Guide to Shear Reinforcement for Slabs

Reported by Joint ACI-ASCE Committee 421

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Tests have established that punching shear in slabs can be effectively resisted by reinforcement consisting of vertical rods mechanically anchored at the top and bottom of slabs. ACI 318 sets out the principles of design for slab shear reinforcement and makes specific reference to stirrups, headed studs, and shearheads. This guide reviews other available types and makes recommendations for their design. The application of these recommendations is illustrated through numerical examples.

Keywords: column-slab connection; concrete flat plate; headed shear studs; moment transfer; prestressed concrete; punching shear; shear stresses; shearheads; slabs; two-way slabs.

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ACI 421.1R-08 supersedes ACI 421.1R-99 and was adopted and published June 2008.

CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

In flat-plate floors, slab-column connections are subjected to high shear stresses produced by the transfer of the internal forces between the columns and the slabs. Section 11.11.3 of ACI 318-08 allows the use of shear reinforcement for slabs and footings in the form of bars, as in the vertical legs of stirrups. ACI 318 emphasizes the importance of anchorage details and accurate placement of the shear reinforcement, especially in thin slabs. Section 11.11.5 of ACI 318-08 permits headed shear stud reinforcement conforming to ASTM A1044/A1044M. A general procedure for evaluation of the punching shear strength of slab-column connections is given in Section 11.11 of ACI 318-08.

Shear reinforcement consisting of vertical rods (studs) or the equivalent, mechanically anchored at each end, can be used. In this report, all types of mechanically anchored shear reinforcement are referred to as "shear stud" or "stud." To be fully effective, the anchorage should be capable of developing the specified yield strength of the studs. The mechanical anchorage can be obtained by heads or strips connected to the studs by welding. The heads can also be formed by forging the stud ends.

1.2—Scope

Recommendations in this guide are for the design of shear reinforcement in slabs. The design is in accordance with ACI 318. Numerical design examples are included.

1.3—Evolution of practice

Extensive tests (Dilger and Ghali 1981; Andrä 1981; Van der Voet et al. 1982; Mokhtar et al. 1985; Elgabry and Ghali 1987; Mortin and Ghali 1991; Dilger and Shatila 1989; Cao 1993; Brown and Dilger 1994; Megally 1998; Birkle 2004; Ritchie and Ghali 2005; Gayed and Ghali 2006) have confirmed the effectiveness of mechanically anchored shear reinforcement, such as shown in Fig. 1.1, in increasing the strength and ductility of slab-column connections subjected to concentric punching or punching combined with moment. Stud assemblies consisting of either a single-head stud attached to a steel base rail by welding (Fig. 1.1(a)) or double-headed studs mechanically crimped into a nonstructural steel channel (Fig. 1.1(b)) are specified in ASTM A1044/A1044M. Figure 1.2 is a top view of a slab that shows a typical arrangement of shear reinforcement (stirrup legs or studs) in the vicinity of an interior column. ACI 318 requires that the spacing g between adjacent stirrup legs or studs, measured on the first peripheral line of shear reinforcement, be equal to or less than $2d$. Requirement for distances s_o and s are given in Chapter 4.

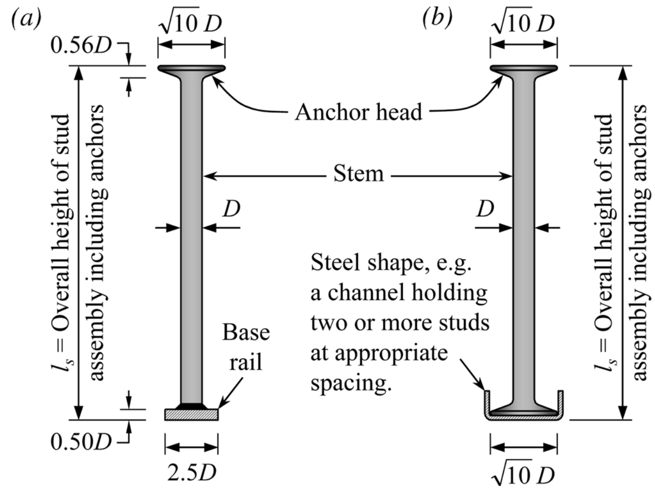

Fig. 1.1—Stud assemblies conforming to ASTM A1044/A1044M: (a) single-headed studs welded to a base rail; and (b) double-headed studs crimped into a steel channel.

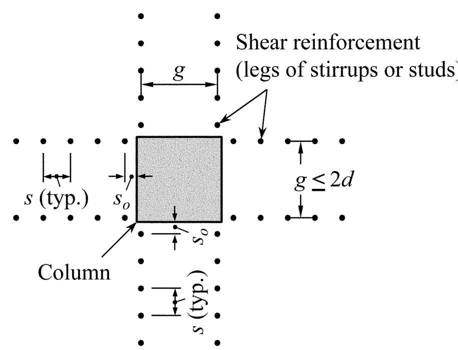

Fig. 1.2—Top view of flat plate showing arrangement of shear reinforcement in vicinity of interior column.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

A_c = area of concrete of assumed critical section
A_v = cross-sectional area of shear reinforcement on one peripheral line parallel to perimeter of column section
b_o = length of perimeter of critical section
c_b,c_t = clear concrete cover of reinforcement to bottom and top slab surfaces, respectively
c_x,c_y = size of rectangular column measured in two orthogonal span directions
D = diameter of stud or stirrup
d = effective depth of slab; average of distances from extreme compression fiber to centroids of tension reinforcements running in two orthogonal directions
d_b = nominal diameter of flexural reinforcing bars
f_c' = specified compressive strength of concrete
f_{ct} = average splitting tensile strength of lightweight-aggregate concrete
f_{pc} = average value of compressive stress in concrete in two directions (after allowance for all prestress losses) at centroid of cross section