DETAILS AND DETAILING OF CONCRETE REINFORCEMENT (ACI 315-92)

Reported by ACI Committee 315

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This document provides standards of practice for both the Engineer and Reinforcing Steel Detaiier in showing reinforcement details. It is divided into three parts: one addressed to the Engineer, one for the Detailer, and a third providing tables and figures. It attempts to define the responsibilities of both the Engineer and Detailer. It then establishes certain standards of practice for both the engineering and placing drawings.

Keywords: beams (supports); bending (reinforcing steels); bridges (structures); buildings; columns (supports); computers; concrete construction; concrete slabs; **detailing;** drafting (drawing); **engineering drawings**; fabrication; floor systems; foundations; hooked reinforcement; **reinforced concrete**; **reinforcing steels**; splicing; stirrups; **structural design**; ties (reinforcement); tolerances (mechanics); walls; welded wire fabric.

FOREWORD

Increased use of computers has led to sophisticated techniques of structural analysis and has also increased manufacturing and fabrication capabilities. The result is that more complex structures are being designed and built with structural members which have long spans, shallow depths, and contain a high percentage of reinforcement.

In the past, during the course of developing placing drawings, the Detailer often suggested solutions in areas where the details were incomplete and where the reinforcing steel appeared to have constructibility problems. Usually these solutions were used only after their acceptance by the Engineer. Unfortunately, many problems do not surface during the detailing phase but rather occur during construction. The Engineer and the Contractor, working together, then solve the problem.

The Engineer prepares the structural design to meet the requirements of the applicable building code and provides sufficient definition through the design documents to convey all the requirements for detailing reinforcing steel. It is then the Detailer's responsibility to develop all of the dimensions and quantities of the reinforcing steel to conform with the drawings and specifications of the Engineer.

As the complexity of design and construction increase, it is imperative that both Engineer and Detailer clearly understand their responsibilities. The responsibilities of the Engineer and the Detailer as they apply to the con-

ACI Committee Reports, Guides, Standard Practices, and Commentaries are intended for guidance in designing, planning, executing, or inspecting construction, and in preparing specifications. Reference to these documents shall not be made in the Project Documents. If items found in these documents are desired to be part of the Project Documents, they should be phrased in mandatory language and incorporated into the Project Documents.

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crete industry are stated more clearly by providing separate sections for each.

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PART A-RESPONSIBILITIES OF THE ENGINEER

CHAPTER l-ENGINEERING DRAWINGS

l.l-General

Engineering drawings are those prepared by the Engineer for the Owner or purchaser of engineering services. The engineering drawings and the project specifications form a part of Contract Documents. Engineering drawings should contain an adequate set of notes and all other essential information in a form that can be quickly and correctly interpreted. These drawings should convey definite instructions and show reinforcing bars and welded wire fabric. Engineering and placing drawings may be combined.*

The responsibility of the Engineer is to furnish a clear statement of design requirements; the responsibility of the Detailer is to carry out these requirements. The Engineer's specifications or drawings should not merely refer the Detailer to an applicable building code for information to use in preparing placing drawings. Instead, this information should be interpreted by the Engineer and shown in the form of specific design details or notes for the Detailer to follow. Where omissions, ambiguities, or incompatibilities are discovered, additional information, clarifications, or corrections should be requested by the Detailer and provided by the Engineer. The Engineer should require in the specifications that placing drawings be submitted for approval.

Section 1.2.1 of the ACI 318 Building Code lists the information that shall be shown on the structural drawings, which includes the following:

- Anchorage length of reinforcement and location and length of lap splices
- Type and location of welded splices and mechanical connections of reinforcement

1.2-Drawing standards

1.2.1 *Materials*-The minimum standard media for production of engineering drawings should be pencil on tracing paper. Other media providing improved reproducibility or durability such as ink, tracing cloth, or polyester film may be utilized.

1.2.2 *Sizes*-Drawings should be made in standard sizes. All sheets in any one set of drawings should be the same size. There are two well-recognized sets of standard sizes.

Commercial standards:

18 x 24 in.
24 x 36 in.
27 x 36 in.
30 x 42 in.

Federal agencies:

17 x 22 in.
22 x 34 in. + 2 in. binding (AASHTO)
28 x 40 in. + 2 in. binding
30 x 42 in.

All dimensions are to cutting line outside of margin. Border lines are inside these dimensions.

1.2.3 *Direction*-An arrow indicating the direction of north should be placed on every drawing which contains a plan view.

1.2.4 *Scales*-The scales used should be indicated on all engineering drawings, preferably under the title of each view. Drawings that may be enlarged or reduced in reproduction should show a graphic scale as well as a descriptive one to aid the user.

1.2.5 *Lettering*- All lettering shall be clear and legible. If reduced-scale photographic prints are to be made for field use, lettering must be correspondingly larger, and meet microfilming standards in accordance with the National Microfilm Association publication "Modern Drafting Techniques for Quality Microreproductions."

* Requirements for placing drawings are in Part B, addressed to the Detailer.

1.3-Engineering drawings-Buildings and other structures

1.3.1 *General*-Engineering drawings and/or specifications for elements like beams, girders, columns, walls, and foundations shall show type and grade of steel, any special coatings, service live load, partition, ceiling and hanging loads, or any special dead loads other than the self-weight and concrete strength. Engineering drawings and/or specifications shall also show concrete dimensions, anchorage length of reinforcement and location and length of lap splices, type and location of welded splices and mechanical connections of reinforcement, concrete cover for the reinforcement, required joints, and any other information needed for the preparation of reinforcement placing drawings. Sleeve locations and any special reinforcement around sleeves or openings should be indicated by the Engineer. See Fig. 1, 2, 3, 7, 15, 16, and 18. In addition to these requirements, engineering drawings of beams, girders, and columns should also show the information presented below.

1.3.2 *Beams and girders*-Schedules for beams and girders must contain: the beam mark; size of member; number and size of straight and bent bars; special notes on bending; number, size, grade, and spacing of stirrups or stirrup-ties; location of top bars; and any special information, such as the requirement of two layers of steel. Show sections for beam-column joints, where necessary.

In continuous beams the number and spacing of top bars to be placed in T-beam flanges (slabs) for crack control must be shown, if so required by the design.

1.3.3 *Columns*-Column designs must show size of columns, number, locations, grade and size of reinforcement, and all necessary details where column section or reinforcement changes. Splicing must always be clearly defined, showing arrangement of splices, whether butt or lapped, any staggers, and type of connection required for butt splices. Orientation of reinforcement in two-way symmetrical columns must be shown when reinforcement is not two-way symmetrical.

1.4-Engineering drawings-Highway and transportation structures*

1.4.1 *Dimensions*-Since the engineering drawings for highway structures usually are a combination of engineering and placing drawings from which the structure will be built, all dimensions should be clearly shown. Drawings must show the dimensions of concrete protection for all reinforcement.? Where separate placing drawings are prepared, structural dimensions may be omitted following the same practice as for buildings (see Section 3.5).

1.4.2 Reinforcement -Combination engineering-placing drawings must show the size, spacing, and location of the bars and welded wire fabric in the structure. The list of bars must show the number of pieces, size, length, mark of bars, and bending details of all bent bars. The list of welded wire fabric must show the mark, style, width, length and number of pieces.

Reinforcement for larger structures is sometimes detailed, fabricated, and delivered by units, for example, footings, abutments, piers, and girders. The reinforcement list may be similarly subdivided. If the structure is sufficiently large, a separate drawing and reinforcement list is usually made for each unit.

Reinforcement for foundations, piers, abutments, wingwalls, and slabs are usually shown on the plan, section, or elevation. Cross sections must be provided for clarification where necessary. The reinforcement list must be a complete summary of materials required.

For reference data on reinforcing bars and welded wire fabric from industry sources, refer to the Supporting Reference Data section of this manual. This section includes specific information on applicable ASTM specifications, coated reinforcing bars, common stock styles and design data for welded wire fabric, and reinforcing bar supports.

CHAPTER 2-STANDARDS OF PRACTICE

2.1-General

This chapter provides the Engineer with minimum standards for application during the development of the design. Information presented here is a collection of notes derived from ACI 318; ACI 343R; AREA "Manual for Railway Engineering," Chapter 8, Concrete Structures and Foundations; and AASHTO "Standard Specifications for Highway Bridges," (restated for emphasis and convenience), industry practice, practical considerations, and research results current at the time of this report. Reinforcement for structures designed under the provisions of ACI 349,‡ ACI 359,§ and other similar documents can generally incorporate the direction given in this standard unless otherwise prohibited by the provisions of the respective related documents.

2.2-Tolerances

Practical limitations of equipment and production efficiency have led to establishment of certain fabrication tolerances which can be met with standard shop equipment. These standard tolerances are shown in Fig. 4 and 5 for both straight and bent bars. Where more restrictive tolerances are required than those shown in the referenced figures, they should be indicated in the Contract Documents. The effects of tolerances on cover, strength, constructability, and serviceability of the structure should be considered by the Engineer.

* The term "highway and transportation structures" used herein includes bridges, drainage, and related structures.

† Subject to requirements of ACI 318, Section 7.7.1 or AASHTO bridge specification.

‡ Code Requirements for Nuclear Safety Related Concrete Structures.

§ Code for Concrete Reactor Vessels and Containments.

2.3-Combination drawings

Combination engineering-placing drawings should show all bar dimensions as out-to-out with bar lengths as the sum of all detailed dimensions, including Hooks A and G (Table 1).

2.4-Hooks and bends

Hooks and bends are specified to standardize the fabrication procedure and to limit the concrete stresses in the area of the hooks. See Table 1 and Fig. 6.

2.5-Beams and girders

2.51 *Beam widths*-To permit satisfactory placing of concrete and to protect bars from corrosion, the Engineer must provide for adequate clear distance between parallel bars and between bars and forms.

The Engineer must specify the required concrete protection for the reinforcement. The Engineer must also specify the distance between bars for bond development and concrete placing. For buildings, the clear space is at least one bar diameter, $1^1/_2$ times the maximum size of coarse aggregate to be used, but not less than 1 in. For cast-in-place bridges, required clear space is not less than 1.5 bar diameters, 1.5 times maximum size aggregate, nor 1.5 in.

