on the stress equal to 5.5 MPa is found to provide adequate calculation of the residual strength of non-precracked pushoff specimens.

1. Introduction

Shear-transfer models which are based on the shear-friction theory (e.g. [1–3]) are semi-empirical models that have been calibrated using experimental data obtained mainly from pushoff specimens (e.g. [4–7]). They can be used to design the transfer of shear across a cold joint or across an existing crack. The transfer can also be across a critical plane not previously cracked, such as the bearing region of a simple girder or the interface between a corbel and the supporting column. See Fig. 1.

Experimental data used in the calibration of these semi-empirical models is available from three main types of pushoff specimens which differ mainly by the conditions at the shear transfer plane: (1) specimens that were precracked, (2) specimens that were not precracked, and (3) specimens that were cast at two different times (with a cold joint). Fig. 2 plots a summary of a survey of the number of available test results from conventional pushoff specimens (with conventional reinforcing bars, and with no applied flexure or axial stresses perpendicular along shear plane) [4–19]. The plot gives separate counts for specimens with normal strength concrete (NSC) (with compressive strength less than 50 MPa) and for relatively higher strength concrete (with strength larger than 50 MPa). The figure shows that there is a limited amount of data from high strength concrete (HSC) uncracked specimens. Recent studies also showed that existing analytical models focus largely on the cases of precracked interfaces and cold joints [20,21]. This research aimed at providing more data on non-precracked HSC specimens.

On the other hand, it has been observed by Mattock et al. [14] that after reaching the ultimate shear strength, non-precracked pushoff specimens resisted a residual strength which was similar to the strength of the precracked specimens. The tests by Kahn and Mitchell [4] and the Finite Element analysis by Xu et al. [22] confirmed this observation. In spite of its practical importance, this residual strength has not been typically reported separately from the ultimate strength. This research aimed at adding to the limited available tests results which differentiate between the ultimate and the residual strengths.

The stresses at which shear cracks first develop are of importance. For example, these values can be used to establish a benchmark for the selection of the minimum amount of clamping

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Nomenclature

c	coefficient related to cohesion
f'_c	specified compressive strength of concrete (cylinder)
f_{cd}	design compressive strength of concrete (EC2)
f_{ck}	characteristic compressive strength of concrete at 28 days (EC2)
f_{ctd}	design tensile strength of concrete (EC2)
f_{cu}	compressive strength of 150 mm concrete cube
f_{cy}	compressive strength of standard concrete cylinder
f_y	yield strength of reinforcement
f_{yL}	yield strength of longitudinal reinforcement
f_{yv}	yield strength of clamping reinforcement
v_{cr}	cracking shearing stress
$v_{cr\text{-}A}$	cracking shearing stress calculated using ACI equation
v_r	observed post-ultimate residual shearing strength
$v_{r\text{-}AASHTO}$	residual shearing strength (AASHTO specifications)
$v_{r\text{-}ACI}$	residual shearing strength (ACI code)
$v_{r\text{-}EC2}$	residual shearing strength (EC2 code)
$v_{r\text{-}Mat}$	residual shearing strength (Mattock model)
v_u	observed ultimate shearing strength
$v_{u\text{-}AASHTO}$	nominal shearing strength (AASHTO specifications)
$v_{u\text{-}ACI}$	nominal shearing strength (ACI code)
$v_{u\text{-}Mat}$	nominal shearing strength (Mattock model)
$v_{u\text{-}SMCS}$	nominal shearing strength (SMCS model)
v_y	observed yielding shearing stress
η	strength reduction factor (EC2 code)
ρ_L	ratio of longitudinal reinforcement (parallel to shear transfer plane)
ρ_v	ratio of clamping reinforcement perpendicular to shear transfer plane
μ	coefficient of friction in shear friction models
ω_L	reinforcement index in longitudinal direction (SMCS model)
ω_v	reinforcement index in transverse direction (SMCS model)

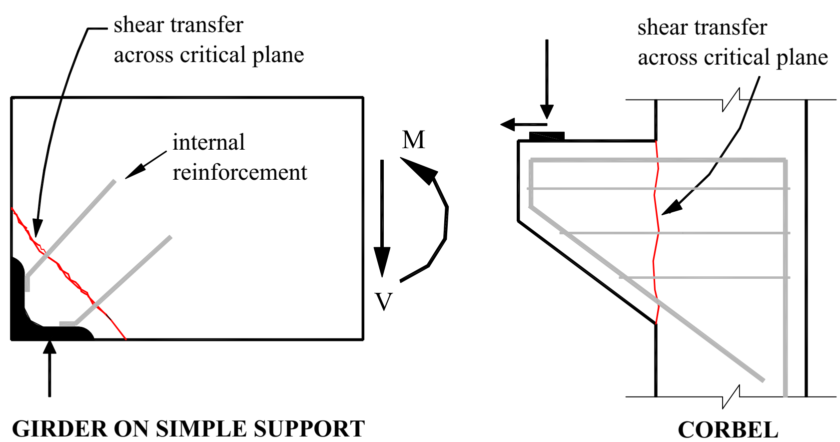

Fig. 1. Transfer of shear across critical planes not previously cracked.

reinforcement. The cracking shearing stresses are not typically reported in pushoff tests. This research aimed at providing information on the cracking shearing stresses.

Hence, this paper reports the results of an experimental program which aimed at gaining a better understanding of the behavior of non-precracked HSC pushoff specimens. Since the use of self-compacting concrete (SCC) is on the rise around the globe, the concrete used was made with SCC properties. The results from 15 specimens are reported. Twelve of the specimens were SCC (six NSC and six HSC specimens), and three specimens were normal strength conventional concrete. The three conventional concrete specimens are control specimens. The experimental behavior and strengths are given, including a detailed account of the cracking, yield, ultimate and residual stresses.

In addition to reporting the experimental results, this paper also compares between the observed ultimate strengths and the calculations of the shear-transfer models of the ACI code [1], the AASHTO LRFD Specifications [2], the Mattock's tri-linear empirical model [3], and the simplified model for combined stress-resultants (SMCS) model [23]. This paper also investigates the possibility of

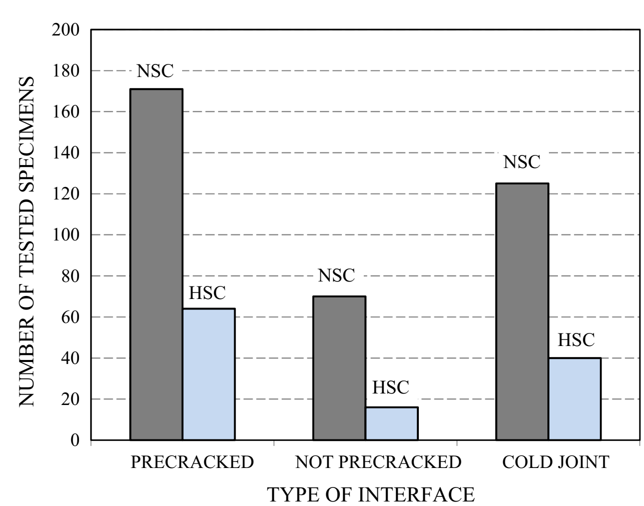

Fig. 2. Number of reported pushoff tests in literature.