Engineering Structures 33 (2011) 855–867

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Crushing and flexural strength of slab–column joints

Roberto Guidotti, Miguel Fernández Ruiz*, Aurelio Muttoni

Ecole Polytechnique Fédérale de Lausanne, Station 18, CH-1015 Lausanne, Switzerland

ARTICLE INFO

Article history:
Received 10 June 2010
Received in revised form
3 November 2010
Accepted 1 December 2010
Available online 30 December 2010

Keywords:
Flat slabs
Concrete crushing
Slab–column joints
Theory of plasticity

ABSTRACT

In multi-storey buildings, columns are usually not continuous through the slabs to enhance ease of construction. Consequently, in slab–column joints, slabs have to carry column loads in addition to the shear and bending moments due to loads applied to the slab. In most cases, when high strength concrete is used for the columns and normal strength concrete for the slabs, compression stresses at the support areas of the inner columns exceed the uniaxial compressive strength of the concrete of the slab. Due to this reason, most current details for such regions reinforce the concrete of the slab between columns to ensure load transfer. Typically, this is achieved by linking top and bottom columns with reinforcement. Sometimes, it is also needed to incorporate special load transfer devices. This latter solution is however relatively complicated and expensive.

In this paper, the crushing and flexural strength of slab–column joints is investigated accounting for an increase of the compressive strength of the failure region (concrete between columns) due to confinement stresses provided by the flexural reinforcement of the slab. The results of an experimental programme on 6 full-scale slabs (250 mm thick) are presented showing that flexural reinforcement of a slab significantly increases the crushing strength of slab–column joints. This allows ensuring load transfer without incorporating special devices or even without linking top and bottom column reinforcement for a wide range of cases leading potentially to more economic designs. An analytical approach, grounded on the theory of plasticity, is also presented allowing one to determine a failure criterion for such regions. This approach, which can also be used for design purposes, leads to an excellent correlation with test results.

1. Introduction

Reinforced concrete flat slabs supported by columns are currently one of the most widespread structural solutions for multi-storey buildings, with columns cast in situ (Fig. 1(a)) or precast with steel plates at their ends (Fig. 1(b)). The slabs are typically cast in normal strength concrete (specified concrete compressive strength around 30 MPa) whereas the columns are usually cast using high strength concrete (with a specified compressive strength between 60 and 120 MPa). Due to the lower compressive strength of the slab, crushing of the slab at the slab–column joint may potentially be governing for design.

The crushing strength of the joint (N_R) can be calculated as the sum of the compression strength of the concrete of the slab ($N_{c,R}$) plus the strength of the reinforcing bars linking the upper and lower columns ($N_{s,R}$ see Fig. 1(a)). In the case where the eccentricity of the column load can be neglected it results in:

$$N_R = N_{c,R} + N_{s,R} = f_{cc}\,(A_c - A_s) + f_y A_s \tag{1}$$

where f_{cc} refers to the confined crushing strength of concrete, f_y to the yield strength of the reinforcement, A_c to the column support area and A_s to the reinforcement area. In current design practice and if no special confinement reinforcement is available, f_{cc} is typically replaced by f_c (concrete uniaxial compressive strength), neglecting the potential confinement of the failure region provided by the flexural reinforcement of the slab. In order to ensure sufficient strength, some structural solutions have been developed in the past, following two basic principles:

1. Increasing the concrete strength of the slab f_{cc}. This can be achieved by casting the slab near the columns in high strength concrete (Fig. 1(e)) or by placing confinement reinforcement around the columns. Although the flexural reinforcement (Fig. 1(b)) can provide a certain level of confinement, circular stirrups are typically used as confinement reinforcement in the slab (Fig. 1(f)).
2. Incorporating special (typically steel) devices, allowing it to carry the compression of the columns through the slab (Fig. 1(c)), in order to increase the reinforcement strength $N_{s,R}$. These devices can is some cases be combined with corrugated surfaces for the introduction of the shear forces (Fig. 1(d)).

From the aforementioned solutions to increase concrete compressive strength, the most economic one is that of providing confinement only by means of the flexural reinforcement (Fig. 1(a, b)).

* Corresponding author.
E-mail addresses: roberto.guidotti@epfl.ch (R. Guidotti), miguel.fernandezruiz@epfl.ch (M. Fernández Ruiz), aurelio.muttoni@epfl.ch (A. Muttoni).

0141-0296/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2010.12.007