Table 2 gives a wide range of beam widths and the maximum number of bars permitted in a single layer for ¾ in. and 1 in. maximum aggregate size, respectively, as provided by ACI 318. Table 3 similarly gives the same information for beams designed under the provisions of the AASHTO bridge specifications. These tables are provided for the use of the Engineer; the Detailer is not in a position to determine whether bars should be permitted to be placed in more than a single layer.

2.52 *Stirrup anchorage*-The Engineer must show or specify by notes the sizes, spacings, location, and types of all stirrups. These types include open stirrups and closed stirrups (or stirrup-ties) (Fig. 12 and 13). Stirrups can also be fabricated from welded wire fabric.

There are various permissible methods of anchorage, but the most common is to use one of the standard stirrup-tie types as shown in Fig. 6. Types S1 through S6, Tl, T2, and T6 through T9 use standard tie and stirrup hooks as shown in Table 1. Where stirrup support bars are required, they must be specified by the Engineer. In designing the anchorage, allowance must be made to insure that the ends of the stirrup hook are fully encased in concrete, as when hooks turn outward into shallow slabs.

Where the design requires closed stirrup-ties for vertical shear, the closure may consist of overlapped standard 90-deg end hooks of one- or two-piece stirrups, or properly spliced pairs of U-stirrups. Where design requires closed ties for torsion, the closure may consist of overlapped standard 135-deg hooks of one- or two-piece ties enclosing a longitudinal bar. At least one longitudinal bar must be located inside each corner of the stirrups or ties, the size of this bar to be equal to at least the diameter of the stirrup (#4 minimum). Ties provided to resist radial forces resulting from bar or tendon curvature must be adequately anchored.

2.53 *Spacings of bundled bars*-When bars are placed in contact with each other in groups of two, three, or four-known as "bundled bars"-the minimum clear space provided between bundles for buildings under ACI 318 must be equal to the diameter of a single round bar having an area equivalent to the area of the bundle. For bridge design, AREA and AASHTO bridge specifications require a minimum spacing equal to 1.5 times diameter of a single equivalent bar.

2.6-Columns

2.6.1 *Column verticals*--In selecting reinforcement for columns, consideration should be given to the minimum spacing of bars or bundles required by Section 7.6.3 of ACI 318. Table 4 shows the maximum number of bars for round columns, and Table 5 indicates the maximum number of bars that can be placed in one face of a rectangular column. Splice arrangements must be shown. For butt-spliced systems, an allowance must be included for increase in diameter at mechanical connections, and for access to weld. Special end preparation required for bars must be shown or specified. Where the steel area required above is different from that in the column below, the engineering drawings must clearly show the extension required (if any) of all reinforcing bars above and below the floor level (see also Section 2.7).

2.6.2 *Offset between column faces*-Where there is a change in size of a column, the engineering drawings must show how the vertical bars are to be offset, or separate dowels must be shown (see Section 3.7.7.2). The slope of the inclined portion should not exceed 1 in 6. See Fig. 7 for recommended splicing details.

Where column verticals are offset bent, additional ties are required and should be placed not more than 6 in. from the point of the bend. For practical purposes, three closely spaced ties are usually used, one of which may be part of the regularly spaced ties plus two extra ties. General arrangements of vertical bars and all tie requirements should be established by the engineering drawings.

In addition to showing size and regular spacing of column ties, the Engineer must also show any additional ties required for special conditions such as splices, offset-bends, etc.

2.6.3 *Changing bar arrangement between floors*-When the bar arrangement is changed at floors, bars may extend through, terminate, or require separate dowels. Reinforcement at least equal in area to that in the column above should be extended to lap bars above by the required lap length or butt splices should be provided. Vertical bars from the column below terminated for any reason are cut off within 3 in. of the top of the finished floor unless otherwise indicated on the engineering drawing. The Engineer must determine what, if any, additional extension of discontinued column verticals is required for adequate embedment, and show it on the engineering drawings.

2.6.4 *Spirals*-Pitch or spacing of spirals should be given to the nearest quarter inch. According to ACI 318, the clear spacing between spiral turns should not exceed 3 in. or be less than 1 in. or 1-⅓ times the maximum size of coarse aggregate used. Spirals should be provided with 1-½ extra turns at both top and bottom. If necessary to splice a spiral, it should be done by welding or by a lap splice of $48d_b$.

Minimum diameters to which standard spirals can be formed and minimum diameters which are considered collapsible are shown below for various sizes of spiral bars.

Spiral bar diameter, (in.)	Minimum outside diameter which can be formed, (in.)	Minimum outside diameter of collapsible spiral, (in.)
⅜	9	14
½	12	18
⅝	15	24
¾ (special)	30	—

Spirals are used primarily for columns, piers, and drilled caissons, but are also used in piles. Continuously wound reinforcement in the form of a circular helix not meeting the ACI 318 definition of a spiral may be used in these structures as tie reinforcement. Such reinforcement, sometimes referred to as continuous ties, are usually specified with a large pitch.

2.6.5 *Column ties*---The vertical bars in tied columns must be tied together laterally. Standard arrangements of ties for various numbers of vertical bars are shown in Fig. 8, 9, and 10. The Engineer may also specify welded wire fabric with an equivalent area of steel for column ties. The arrangements of one-piece ties shown in Fig. 8 provide maximum rigidity for column cages preassembled on the site before erection. Preassembly is preferred only for the common designs employing one-story length vertical bars all lap spliced at or near one point above the floor line. See Section 2.7.3 for lap splice restrictions.

With staggered butt splices on large vertical bars in two-story lengths, practical erection limitations usually require that column ties be assembled on free-standing vertical bars. Standard arrangements for two-piece column ties shown in Fig. 9 and 10 are recommended to facilitate field assembly. They are universally applicable to any splice arrangement required by the Engineer. If access to the interior of a column or a pier is necessary, or if the Engineer prefers, some other pattern of ties may be substituted, provided that the tie arrangement meets ACI 318 requirements.

The spacing of ties depends on the sizes of vertical bars, size of columns, and the size of ties. The maximum spacings permitted are shown in Table 6.

In addition to showing size and regular spacing of column ties, the Engineer must also show any additional ties required for other special conditions such as at splices, offset-bends, etc. (also see Section 2.10, Seismic Details).

If the design requires lateral reinforcement in the column between the top of the main spiral and the floor level above, it may be provided by a stub spiral (short section of spiral) or circular column ties to permit placing of the reinforcement in the floor system, and the arrangement must be shown.

2.6.6 *Bundled bars*--Bundled bars may be used as column verticals. A bundle is defined as a group of parallel bars bundled in contact to act as a unit. Not more than four bars may be grouped into one bundle. Butt splices or separate splice bars should be used.

Bundled bars must be tied, wired, or otherwise fastened to insure that they remain in position. All bundles of column verticals must be held by additional ties above and below the end-bearing mechanical connections and any short splice bars added for tension should be tied as part of the bundle within the limitation of number of bars in a bundle. A corner of a tie should be provided at each bundle. Ties smaller than #4 for bundled bars must not be used. Design and detail information on bundled bars as column verticals is provided in Table 8.

2.7-Development and splices of reinforcement

2.7.1 *General*-In ACI 318, development and lap splice lengths for deformed reinforcing bars were significantly changed following the recommendations of ACI Committee 408, Bond and Development of Reinforcement. The changes increase these lengths for closely spaced bars and bars with minimal cover. The following category tables, as well as the development and lap splice tables of this Standard were prepared to facilitate compliance with the 318 Code.

Tables 10 through 13 give values of tension development lengths and tension lap splice lengths of straight bars. Values of tension ℓ_d and tension lap splice lengths in the tables are based on the provisions in Chapter 12 of the ACI 318 Building Code. All tabulated data are for Grade 60 reinforcing bars in normal weight concrete with the concrete compressive strength, f_c', ranging from 3000 to 8000 psi.

The tables use the terminology "Categories 1, 2, 3, 4, 5, and 6". Categories 1 through 6, which depend on the type of structural element, concrete cover, and the center-to-center spacing of the bars, are defined in the table on the next page.

Table 10, tension development lengths, and Table 11, tension lap splice lengths, are for uncoated bars. Table 12 and Table 13 are for epoxy-coated bars. There are no special development requirements in the Code for zinc-coated (galvanized) bars and they should be treated as uncoated bars. For lightweight aggregate concrete, the values in the tables would have to be modified by the applicable factor (ACI 12.2.4.2).

Reinforcing bars in structural element	Concrete cover	Category, according to center-to-center bar spacing*			
		$\leq 3d_b$	$> 3d_b$ $< 4d_b$	$\geq 4d_b$ $< 6d_b$	$\geq 6d_b$
Longitudinal bars in beams and columns, and inner layer of walls or slabs	$\leq d_b$	1	1	1	2
	$> d_b$	1	3	5	6
All other reinforcing bars	$\leq d_b$	1	1	1	2
	$> d_b$, $< 2d_b$	1	3	3	4
	$\geq 2d_b$	1	3	5	6

Where d_b= nominal diameter of a bar

* When bars are lap-spliced in-plane, in which the bars all lie in one plane, the center-to-center spacing of the bars must be reduced by one bar diameter when determining the development category.

These notes apply to all the tabulated values of tension development and tension lap splices:

1. Values of ℓ_d for bars in beams or columns are based on transverse reinforcement meeting minimum requirements for stirrups in ACI 115.4 and 11.5.5.3, or meeting tie requirements in ACI 7.105; and are based on minimum cover specified in ACI 7.7.1.
2. Top bars are horizontal bars with more than 12 in. of concrete cast below the bars.
3. #11 and smaller edge bars with center-to-center spacing not less than $6d_b$ are assumed to have a side cover not less than $2.5d_b$. Otherwise, Category 5 applies rather than Category 6.
4. Conditions which require Category 1 or Category 2 development or lap splice lengths should be avoided if at all possible for the larger bar sizes. These inordinately long lengths present possible constructability problems in placing reinforcement and causing congestion that interferes with placing and consolidation of concrete. Options available for avoiding Category 1 or 2 conditions include:
   a. Increasing the concrete cover to more than one bar diameter and/or increasing the bar center-to-center spacing to more than three bar diameters. See Table 2b.
   b. Using the A_{tr} allowance in ACI 12.2.3.1(b) for beams or columns. Note that if ties or stirrups meet the minimum A_{tr} requirement, Category 1 lengths are reduced to Category 5 lengths and Category 2 lengths are reduced to Category 6 lengths.

