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# Guide for Shear Reinforcement for Slabs

Reported by Joint ACI-ASCE Committee 421

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## **Guide for Shear Reinforcement for Slabs**

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# Guide for 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 top and bottom of slabs. ACI 318 sets out the principles of design for slab shear reinforcement and makes specific reference to stirrups and headed studs. This guide reviews 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 heads; shear stresses; slabs; two-way slabs.

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## 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. ACI 318-14 Section 8.7.6.1 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. ACI 318-14 Section 8.7.7.1 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 ACI 318-14 Section 8.5.3.

Shear reinforcement consisting of vertical rods (studs) or the equivalent, mechanically anchored at each end, can be used. In this guide, 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 the practice

Extensive tests (Dilger and Ghali 1981; Andr a 1981a,b; Van der Voet et al. 1982; Mokhtar et al. 1985; Elgabry and Ghali 1987; Mortin and Ghali 1991; Dilger and Shatila

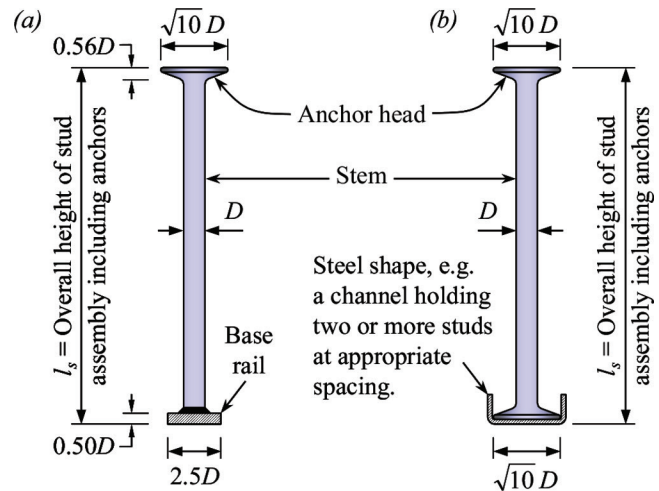


Fig. 1.3a—Stud assemblies conforming to ASTM A1044/A1044M: (a) single-headed studs welded to a base rail; and (b) double-headed studs crimped into a steel channel.

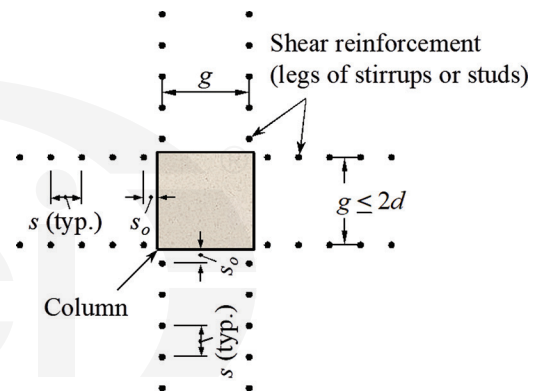


Fig. 1.3b—Top view of flat plate showing arrangement of shear reinforcement in vicinity of interior column.

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. 1.3a, 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. 1.3a(a)) or double-headed studs mechanically crimped into a nonstructural steel channel (Fig. 1.3a(b)) are specified in ASTM A1044/A1044M. Figure 1.3b 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  $2d$ . Recommendations for the distances  $s_o$  and  $s$  are given in Chapter 4.

## CHAPTER 2—NOTATION AND DEFINITIONS

### 2.1—Notation

$A_c$  = area of concrete of assumed critical section, in.<sup>2</sup> (mm<sup>2</sup>)