Available online at www.sciencedirect.com

ScienceDirect

Construction and Building Materials 22 (2008) 1708–1722

Construction and Building MATERIALS

www.elsevier.com/locate/conbuildmat

Tests and analysis on shear strength of composite slabs of hollow core units and concrete topping

Ulf Arne Girhammar [a,*], Matti Pajari [b]

[a] Department of TFE – Civil Engineering, Faculty of Science and Technology, Umeå University, SE-901 87 Umeå, Sweden
[b] VTT Building and Transport, VTT Technical Research Centre of Finland, Espoo, Finland

Received 27 July 2006; received in revised form 11 May 2007; accepted 30 May 2007
Available online 26 July 2007

Abstract

Prestressed concrete hollow core slabs are commonly used as load-bearing floors and roofs. The upper surface of the hollow core slabs is usually levelled with a cast-in situ screed or concrete topping. Reducing the thickness of the precast unit and increasing the thickness of the concrete topping, but maintaining the load-carrying capacity for the whole composite section is technically and economically an interesting alternative. The expensive screed could be replaced by a cheaper concrete and installations could be embedded in the topping layer. Proper shear and bond strength at the interface is required for composite action. An experimental and theoretical study on the effect of structural topping on the shear capacity of hollow core slabs and of the adequacy of the shear or bond strength of the non-treated interface is presented. It is concluded that concrete topping can be used to improve the shear capacity of hollow core units. For the test specimens, the theoretical increase was of the order of 35%, which was verified by the tests. The bond strength at the interface is adequate and the topping interacts with the slab in a proper manner.

Keywords: Precast concrete; Hollow core slabs; Concrete topping; Composite construction floors; Composite action; Shear/bond strength

1. Introduction

1.1. General

Prestressed hollow core slabs are commonly used as load-bearing floors and roofs. In most cases, the upper surface of the hollow core slabs must be levelled with a cast-in situ screed. Normally, advantage is not taken of this topping layer as a composite construction because of the uncertainty concerning the bond strength between the precast and cast-in situ concrete. Also, the thickness of the screed layer is often too small to significantly increase the moment capacity of the structure.

Reducing the thickness of the precast unit from the present 27 to 20 cm and increasing simultaneously the thickness of the topping to 5–8 cm might be an interesting alternative. The expensive screed could be replaced by a cheaper concrete and installations could be embedded in the topping layer. The total depth or the self-weight of the construction might be reduced.

Proper shear strength at the interface is required for the composite action. It is also important that the horizontal and vertical shear strength of the joint between adjacent hollow core units is high enough to transmit the forces due to horizontal diaphragm action and load-sharing of concentrated loads.

Sometimes, when making the topping of normal concrete, some kind of fabric reinforcement in the topping and special shear reinforcement in the joints are needed. It would be more rational to use fibre reinforced concrete, even if it is more expensive.

Therefore, it is important to study what kind of surface is required for good bond at the interface and whether the fibre reinforcement in the topping and in the joints can guarantee the composite action. It is also important to

* Corresponding author. Tel.: +46 90 786 74 95; fax: +46 90 786 64 69.
E-mail address: ulfarne.girhammar@tfe.umu.se (U.A. Girhammar).

0950-0618/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.conbuildmat.2007.05.013

Nomenclature

a	shear span length
A	cross-sectional area
A_S	cross-sectional area of strands
ACI	American Concrete Institute
b	width
b_w	thickness of web of hollow core slab
d	effective depth of slab
E_c	modulus of elasticity of concrete
E_p	modulus of elasticity of tendons
f_{cc}	compressive strength of concrete
f_{cs}	concrete shear strength at interface of hollow core unit and concrete topping
f_{ct}	tensile strength of concrete
f_p	yield or ultimate tensile strength of tendons
F	imposed load
FRC	fibre reinforced concrete
h	depth of slab
I	second moment of inertia
K	concrete grade
L	span length
M_i	imposed moment
P	prestressing force (acting on the cross-section of the hollow core slab (HC))
PC	plain concrete
s	standard deviation
S	first moment of area
S_{top}	first moment of area of the concrete topping cross-section around the centroidal axis of the total cross-section (HCT)
V	shear force
x	coordinate

Greek letters

∅	diameter
η_{HCT}	distance between neutral axes of the hollow core slab (HC) and hollow core slab and concrete topping (HCT)
σ	normal stress
σ_p	principal normal stress
τ	shear stress

Subscripts

adj	adjusted
c	concrete
cc	concrete compression
cs	concrete shear
ct	concrete tension
cyl	cylinder
d	design
F	attributable to external load F
G	attributable to self-weight G
HC	attributable to cross-section of hollow core slab
HCT	attributable to cross-section of hollow core slab and concrete topping (the whole cross-section)
i	imposed
ib	interface bond
int	interface between hollow core unit and concrete topping
k	characteristic
m	mean
max	maximum
min	minimum
obs	observed
p	principal
pre	predicted
P	attributable to external load P
ref	reference
top	topping
u	ultimate
u, i	ultimate with respect to the ith failure mode
w	web

study the effects of differential shrinkage and creep for interacting precast "high-grade concrete" and cast-in situ "low-grade concrete".

1.2. Previous work

Earlier works on prestressed hollow core slabs with concrete topping include Scott [1] and Ueda and Stitmannaithum [2]. Scott [1] presented a load test of a machine-made hollow core slab with composite topping and found that composite action between the precast and cast-in place portions was evident up to ultimate load. The top surface of the precast slab was a smooth, even, machine cast finish. There was no reinforcing steel projecting from the precast slab into the topping concrete. The test further demonstrated substantial shear strength capabilities for the hollow core member when used in conjunction with a 50 mm concrete topping of modest strength. Ueda and Stitmannaithum [2] conducted an experimental program to investigate the shear-carrying capacity of precast prestressed hollow core slabs with concrete topping. The parameters investigated were prestressing force, thickness of concrete topping, shear span-to-effective depth ratio, and tensile reinforcement ratio. They observed in their tests complete composite action although only rough surface finishing was provided. Only small slips were measured between the precast and topping concrete elements, and there was no evidence that their interface was an initiator of ultimate failure. For both thick and thin concrete topping, web shear cracking always took place in the precast element