Two additional notes apply to the tabulated values of tension lap splice lengths in Table 11 and Table 13:

5. Lap splice lengths are multiples of tension ℓ_d, i.e., values in Table 11 are multiples of ℓ_d in Table 10 and values in Table 13 are multiples of ℓ_d in Table 12. Class A = 1.0 ℓ_d and Class B = $1.3\ell_d$ (ACI 12.15.1).
6. When bars are lap-spliced in plane, in which the bars all lie in one plane, the center-to-center spacing of the bars must be reduced by one bar diameter when determining the development category.

One additional note applies to the tabulated values of tension development and lap splice lengths for epoxy-coated bars in Table 12 and Table 13:

7. If center-to-center spacing is at least $7d_b$ and concrete cover is at least $3d_b$, then Category 6 lengths may be multiplied by 0.918 (top bars) or by 0.8 (other bars).

Section 1.2.1 of ACI 318 requires that all development and lap splice details be shown on the structural drawings. This information can be shown by dimensioning cut-off locations and including tables of applicable lap splice lengths.

2.7.2 *Splices, general*-In beams or girders that require bars longer than can be carried in stock, splices must be specified. The Engineer must show or specify by notes how the splicing is to be realized; viz., lapping, welding, or mechanical connections.

The Engineer must also show by details on engineering drawings the location and length of all splices. In beams or girders splices should preferably be made where the stress in the bar is minimum, i.e., at the point of inflection. Splices where the critical design stress is tensile should be avoided by the Engineer wherever possible. Lapped bars may be either in contact or separated. The Engineer should show or note on the drawings whether splices are to be staggered or made at the same location. Bars to be spliced by noncontact lap splices in flexural members shall not be spaced transversely more than one-fifth the length of lap nor 6 in.

2.7.3 *Lap splices*-Since the strength of a lap splice varies with bar diameter, concrete strength, bar spacing, concrete cover, position of the bar, distance from other bars, and type of stress (compressive or tensile), it is necessary for the Engineer to show the location and length of all splices. Where bars of two sizes are lap spliced, the Engineer shall indicate the appropriate lap splice length. Lap splices are not permitted for #14 and

18 bars, except for transferring compression to smaller size dowels that are anchored into footings for buildings. Lap splices for bars larger than # 11 are not permitted by the AASHTO or AREA bridge specifications.

Tables 9 through 15 are provided for the convenience of the Engineer.

At column bar splice points, sufficient bars (or dowels) from the lower columns must extend into the upper column to provide not less than the cross-sectional area of the required bars in the upper column. These bars must extend the minimum distance required for column splices. At least four bars should be so extended for tied columns and six for spiral columns. The Engineer should note that unless otherwise specified or shown on engineering drawings, the Detailer will detail the remaining bars in the lower column extending to within 3 in. of the top of the floor or other member transmitting the additional load to the column. Where the top ends of column bars are less than 6 ft above the top of footings or pedestals, the bars should extend into the footing or pedestals. Normally, dowels will be used only if specifically noted on engineering drawings.

Dowels for lap splices at column offsets should have a cross-sectional area at least equal to that of the bars above and they must extend both above and below the splice points, as shown or specified by the Engineer.

The Engineer should also be aware that it is a standard practice in the industry when detailing column verticals to use the appropriate lap splice length for the bars in the column above. This applies regardless of differences in bar sizes.

For columns, the arrangement of bars at a lap splice is shown in Fig. 7. It should be noted that the amount of offset of the bars is greater for rectangular columns than for round columns. Column verticals to be lap spliced in square or rectangular columns, where column size does not change, are usually shop offset bent into the column above, unless otherwise shown by the Engineer. The Engineer must indicate which vertical bars are to be offset bent for round columns in those cases where the column size doesn't change.

Where the depth of the footing, or footing and pedestal combined, is less than the minimum length of embedment required for dowels of a certain size, the size of dowel should be decreased and the number of dowels should be increased to give equivalent area and shown on the engineering drawings. Hooks at the ends of the bars may be desirable to resist tension, but the hook may not be considered in determining the embedment provided for compression.

Separate splice bars (dowels) are necessary for splicing column bars where the column section changes 3 in. or more, or the placing of parts of the structure is delayed, or between various units of structures. Except for special cases, separate splice bars (dowels) should be of the same number, size, and grade as the bars joined and should be of proper length to splice with the main bars, and must be specified by the Engineer.

Lap splices for deformed welded wire fabric must be shown by the Engineer.* ACI 318 requires that, for deformed welded wire fabric, the splice shall be at least 1.3 times the development length (8 in. minimum). The Engineer shall indicate the required splice dimension(s).

Lap splices for plain welded wire fabric must also be shown by the Engineer.* ACI 318 requires that the splice length, as measured between outermost cross wires of each fabric sheet, must be not less than one spacing of cross wires plus 2 in. nor less than 1.5 ℓ_d (6 in. minimum) when A_s provided/A_s required < 2. When A_s provided/A_s required $\geq$ 2, only the requirement of $1.5\ell_d$ (2 in. minimum) will apply. Therefore the Engineer may either show the required splice dimension or indicate a typical detail showing splice length equal to one spacing of cross wires plus 2 in., if that controls.

2.7.4 *Butt splices*-Full welded splices or mechanical connections may be specified or, for compression only, end bearing splices may be specified as butt splices for vertical column bars. For #14 and #18 bars, butt splices must be used. Special preparation of the ends of the vertical bars is usually required for butt splices. Where bars are arc welded, the most common practice is to provide a square-cut end at the top of the lower bar and a double-beveled end on the bottom of the upper bar. Field preparation of ends by flame cutting is satisfactory. All welding of reinforcing bars must conform to AWS Dl.4. Where a mechanical connection is used, both ends of the bar may be either square cut, flame cut, or standard shear cut, depending on the type of connection used. Since the mechanical connections are usually staggered between alternate vertical bars and their location depends on the design requirements, the Engineer must indicate the types of mechanical connections permissible, their location, and end preparation required.

2.8-Connection details

2.8.1 *Rigid frame comers*-The Engineer must exercise care in designing the corner joint of a rigid frame. All main reinforcement which passes through the joint must be free of any kinks or discontinuous bending. The center of radius of the bend must be kept within the joint. This point is important in splicing the top bars from the girder to the outside bars in the column. The Engineer must provide complete information, showing radius of bend and location and dimensions of lap splices. If welding or a mechanical connection is to be used, a full description must be provided. Radial tension in concrete as well as tension caused by reentrant corner bends in bars should be considered.

2.8.2 *Wall intersections and comers*-All horizontal wall reinforcement in one, or sometimes both, faces of a wall should be sufficiently extended past a corner or intersection to be fully developed (Fig. 11). The Engineer must indicate which, if any, horizontal reinforcement

*** Supplementary data on welded wire fabric appears in the Detailing Manual SP-66, Supporting Reference Data, Chapter 2-Welded Wire Fabric.**

must be extended, how far it must be extended, and how it must be anchored at intersections and corners of walls and footings. In areas where the applicable building code requires earthquake-resistant design, standard practice requires anchorage of all horizontal bars.

Walls with loads that open corner intersections must be reinforced differently than walls with loads that close such intersections. Typical details are shown in Fig. 11 for resistance against loads from outside or inside, with the reinforcement from the appropriate face or faces anchored. Precautions to restrain radial tension are similar to those for rigid frame corners.

2.8.3 *Closed stirrups*-Where the engineering drawings show closed stirrups, these stirrups may be closed by two-piece stirrups using overlapping standard 90-deg end hooks enclosing a longitudinal bar, or by properly spliced pairs of U-stirrups or a standard one-piece Type T1 or T2 stirrup tie. At least one longitudinal bar must be located at each corner of the section, the size of this bar to be at least equal to the diameter of the stirrup but not less than #4. These details must be shown by the Engineer. See Fig. 13. It should be noted that the use of 90-deg hooks and lap splices in closed stirrups is not considered effective in situations where the member is subjected to high torsional stress. Tests* have shown premature failure due to spalling of the concrete covering and consequent loss of anchorage in the 90-deg hooks and lap splices in these situations. See Fig. 14.

2.8.4 *Structural integrity*-Specific details for continuity of reinforcement to meet structural integrity requirements must be incorporated in the design details by the Engineer. Continuity is required in cast-in-place construction for joists, beams, and two-way slabs. Continuity of selected flexural reinforcement is achieved by making bars continuous or providing Class A tension splices and terminating bars with standard hooks at non-continuous supports. Certain proportions of top and bottom flexural reinforcement in perimeter beams must be made continuous around the structure and confined with closed stirrups. See ACI 318, Section 7.13 and Figures 2 and 3 for example details for structural integrity.

2.9-Reinforcement supports

The Engineer is responsible for specifying acceptable materials and/or corrosion protection required for reinforcement supports, and if required, for side form spacers, as well as the particular structural elements or areas in which each is to be used. Specifications for use of reinforcement supports usually are based on established industry practice.† For more details on bar supports and side form spacers see Chapter 5.

2.10-Special details for seismic design of frames, joints, walls, diaphragms and two-way slabs

2.10.1 *Introduction*-In regions of high seismic risk (such as NEHRP Map Area Numbers 6 and 7)‡ reinforced concrete members must satisfy ACI 318, Chapters 1 through 18 and Sections 21.2 through 21.8 of Chapter 21 in order to provide a structural system with adequate details to permit nonlinear response without critical loss of strength.

In regions of moderate seismic risk (such as NEHRP Map Area Numbers 3, 4, and 5)‡ reinforced concrete frames and two-way slabs must satisfy ACI 318, Chapters 1 through 18 and Section 21.9 of Chapter 21.

The provisions of Chapters 1 through 18 of ACI 318 apply to the design and detailing of reinforced concrete structures in regions of low or no seismic risk (such as NEHRP Map Area Numbers 1 and 2).‡

For seismic design, member sizes should be selected and reinforcement arranged to avoid congestion of reinforcement. Careful selection of member size and reinforcement arrangement will help to avoid difficulties in the placement of reinforcement and concrete.

The requirements of Chapter 21 of ACI 318 are used to illustrate what the Engineer should convey to the Detailer (and to familiarize the Detailer with the seismic reinforcement details). Much information can be shown by schematic diagrams as shown in Fig. 15 to 19. These special seismic details are, in principle, applicable to flexural frame members and frame members subjected to both bending and axial load in regions of high seismic risk.

It is important for the Engineer to examine the reinforcement layouts carefully in three dimensions and give the Detailer the proper information. This examination will show congestion at beam-column joints of beam, column, and hoop reinforcement. Large scale drawings, models, or mock-ups of the joint details such as shown in Fig. 18 may be worthwhile to assure that a design can be assembled and concrete can be placed.

Joints in frames and boundary members of walls should be capable of yielding and continuing to resist loads after yielding without brittle failure of the concrete when subjected to reversals of lateral overloads. To develop this ductility, concrete in these members including the joints must be confined by transverse reinforcement consisting of rectangular or circular hoops. See Figs. 15 to 19.

2.10.2 *Concrete*-AC1 318 requires that the specified concrete strength f_c' must not be less than 3000 psi. For lightweight aggregate concrete, f_c' must not exceed 4000 psi.

2.10.3 *Reinforcement*-Longitudinal reinforcement resisting earthquake-induced flexural and axial forces in frame members and in wall boundary members should comply with ASTM A 706. ASTM A 615 Grade 60 and

* Collins, M.P. and Mitchell, D., "Detailing for Torsion," ACI JOURNAL, Proceedings, V. 73, No. 9, Sept. 1976, pp. 506-511.

† Established industry practices recommended for general use of bar supports issued by the Concrete Reinforcing Steel Institute are reprinted in the Supporting Reference Data section.

‡ "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," prepared by the Building Seismic Safety Council for the Federal Emergency Management Agency, issued in 1988, referred to as NEHRP. Regions of high earthquake risk correspond to Zones 3 and 4, regions of moderate earthquake risk to Zone 2, and low or no risk in Zone.1 in both ASCE 7 and Uniform Building Code.

Grade 40 may be used provided that actual yield strength does not exceed the specified yield strength by more than 18,000 psi, and tensile strength is at least 25 percent greater than the actual yield strength.

In regions of moderate seismic risk standard ASTM A 615 Grade 60 and 40 may be used.

Test results indicate that welded wire fabric hoops designed according to ACI 318 requirements are effective in confining the concrete in the joints.*

2.10.4 *Beams-High seismic risk*†—At least two bars, top and bottom, must be provided as continuous longitudinal steel for beams. For beams framing into both sides of a column these bars must extend through the column at least twice the beam depth without splices (see Fig. 15), but in any case must develop the bars beyond their theoretical cut-off points.

At joint faces, the positive moment strength of the beam must be equal to or greater than one-half the negative moment strength. At other locations in the beam, the positive and negative moment strengths must be equal to or greater than one-fourth the negative moment strength at the face of either joint. The Engineer must indicate quantities of reinforcement, cut-off points, and length and location of splices to satisfy these multiple code requirements.

Continuous top bars must be spliced near the center of a span in frames where moments are usually minimum and gravity load moments do not usually produce tensile stresses. Bottom bars must not be spliced at the columns because of possible reversal of beam stresses.

At beam-column joints, the Engineer must indicate where and how the bars, straight or hooked, are to be terminated.

Where beams frame into only one side of a column, as at exterior columns, top and bottom beam steel must have a 90-deg hook that extends to the far face of the confined region (core).‡ The development length of the hook for tension must not be less than $8d_b$, 6 in., or $f_y d_b/(65\sqrt{f_c'})$.

Hoops must be provided in frame members over twice the member depth from the faces of the supports and toward midspan. If inelastic yielding may occur elsewhere, the Engineer must indicate location and hoop spacing requirements on both sides of the sections where the inelastic yielding may occur. Hoop spacing requirements are shown in Fig. 15.

Where hoops are not required by the Engineer, stirrups must be provided spaced at not more than $d/2$ throughout the remaining length of the member, and detailed as shown by the Engineer.

2.10.5 ***Beams-Moderate seismic risk***†—ACI 318 requires that at joint faces the positive moment strength of the beam must be equal to or greater than one-third the negative moment strength. At other locations in the beam, the positive and negative moment strengths must be equal to or greater than one-fifth the negative moment strength at the face of either joint. The Engineer must indicate quantities of reinforcement required to satisfy the code, cut-off points, and length and location of splices.

Stirrups must be provided for a minimum length of twice the member depth from the support at a beginning spacing of 2 in. and a remaining spacing not more than $d/4$, $8d_b$ of the smallest enclosed longitudinal bar, 24 diameters of the stirrup bar, or 12 in. For the remaining beam length, stirrups must be spaced at not more than d/2.

2.10.6 *Columns-High seismic risk*§—Transverse reinforcement consisting of single or overlapping rectangular hoops for rectangular columns, and single circular hoops or spirals for round columns are required (see Fig. 16). A rectangular hoop is closed by overlapping 135-deg hooks having tail extensions of six bar diameters (3 in. minimum) inside the core of the hoop.

Crossties of the same bar size and spacing of hoops may be used but each end of the crosstie must engage a peripheral vertical bar. See Fig. 16 and 17.

Hoops at a maximum spacing of one-quarter of the minimum column dimension and 4 in. must be provided within the joint and above and below the joint for a distance not less than the column depth, one-sixth the column clear height, or 18 in. Code provisions regulate the size and spacing of the hoops. It is essential that hoops be in contact with all column verticals.

Column verticals may be spliced by lap splices, welded splices, or by mechanical connections. Lap splices are permitted only within the center half of the column length and must be designed as tension splices. Welded splices or mechanical connections must be staggered at least 24 in. and applied to alternate verticals.

2.10.7 *Columns-Moderate seismic risk*§—Tie spacing s_o over a length l_o from the face of the member must not exceed 8 diameters of the smallest enclosed bar, 24 diameters of the tie bar, one-half the smallest cross-sectional column dimension, or 12 in. Length l_o must be equal to or greater than one-sixth of the clear span (height) of the member, maximum cross-sectional dimension of the member, or 18 in. The first tie must be spaced not more than $s_o/2$ from the joint face and the remaining ties not more than s_o.

2.10.8 *Walls and diaphragms-High and moderate seismic risk*-Walls and diaphragms, if designed as parts of the force resisting system, are relatively stiff members compared to ductile beam-column frames. Since walls may or may not be designed as part of the primary lateral load resisting system, it is most important that the Engineer provide a complete description of the requirements for wall reinforcement. Usually this task may be

* "Reinforced Concrete Frame Connections Constructed Using High-Strength Materials" by G.N. Guimaraes, M.E. Kreger and J.O. Jirsa, University of Texas at Austin, August 1989 (PMFSEL Report No. 89-l).

† A frame member is defined as a beam if the factored compressive axial load is not greater than $(A_g f_c')/10$.

‡ Core. This term is indirectly defined in ACI 318, Section 10.0, by the term "A_c" (area of core) = area within outside dimension of the confining reinforcement.

§ A frame member defined as a column if the factored compressive axial load is greater than $(A_g f_c')/10$.

accomplished by identifying structural walls and diaphragms and reference to typical details. See Fig. 19.

The vertical and horizontal reinforcement must be placed in at least two curtains if the in-plane factored shear force exceeds $2A_{cv}\sqrt{f_c'}$. The reinforcement ratio in each direction must be equal to or greater than 0.0025 with a maximum bar spacing of 18 in.

When the compressive force in a boundary member exceeds $0.2f_c'A_g$ the member must be reinforced as a column in a high seismic risk area. Transverse reinforcement from wall and diaphragm members must be fully developed within the confined cores of boundary members.

2.10.9 *Joints-High seismic risk frames*-Forces in longitudinal beam reinforcement at joint faces must be based on a flexural tension stress of $1.25f_y$ and a corresponding increase in balancing compressive stresses and shear. Transverse hoop reinforcement as for high risk seismic columns must be provided in joints. If the joint is confined by structural members, meeting special requirements lesser amounts of transverse reinforcement may be used. The Engineer should evaluate requirements for confinement and end anchorage of longitudinal beam reinforcement. These requirements can often be shown by typical details. See Fig. 15-18.

2.10.10 *Two-way slabs without beams-Moderate seismic risk*-Reinforcement for the fraction of M_u to be transferred by moment [Eq. (13-l), ACI 318], but not less than half the total reinforcement required for the column strip, must be placed in the width of slab between lines 1.5 times slab or drop panel thickness on opposite faces of the column. (This width equals $3h + c_2$ for edge and interior columns or $1.5h + c_2$ for corner columns.) The Engineer must show the reinforcement to be concentrated in this critical width. See Fig. 23(d) for typical detail used for locating other bars in nonseismic areas.*

A minimum of one-fourth of the column strip top reinforcement must be continuous throughout the span.

Continuous column strip bottom reinforcement must be not less than one-third of the total column strip top reinforcement at the support. A minimum of one-half of all bottom reinforcement at midspan must be continuous and developed at faces of supports.

All top and bottom reinforcement must be developed at discontinuous edges.

2.11-Corrosion resistant coatings for reinforcement

2.11.1 *General*

2.11.1.1 *Specification*-Coated reinforcement provides a corrosion-protection system for reinforced concrete structures. Engineering drawings for structures or elements of structures which contain coated reinforcement should include all of the essential information previously noted for uncoated reinforcement. The Engineer must be cognizant that coated reinforcement undergoes further processing as compared to uncoated reinforcement. The coating process adds time to the normal delivery cycle. Replacement reinforcement or additional reinforcement to correct oversights may not be readily available. Therefore, it is important that the Engineer convey specific complete instructions in the project specifications or on the drawings for use of coated reinforcement.

2.11.1.2 *Provisions to be included in project specifications*-Provisions to be included are:

a) *Welded splices*-Specify any desired or more stringent requirements for preparation or welding, such as removal of coating, than those contained in AWS D1.4; specify requirements for repair of damaged coating after completion of welding.

b) *Mechanical connections*-Specify requirements for repair of damaged coating after installation of mechanical connections.

c) *Field bending of coated bars partially embedded in concrete*-If permitted by the Engineer, specify requirements for repair of damaged coating after completion of bending operations.

d) *Cutting of coated bars in the field*-Such a practice is not recommended; but if required and permitted by the Engineer, specify requirements for coating the ends of the bars.

e) *Limits on coating damage*-Specify limits on permissible coating damage due to handling, shipment, and placing operations, and when required, the repair of damaged coating.

2.11.1.3 *Usage*-Foroverall economy, maximize the use of straight bars, and use the fewest possible different bar sizes for a project. On projects where uncoated and coated bars are used, to avoid confusion, be precise in identifying those bars which are to be coated. It is seldom sufficient to call for coated reinforcing bars in an element with a general note. Reinforcing bars projecting into the element should be identified if they are to be coated.

2.11.2 *Epoxy-coated reinforcing bars*

2.11.2.1 Material specification-'Standard Specification for Epoxy-Coated Reinforcing Steel Bars" (ASTM A 775). To meet the ACI Building Code, the reinforcing bars that are to be epoxy-coated must conform to the requirements of ACI 318, Section 3.5.3.1.

2.11.2.2 *Identification*-Epoxy-coated bars are identified with a suffix (E), or with an asterisk (*) and a note stating that all bars marked as such are to be epoxy-coated.

2.11.2.3 *Compatible tie wire and bar supports*-Coated tie wire should be specified for fastening epoxy-coated reinforcing bars. Suitable coatings are nylon, epoxy, or vinyl. Bar supports should be made of dielectric material, or wire bar supports should be coated with dielectric material such as epoxy or vinyl compatible with concrete, for a minimum distance of 2 in. from the point of contact with the epoxy-coated reinforcing bars. Reinforcing bars used as support bars should be epoxy-coated.

2.11.3 *Zinc-coated (galvanized) reinforcing bars*

2.11.3.1 *Material specification*-"Standard Specification for Zinc-Coated (Galvanized) Steel Bars For

*Even more necessary for moderate seismic risk, wind, or other lateral load.

Concrete Reinforcement" (ASTM A 767). To meet the ACI Building Code requirements, the reinforcing bars that are to be zinc-coated (galvanized) must conform to ACI 318, Section 3.5.3.1.

2.11.3.2 *Supplementary requirements*-There are three Supplementary Requirements in ASTM A 767; Supplementary Requirement Sl requires sheared ends to be coated with a zinc-rich formulation; when bars are fabricated after galvanizing, S2 requires damaged coating to be repaired with a zinc-rich formulation; and if ASTM A 615 billet-steel bars are being supplied, S3 requires that a silicon analysis of each heat of steel be provided. It is recommended that S1 and S2 should be specified when fabrication after galvanization includes cutting and bending. S2 should be specified when fabrication after galvanization includes only bending.

2.11.3.3 *Coating weights*-Table 1 of ASTM A 767 has two classes of coating weights. Class 1 (3.5 oz/sq ft) is normally specified for general construction.

2.11.3.4 *Other embedded metals*-No uncoated reinforcing steel nor any other embedded metal dissimilar to zinc should be permitted in close proximity to galvanized reinforcing bars except as part of a cathodic protection system.

2.11.3.5 *Identification*-Bars are usually galvanized after fabrication. Bars which require special finished bend diameters (usually smaller bar sizes for stirrups and ties) should be identified. Maintenance of identification to the point of shipment during the galvanizing process is the responsibility of the galvanizer. Regular tags plus metal tags should be attached to each bar bundle. (The regular tag is often consumed in the galvanizing process, leaving the metal tag for permanent identification.) Zinc-coated (galvanized) bars are identified with a suffix (G) and a note stating that all bars marked as such are to be zinc-coated (galvanized).

2.11.3.6 *Compatible tie wire and bar supports*-No dissimilar metals nor uncoated bars should be permitted in the same concrete element with galvanized bars. Galvanized bars should not be coupled to uncoated bars. Zinc-coated tie wire or nonmetallic coated tie wire should be used. Wire bar supports and support bars should be galvanized or coated with dielectric material, or bar supports should be made of dielectric material.

PART B-RESPONSIBILITIES OF THE DETAILER

CHAPTER 3-PLACING DRAWINGS

3.1-Definition

Placing drawings are working drawings that show the number, size, length, and location of the reinforcement necessary for the placement and fabrication of the material. Placing drawings may comprise plans, details, elevations, schedules, material lists, and bending details. They may be prepared manually or by computer.

3.2-Scope

Placing drawings are intended to convey the Engineer's intent as covered in the Contract Documents. The Contract Documents plus any additions thereto, such as "Addenda" issued by the Engineer (per terms agreed on in the contract if issued after the contract is made), constitute the sole authority for information in placing drawings. The placing drawings must include all information necessary for complete fabrication and placing of all reinforcing steel and bar supports.

3.3-Procedure

Placing drawings are prepared by a Detailer in accordance with the Engineer's instructions contained in the Contract Documents. Any necessary additional information must be supplied by the Contractor concerning field conditions, field measurements, construction joints, and sequence of placing concrete. After approval by the Engineer, including necessary revisions, the drawings may be used by the Fabricator and Placer.

3.4-Drawing standards

Placing drawings are prepared to the same general standards as engineering drawings.

3.4.1 *Layout*-Drawings usually show a plan, elevations, sections, and details of a structure, accompanied by schedules for footings, columns, beams, and slabs. The plan should be drawn in the upper left corner of the sheet, with the elevations and details below and to the right of the plan. Schedules (and bending details) should be placed in the upper right corner of the drawing. See Fig. 20 for recommended layout. Unless otherwise specified, standard industry practice is followed-placing drawings are prepared by pencil on tracing paper.

Other media providing equal or improved reproducibility or durability may be utilized, such as ink, computer or mechanically generated graphics and printout, tracing cloth, or polyester film.

An arrow indicating the direction of north should be placed beside every plan view.

3.4.2 *Symbols and notation*-Common symbols and abbreviations for placing drawings are shown in the Supporting Reference Data section of the ACI Detailing Manual SP-66.

Where unusual details or conditions require use of other (special) symbols or abbreviations, the drawings must provide an explanation of the notation applied.

3.4.3 *Schedules*-The reinforcement of floors and many other parts of structures can best be shown in tabular form commonly referred to as a schedule. The schedule is a compact summary of all the bars complete with the number of pieces, shape and size, lengths, marks, grades, coating information, and bending details from which shop orders can be easily and readily written. While these schedules usually include the bending details for bent bars, separate bending detail schedules may be used.

3.4.4 *Coated reinforcing bars*-The Detailer is responsible for carrying out the instructions on the Contract Documents. When coated reinforcing bars are detailed along with uncoated reinforcing bars the coated reinforcing bars should be identified in some manner such as with a suffix (E) or (G), or with an asterisk (*) and a note stating that all reinforcing bars marked as such are to be epoxy coated or galvanized. Epoxy-coated reinforcing bars listed with uncoated reinforcing bars in schedules or Bills of Materials should also be marked with (E) or (*). The designation (G) is appropriate for galvanized reinforcing bars.

3.5-Building drawings

Placing drawings, ordinarily prepared by the Fabricator, show details for fabrication and for placing of reinforcement. They are not for use in constructing formwork (except joist forms when these are supplied by the same Fabricator), and consequently the only required dimensions are those necessary for the proper location of the reinforcement. Building dimensions are shown on the placing drawing only if necessary to locate reinforcement properly, since the Detailer becomes responsible for accuracy of dimensions when given. The placing drawings must be used with the engineering drawings.

Bending details may be shown on a separate list instead of on the drawings.

3.5.1 *General requirements*-On receipt of the engineering drawings, the Fabricator takes the following steps:

1. Prepares placing drawings (including bending details).
2. Obtains Engineer's, Architect's, or Contractor's approval, if required.
3. Prepares bar lists (shop lists) and fabricates the reinforcement.
4. Provides coated bars if specified.
5. Tags, bundles, and delivers the fabricated reinforcing bars to the job site.

Placing drawings must show the size, shape, grade, and location of coated and uncoated bars in the structure, including bar supports, if supplied by the Fabricator. They also serve as the basis for preparing bar lists.

To assure proper interpretation of the engineering drawings and the contractor's requirements, the placing drawings are usually submitted for approval to the Contractor before shop fabrication is begun.

For convenience of both Contractor and Fabricator, reinforcement is detailed, fabricated, and delivered by units which generally consist of footings, walls, columns, each floor, and roof. A separate placing drawing and bar list is usually made for each unit. For small structures all requirements may be handled as one unit. For large projects, the Contractor may desire a unit, such as a single floor, to be divided to correspond with his construction schedule. Such arrangements, between the Contractor and Fabricator, with the Engineer's approval, are made before the detailing is begun. All sections should be kept as large as practicable since it is more economical to detail and fabricate for large units, especially where there is apt to be a duplication of bars.

It should be noted that the general term Fabricator, as used in this Standard, refers to a company which employs detailers, estimators, shop personnel, etc. In this regard, it is actually the Detailer who performs steps 1, 2 and the first part of step 3 while the shop personnel do the remainder of step 3 and steps 4 and 5.

3.5.2 *Marks*-Slabs, joists, beams, girders, and sometimes footings that are alike on engineering drawings are given the same designation mark. Where possible, the same designations should be used on the placing drawings as on the engineering drawings. When members alike on the engineering drawings are slightly different on the placing drawings, a suffix letter is added to the designation to differentiate the numbers. If part of the beams marked 2B3 on the engineering drawing actually differ from the others, the placing drawing would show part of the beams as 2B3 and the others as 2B3A. In concrete joist floors there may be so many variations from the basic joists shown on the engineering drawings that it is necessary to change the basic designations (as, for example, from prefix J to prefix R, for rib).

Columns, and generally footings, are numbered consecutively or are designated by a system of coordinates on the engineering drawings. The same designations should be used on placing drawings.

The described systems of marking designate individual concrete members of a structure. Reinforcing bars must be individually identified on placing drawings. Only bent bars are given a mark to assist the reinforcing bar placer in selecting the proper bars for each member. The straight bar size and length is its own identification.

3.5.3 *Schedules*-Reinforcement in elements of a structure may be drawn on placing drawings either on the plan, elevation, or section or may be listed in a schedule. It is acceptable practice to detail footings, columns, beams, and slabs in schedules. There is no standard format for schedules. They take the place of a drawing, such as a beam elevation, and must clearly indicate to the reinforcement placer exactly where and how all the material listed must be placed.

3.5.4 *Responsibility of the Detailer*-The responsibility of the Detailer in preparing a placing drawing is to carry out all instructions on the Contract Documents.

The Engineer must furnish a clear statement of the requirements; the Detailer must carry out these requirements. The Engineer in either the specifications or drawings may not refer the Detailer to an applicable building code for information to use in preparing placing drawings. This information must be interpreted by the Engineer and should be shown in the form. of specific design details or notes for the Detailer to follow.

3.5.5 *Beams and joists*-For beams, joists, and girders, reinforcement is usually shown in schedules. Bending details may be separate or incorporated in the schedule. The Detailer must show number, mark, and size of members; number, size, and length of straight bars; number, size, mark, and length of bent bars and stirrups; spacing of stirrups; offsets of bars; lap splices; bar supports; and any other special information necessary for the proper fabrication and placement of the reinforcement.

Among the special items that must be noted are: (1) overall length of bar, (2) height of hook where such dimensions are controlling, (3) lap splice lengths, (4) offset dimensions, if any, and (5) location of bar with respect to supporting members where the bar is not dimensioned symmetrically on each side of the support.

3.5.6 *Slabs*-Reinforcement for slabs may be shown in plan or schedule, sometimes even in section. The schedule and bending details for slabs are similar to those for beams.

Panels exactly alike are given an identifying letter and reinforcement is shown for only one panel of each kind. In skewed panels, bars are fanned to maintain given spacing usually at midspan. Additional bars around openings, if required, must be shown.

3.5.7 *Columns*-Placing drawings for columns generally use a schedule form for detailing. The Detailer must not only interpret the engineering drawing but must clearly convey this interpretation to the reinforcement placer. The Detailer must show the quantity, size, and length or mark of all bars, including dowels, principal vertical bars, and ties. The Detailer must also include plan sketches of typical bar arrangements for all but the simplest conditions. The Detailer must show clearly length and location of lap splices, and location of mechanical connections or welded splices, and position of offset bars.

3.5.8 *Dowels*-Dowels preferably should be detailed with the reinforcement in the element that is placed first. They must be ordered with the element to be available for placement at the proper time.

3.5.9 *Reinforcement supports*-Reinforcement supports specified in the Contract Documents, including quantities and description, must be specifically listed on the placing drawings.

Bar support placing layouts for typical panels are required for two-way reinforcement and wherever needed to clarify placing sequence or quantities required. These layouts may be shown on the placing drawing or given by reference to the CRSI Manual of Standard Practice.* Support bars, when required, must be clearly shown and identified on the placing drawings.

3.6-Highway drawings

Unlike the customary practice in the field of reinforced concrete buildings, many state highway departments prepare a combination engineering and placing drawing. The combination drawing includes a list of reinforcing materials from which the Fabricator prepares bar lists. The Placer uses the combination drawing to place the reinforcing bars. Highway departments that do not utilize combination drawings follow the procedures of Section 3.5.

3.6.1 *Marks*-Each highway structure is identified by a bridge number or a station number (each station being 100 linear ft) which designates its location on the project. This station identification or bridge number must be shown on all bundle tags and shipping papers to facilitate proper distribution of reinforcing bars on delivery.

For small, simple structures such as culverts, slab bridges, manholes, and catch basins, a station number in addition to the title description of the structure is sufficient identification without dividing the structure into smaller units by further marking.

Larger structures such as concrete deck girders, I-beam bridges, continuous-type bridges, and arches consist of small units which together make up a complete structure. These units are referred to as end bents, intermediate bents, abutments, piers, retaining walls, end spans, intermediate spans, etc., and must be designated by markings. The construction units of unusually long culverts with more than one design of barrel, for varying load conditions or, where construction joints are required across the barrel, may be identified by section numbers. Schedules of reinforcing bars are used to divide a structure into parts enabling the Fabricator to make it more convenient for the Placer by delivering the bars in lots as required.

For highway structures, both straight and bent bars are given an individual mark. In highway structures such as culverts and bridge spans, the arrangement of bars is the same, regardless of size or length. Standardized marks are sometimes used for bars occurring in the same relative position in culverts.

Any system of letters and numerals is acceptable. Some designers not only provide individual bar markings, but also indicate, by the mark, where the bar is placed in the structure.

3.6.2 *Schedules*-Highway structure engineering drawings most often show details of the various elements directly on the plan or elevation. Schedules are sometimes used for piers, small structures, and even retaining walls. Highway engineering drawings usually include, when completely detailed, a type of schedule that is really a bill of material, sometimes segregated by elements of a structure. These drawings are used by the Fabricator to prepare shop bar lists.

3.6.3 *Dimensions*-When the drawings for highway structures are combination engineering and placing drawings from which the structure must be built, all dimensions must be clearly shown. The builder of a bridge should not have to compute any needed dimensions. Drawings must show the dimensions of concrete protection for all reinforcement. For example, they must

* Manual of Standard Practice, 25th Edition, Concrete Reinforcing Steel Institute, Schaumburg, Illinois, 1990.

plainly show whether the cover dimension specified on a girder is the clear distance from the main reinforcement or the clear distance from the stirrups. Where separate placing drawings are prepared, structural dimensions may be omitted following the same practice as for buildings.

3.6.4 *Reinforcement*-Drawings must show the grade, size, spacing, splices, and location of the coated and uncoated bars in the structure. The bar schedule (combined drawing) must show the number of pieces, size, length, mark of bars, and bending details of all bent bars.

Reinforcement for larger structures is usually detailed, fabricated, and delivered by units for the convenience of both the Contractor and Fabricator; for example, footings, abutments, piers, and girders. The bar list is then similarly subdivided. If the structure is sufficiently large, a separate drawing and bar schedule is made for each unit.

Reinforcing bars for foundations, piers, abutments, wingwalls, and slabs are usually shown on the plan, section, or elevation. Reinforcement may be shown in the simplest and clearest manner; however, the bar schedule must be a complete summary.

To be certain that all of the reinforcement is properly placed or positioned in a unit, a cross section is frequently required in addition to the plan and elevation of the unit whereon the bars are shown.

3.6.5 *Reinforcement supports*-plain metal supports are widely used as a means of securely holding reinforcement in proper position while concrete is being placed. Plastic coated or stainless legs can be specified to avoid possible rusting at points of exposure. Precast concrete blocks are used in some states, particularly in the western U.S. Other types of proprietary supports are available and may be suitable. Support bars, when required, should be clearly shown and identified.

Where exposed concrete surface is to receive special finishing treatments such as sandblasting, bushhammering, or any other removal of surface mortar, special consideration must be given to selecting bottom bar supports, side-form spacers, etc., which will not rust or otherwise impair the finished surface appearance.

Class of wire bar support, blocks, or other proprietary supports, and locations where each is to be employed, should be specified or shown in the Contract Documents. The Detailer must identify the specified types and show locations where each is to be used.

3.7-Detailing to fabricating standards

It is standard practice in the industry to show all bar dimensions as out-to-out and consider the bar lengths as the sum of all detailed dimensions, including Hooks A and G (see Table 1).

All tables herein which give clearances, spacing, hooks, etc., are based on the use of deformed bars meeting ASTM specifications.

3.7.1 *Bending*-To avoid creating excessive stresses during bending, bars must not be bent too sharply. Controls are established by specifying the minimum inside radius or inside diameter of bend which can be made for each size of bar. The radius or diameter of the completed bend is usually expressed as a multiple of the nominal diameter of the bar d_b. The ratio of diameter of bend to diameter of bar is not a constant because it has been found by experience that this ratio must be larger as the bar size increases.

The minimum diameters of bend specified by ACI 318 for reinforcing bars, measured on the inside of the bar are:

Bar sizes	Other than ties/stirrups	Ties or stirrups
#3, #4, #5	$6d_b$	$4d_b$
#6, #7, #8	$6d_b$	$6d_b$
#9, #10, #11	$8d_b$	—
#14, #18	$10d_b$	—

The inside diameter of bends of welded wire fabric (plain or deformed) for stirrups and ties, as specified by ACI 318, shall not be less than $4d_b$ for deformed wire larger than D6 and $2d_b$ for all other wires. Bends with inside diameter of less than $8d_b$ shall not be less than $4d_b$ from the nearest welded intersection.

3.7.2 *Hooks*-ACI 318 specifies minimum bend diameters for reinforcing bars (Section 3.7.2). It also defines "standard hook" (Section 7.1) to mean the following:

a) A 180-deg bend plus an extension of at least $4d_b$ but not less than $2^1/2$ in. at the free end of the bar, or

b) A 90-deg bend plus an extension of at least $12d_b$ at the free end of the bar, or

c) For stirrup and tie hooks only, either a 90-deg bend plus $6d_b$ extension for #3, #4, #5, and $12d_b$ extension for #6, #7, and #8 or a 135-deg bend plus an extension of at least 6db at the free end of the bar. For closed ties defined as hoops in Chapter 21 of ACI 318, a 135-deg bend plus an extension of at least $6d_b$ but not less than 3 in.

The minimum bend diameter of hooks must meet the foregoing provisions. The standard hooks (Table 1) were developed such that the minimum requirements were met but at the same time recognizing the need to allow for "springback" in fabrication, and maintaining a policy of production fabrication pin size no smaller than the ASTM A 615 bend test pin size. In the table, the extra length of bar allowed for the hook is designated as A or G and shown to the nearest inch for end hooks and to the nearest half inch for stirrup and tie hooks.

Where the physical conditions of the job are such that either J, A, G, or H of the hook is a controlling dimension, it must be so noted on the plans, schedules, and bar lists.

3.7.3 *Stirrup anchorage*

3.7.3.1 There are several permissible methods for stirrup anchorage. The most common is to use one of the hooks shown in Table 1. Types S1 to S6 in Fig. 6 illustrate not only the uses of the two types of hooks, but also the directions in which the hooks may be turned. In detailing the anchorage, care must be taken that the ends of stirrup hooks turned outward into shallow slabs have adequate cover. If not, the hooks should be turned inward and this change brought to the Engineer's attention.

3.7.3.2 Where the free ends of stirrups cannot be wired to longitudinal bars, or where there are no longitudinal bars, stirrup support bars should be specified by the Engineer.*

3.7.4 *Standard bar bends*

3.7.4.1 To list the various types of bent bars in a schedule, it is necessary to have diagrams of the bars with the lengths of the portions of the bars designated by letters. A chart of such standard bar bends is shown in Fig. 6.

3.7.4.2 Dimensions given for Hooks A and G are the additional length of bar allowed for the hook as shown in Table 1. For straight portions of the bar, the distance is measured to the theoretical intersection of the outside edge line extended to the outside edge line of the adjacent straight portion, or to the point of tangency to a curve, from which point the length of the latter is tabulated, as in Types 10 and 11 in Fig. 6. Truss bar dimensioning is special and is shown in large scale detail in Fig. 6.

3.7.5 *Radius bending*-When reinforcing bars are used around curved surfaces, such as domes, tanks, etc., and when no special requirement is established in the contract, bars prefabricated to a radius equal or less than those in the following table are prefabricated by the reinforcing bar fabricator. In the smaller sizes, the bars are sprung to fit varying job conditions such as location of splices, vertical bars, jack rods, window openings, and other blocked out areas in the forms. The larger size bars which are more difficult to spring into desired position are ordinarily employed in massive structures where placing tolerances are correspondingly larger. Radially prefabricated bars of any size tend to relax the radius originally prefabricated as a result of time and normal handling. The last few feet involved in the lap splice area often appear as a tangent rather than a pure arc due to limitations of standard bending equipment. For these reasons, final adjustments are a field placing problem to suit conditions and tolerance requirements of a particular job. See Fig. 4 and 5 for radial tolerances and Section 4.2(c)3. Bars requiring a larger radius or length than shown in the table at the top of the next column are sprung in the field without prefabrication.

The presence of the tangent end does not create any problem on bar sizes #3 through #ll since they are generally lap spliced and tangent ends are acceptable. However, #14 and #18 bars cannot be lap spliced and are usually spliced using a proprietary mechanical connection device or by butt welding. It is a problem to place a radially bent bar when using a mechanical splice sleeve due to the tangent ends on bars bent to small radii. To avoid this problem, all #14 and #18 bars bent to a radius of 20 ft or less should be furnished with an additional 18 in. added to each end. This 18 in. tangent end is to be

WHEN RADIAL PREFABRICATION IS REQUIRED

Bar size	Bars are to be prefabricated when either radius or bar length is less than the tabulated value	
	Radius, ft	Bar length, ft
#3	5	10
#4	10	10
#5	15	10
#6	40	10
#7	40	10
#8	60	30
#9	90	30
#l0	110	30
#11	110	60
#14	180	60
#18	300	60

removed in the field by flame cutting. Bars bent to radii greater than 20 ft will be furnished to the detailed length with no consideration given to the tangent end. The ends of these bars generally are saw cut.

Shop removal of tangent ends may be made by special arrangement with the reinforcing bar supplier.

3.7.6 *Slants*-To determine the length of straight bar necessary to form a truss bar, the length of the slant portion of the bar must be known. The standard angle is 45 deg for truss bars, with any other angles being special. Slants and increments are calculated to the closest ½ in. so that for truss bars with two slants, the total increment will be full inches. This makes the computation easier and is within the tolerances permitted. It is important to note that when the height of the truss is too small, 45-deg bends become impossible. This condition requires bending at a lesser angle and lengthens the slant portion.

3.7.7 Column verticals

3.7.7.1 *General*-The Engineer must indicate grade of steel required on drawings or in specifications. The Detailer must show special specification requirements for grade in listing column verticals for each story. In multistory columns, lower stories are sometimes designed for higher strength grades. Special requirements for bars to be butt welded may also be included.

Table 4 shows the number of bars that can be placed within spiral reinforcement in conformance with ACI 318. Three splice arrangements are shown: butt splices, radially lapped splices with dowels from below inside of bars above, and circumferentially lapped splices with dowels from below beside the bars above. Spacing for the latter also applies to butt-spliced two-bar bundles.

* These decisions should be shown on the engineering drawings. If not, the Detailer may suggest solutions, but only when subject to review and approval by the Engineer. The final decision on these design problems is. the Engineer's responsibility.

Maximum number of bars for the two lapped splice arrangements assumes all bars are spliced at the same cross section. For the butt-splice arrangement, no allowance was included for increase in diameter at couplers or end-bearing devices, nor for access to butt weld.

3.7.7.2 *Offset between column faces*-Where a column is smaller than the one below, vertical bars from below must be offset to come within the column above, or separate dowels must be used. The slope of the inclined portion must not exceed 1 to 6. In detailing offset column bars, a bar diameter plus clearance must be added to the desired offset. In the corners of columns, bars are usually offset on the diagonal which requires that the offset be increased accordingly.

For any offset between column faces less than 3 in., the vertical bar should be shop offset bent. When the offset is 3 in. or more, the vertical bars in the column below should be terminated at the floor slab and separate straight dowels provided.

3.7.7.3 *Lap splices*-Typical arrangement of bars at a lap splice is shown in Fig. 7. Unless special details are provided on the engineering drawings, all column verticals to be lap spliced in square or rectangular columns must be shop offset bent into the column above except as noted in Section 3.7.7.2. General practice is to use the offset for the corner bars which must be bent diagonally as the typical offset dimension for all the bars in the column. Column verticals in round columns where column sizes do not change must be offset bent only if a maximum number of lap spliced bars is desired in the column above. See Table 4.

3.7.8 *Column spirals*

3.7.8.1 *General*-Spirals must be provided with $1^1/_2$ extra turns at both top and bottom. The height (or length) of a spiral is defined as the distance out-to-out of coils, including the finishing turns top and bottom, with a tolerance of plus or minus 1½ in. Where a spiral cannot be furnished in one piece, it may be furnished in two or more sections to be field welded, or by additional length at each of the ends of each section to be lapped in the field, 48 diameters minimum, but not less than 12 in. The sections must be properly identified by mark numbers to insure proper assembly.

Spacers are sometimes used for maintaining the proper pitch and alignment of the spiral and, when used, should conform to the minimum requirements of Table 7. Maximum length of spacers is that of the spiral plus one pitch. One alternate method to using spacers is to ship the spiral as a compressed coil and tie it in place in the field. The project specifications or subcontract agreements should be clearly written to cover the supply of spacers or field tying of the spiral reinforcement.

The height of one-piece assembled spirals for fabrication and shipping is limited to 25 ft unless special handling arrangements are made. For greater heights, spirals must be field spliced by lapping or welding. Spacers are provided. Spirals are also used in piles, but these do not fall within the ACI 318 definition of a spiral and are usually made of light wire and relatively large pitch. Spacers are not provided.

3.7.8.2 *Buildings*- Unless otherwise specifically provided, spirals shall be detailed as extending from the floor level or top of footing or pedestal to the level of the lowest horizontal reinforcement in the slab, drop panel, or beam above. In a column with a capital, the spiral shall extend to the plane at which the diameter or width of the capital is twice that of the column. See Detail 2, Fig. 7. If the engineering drawings require lateral reinforcement in the column between the top of the main spiral and the floor level above, it shall be provided by a stub spiral (short section of spiral) or by circular column ties. Where stub spirals are used, they must be attached to the main spiral for shipment or fully identified by mark numbers.

3.7.9 *Dowels*-Dowels will be provided by the Detailer as specified in the Contract Documents for the following:

a) Column footings to column
b) Wall footings to wall
c) Wall intersections
d) Stairs to walls
e) Construction joints in footings, walls, and slabs
f) Columns at floor levels where the vertical reinforcement cannot be offset bent and extended
g) Other places where it is not possible or desirable to extend the reinforcement continuously through a joint.

Dowels preferably should be detailed with the element that is placed first. They must always be ordered with that element.

3.7.10 *Bar lists*-Bar lists used in cutting, bending, tagging, shipping, and invoicing are prepared from placing drawings. Bars are grouped separately on the bar list as follows: (1) straight, (2) bent, including stirrups and ties, and (3) spirals. The grade of steel for all items must be shown.

Straight bars are usually grouped according to size with the largest size first and those of the same size listed in the order of their length with the longest bar first.

Bent bars, stirrups, and ties are usually listed in a similar manner.

Spirals may be subdivided and listed in groups by the size of bar, diameter of spiral, pitch of spiral, and length. For example, See Fig. 21.

CHAPTER 4-FABRICATING PRACTICE STANDARDS

4.1-Fabrication

A fabricated reinforcing bar is any deformed or plain steel bar for concrete reinforcement, conforming to ASTM specifications A 615, A 616, A 617, or A 706, that is cut to a specified length or cut and bent to a specified length and configuration. Welded plain and deformed wire fabric meeting ASTM A 185 or A 497, respectively, and spirals formed from cold drawn wire conforming to ASTM A 82 or A 496 are also considered concrete reinforcement within this definition. Other materials used as concrete reinforcement and processes other than cutting and bending are not included in this definition.

4.2-Extras

Reinforcing bars are sold on the basis of their theoretical weights computed from the values given in the ASTM specifications, as calculated from the detailed placing drawings, lists, and/or purchase orders. In determining the weight of a bent bar, it is standard practice in the industry to show all bar dimensions as out-to-out and consider the bar lengths required for fabrication as the sum of all detailed dimensions, including Hooks A and G. See Figure 6.

Charges for extras may be added to the base price per hundredweight. In this event, the principal extra charges are:

a) Size Extras-vary as bar size changes.
b) Grade Extras-are added to some grades of bars.
c) Bending Extras- areadded for all shop bending.

Bending extra charges are separated into three classes as follows:

1. Light bending. All #3 bars, all stirrups, hoops, supplementary ties, and ties, and all bars #4 through #18 which are bent at more than six points in one plane, or bars which are bent in more than one plane (unless "Special Bending"), all one-plane radius bending with more than one radius in any bar (three maximum), or a combination of radius and other type bending in one plane (radius bending being defined as all bends having a radius of 12 in. or more to inside of bar).
2. Heavy bending. Bar sizes #4 through #18 which are bent at not more than six points in one plane (unless classified as "Light Bending" or "Special Bending") and single radius bending.
3. Special bending. All bending to special tolerances (tolerances more restrictive than those shown in Fig. 4 and 5), all radius bending in more than one plane, all multiple plane bending containing one or more radius bends, and all bending for precast units.

d) Services and Special Fabrication-Extra charges for services and special fabrication may be individually computed to suit conditions for each product on items such as:

1. Detailing and/or listing
2. Owner's quality assurance/control requirements
3. Transportation
4. Galvanizing and epoxy coating
5. Painting, dipping, or coating
6. Spirals and continuous hoops
7. Shearing to special tolerances
8. Square (saw-cut) ends
9. Beveled ends or ends not otherwise defined
10. Bar threading
11. Special bundling and tagging
12. Overlength and/or over-width bars
13. Welding

4.3-Tolerances

There are established standard industry fabricating tolerances that apply unless otherwise shown in the contract specifications or drawings. Fig. 4 and 5 define these tolerances for the standard bar bends shown in Fig. 6. Note that tolerances more restrictive than these may be subject to an extra charge. See ACI 117 for further tolerance information.

CHAPTER 5-SUPPORTS FOR REINFORCEMENT

5.1-General

The Contract Documents usually outline the need and requirements for reinforcement supports. The following requirements are applicable to supports for reinforcing bars, and may be applicable to supports for wire or welded wire fabric.

5.1.1 *General requirements*-When Contract Documents specify merely that reinforcement "shall be accurately placed and adequately supported before the concrete is placed, and shall be secured against displacement within permitted tolerances," the Contractor is free to select and purchase the type and class of wire bar supports, precast block, or other materials for each area.

5.1.2 *Specific requirements*-when the Contract Documents specify types or material for bar supports in different areas, the Detailer for the supplier must indicate these materials and areas in which they are to be used, number, size, type, arrangement, and quantities required. These details must be outlined or must be referenced to a generally accepted document that shows such arrangements.*

5.2-Types of bar supports

5.2.1 *Wire bar supports*-Descriptions of wire bar supports and examples of their usage are available as industry recommendations in the CRSI Manual of Standard Practice, which is revised periodically to reflect the latest practice. Caution: When multiple layers of unusually heavy reinforcing bars are to be supported on wire bar supports, the number of wire bar supports may need to be increased to prevent penetration of support legs into the form material, especially where the surface is exposed to view or corrosion.

5.2.2 *Precast concrete bar supports*-Descriptions of commonly used types and sizes are available in the CRSI

* Suggested sizes, styles, and placing of bar supports are shown in the Detailing Manual SP-66, Supporting Reference Data, Chapter 3-Bar Supports.

Manual of Standard Practice. Requirements for texture and color to suit job conditions must be added if necessary. Caution: If the finished surface will be subjected to sandblasting, bushhammering, or chemical removal of external mortar, the different texture of the exposed precast blocks (unless part of a planned pattern) may be objectionable.

5.2.3 *Other types of bar supports*-CRSI's Manual of Standard Practice contains descriptions of two other types of bar supports: (1) cementitious fiber-reinforced bar supports, and (2) all-plastic bar supports. See the Reference Data.

5.3-Side form spacers and beam bolsters

All steel reinforcement must be firmly held in place before and during casting of concrete by means of concrete blocks, metallic or plastic supports, spacer bars, wires, or other devices adequate to insure against displacement during construction and to keep the steel at the proper distance from the forms. Selection of the type of spacer has traditionally been the responsibility of the Contractor. Detailing of side form spacers is not a standard requirement and is performed only when specifically required by the Contract Documents. The reinforcing bar placing drawings need only show, and the Fabricator will only be responsible to supply, those side form spacers that are equal to the standard wire bar supports referred to in Section 5.2.1.

Beam bolsters are typically placed transversely to the beam. Beam bolsters placed longitudinally with the beam are supplied only upon special arrangements between the Contractor and the Supplier, if approved by the Engineer.

5.4-Placing reinforcement supports

5.4.1 *General*-Reinforcing steel must be accurately located in the forms, and firmly held in place before and during the placing of concrete. Adequate supports are necessary to prevent displacement during construction and to keep the steel at a proper distance from the forms. Bar supports are sometimes specified to be "sufficient in number and strength to carry properly the reinforcing steel they support." The Detailer should show bar supports as required.* Bar supports are detailed for temperature reinforcement in top slabs of concrete joist construction only if specifically required in the Contract Documents.

Bar supports are not intended to and should not be used to support runways for concrete buggies or similar loads.

5.4.2 *Supports for bars in concrete cast on ground*-Bar supports are detailed for the top bars only in slabs on grade, grade beams, footings, and foundation mats 4 ft or less in thickness, in quantities not to exceed an average spacing of 4 ft in each direction. Separate support bars are detailed only if so indicated by the Engineer or on special arrangements with the Contractor, as principal reinforcement is assumed to be used for support.

Bar supports will be furnished by the reinforcing steel supplier for bottom bars in grade beams or slabs on ground and for the bars in singly reinforced slabs on ground only if specifically required in the Contract Documents. There are so many ways of supporting top bars in footings and foundation mats more than 4 ft thick that suppliers furnish supports for such purposes only by special arrangement.

CHAPTER 6- COMPUTER-ASSISTED DETAILING

6.1-Use of computers in detailing

The computer system for detailing reinforcing bars has been devised to use digital computers and other data processing equipment to speed up the preparation of placing drawings, to facilitate neater and more compact drawings, and to relieve the Detailer of tedious and time-consuming computations which can be accurately performed by a computer.

Computer aided drafting, commonly called CAD, is also being used in the drawing and detailing of placing drawings. This system gives the detailer speed, accuracy and an expeditious way of making changes when necessary.

6.2-Placing drawings

The Detailer prepares the graphical part of the placing drawing in a conventional manner. However, all the listing of quantities and other descriptive printing is performed by the computer's output device (that is, plotter, matrix printer, laser printer). While producing the placing drawings, the Detailer may directly or indirectly input information into the computer for processing. When the input data have been processed, the drawing is completed by attaching to it the printed output from the computer. It contains all the necessary descriptive information pertaining to the steel as well as the bending details. Computer output may be printed on transparent paper so that bar lists and bending details will be reproduced as part of the placing drawing.

The "label system" is often used to reference the bars on the drawing with its attached machine printout. Under this system the Detailer assigns a label number to each separate bar placing operation comprising either an individual bar or a group of bars. This label number indicating the designated bars is clearly shown on the drawing and is also written on the input sheet along with other pertinent data such as bar size, spacing, etc. The output from the computer prints the label number and then lists the descriptions of the various bars under each label. In this way a quick reference can be made between the graphical section of the drawing and the machine printed bar descriptions.

* Suggested sizes, styles, and placing of bar supports are shown in the Detailing Manual SP-66, Supporting Reference Data, Chapter 3-Bar Supports.

6.3-Ordering procedures

When placing drawings have been approved, preparation of shop orders is greatly simplified by using the data already generated for the label list or column or beam and slab schedule and bending details. All the Detailer must indicate are the labels or the portions thereof that are to be ordered from a particular drawing, and the data processing equipment weighs and sorts and lists the material by grade, tag color, type of bending, and size and length in descending order on the bar list. The equipment can also produce the shipping tags and all manifest documents.

CHAPTER 7-RECOMMENDED PRACTICES FOR LOCATION OF BARS DESIGNATED ONLY BY SIZE/SPACING

Especially in slabs and walls designed for a given area of reinforcement per running foot, required reinforcement is commonly designated by size and spacing combinations to the nearest ½ in. for spacing. If the engineering drawing shows specifically the positions of the first bar per panel, or for a given length, shows the total number of bars, no problem is created-the Detailer simply follows the specific requirements. Thus design notes such as "20-#4" in a designated length, or "#4 @ 12" " with location of the starting bar shown, no further interpretation is required to complete a placing drawing, nor to calculate total number of bars required. When the engineering drawing shows "#4 @ 12" " with no further instructions in the general notes, or in specifications, the procedures shown in Fig. 23 are recommended.

CHAPTER 8-REFERENCES

The documents of the various organizations referred to in this standard are listed below with their serial designation, including year of adoption or revision. The documents listed were the latest edition at the time this standard was revised. Since some of these documents are revised frequently, generally in minor detail only, the user of this standard should check directly with the sponsoring group if it is desired to refer to the latest revision.

American Association of State Highway and Transportation Officials

1989 AASHTO Standard Specifications for Highway Bridges

American Concrete Institute

117-90 Standard Specifications for Tolerances for Concrete Construction and Materials

318-89 Building Code Requirements for Reinforced Concrete

349-90 Code Requirements for Nuclear Safety Related Concrete Structures

359-89 Code for Concrete Reactor Vessels and Containments

408.1R-90 Suggested Development, Splice and Standard Hook Provisions for Deformed Bars in Tension

American Railway Engineering Association

1990 Manual for Railway Engineering, Chapter 8, Concrete Structures and Foundations

American Society for Testing and Materials

A82-90a Standard Specification for Steel Wire, Plain, for Concrete Reinforcement

A185-90a Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement

A496-90a Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement

A497-90a Standard Specification for Steel Welded Wire Fabric, Deformed, for Concrete Reinforcement

A615-90 Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

A616-90 Standard Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement

A617-90 Standard Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement

A706-90 Standard Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement

A767-90 Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement

A775-90 Standard Specification for Epoxy-Coated Reinforcing Steel Bars

American Societv of Civil Engineers

ASCE 7-88 Minimum Design Loads for Buildings and Other Structures

American Welding Societv

Dl.4.-79 Structural Welding Code - Reinforcing Steel

Association for Information and Image Management

Modern Drafting Techniques for Quality Microreproductions

Building Seismic Safety Council

NEHRP-88 NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings

Concrete Reinforcing Steel Institute

25th Edition 1990 *Manual of Standard Practice*

International Conference of Building Officials

1991 Uniform Building Code

These publications may be obtained from the following organizations:

American Association of State Highway and Transportation Officials
444 North Capitol Street, N.W., Suite 225
Washington, DC 20001

American Concrete Institute
P.O. Box 9094
Farmington Hills, Michigan 48333-9094

American Railway Engineering Association
50 F Street, N.W.
Washington, DC 20001

American Society for Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19103

American Society of Civil Engineers
345 East 47th Street
New York, New York 10017

American Welding Society
550 N.W. LeJeune Road
Miami, Florida 33126

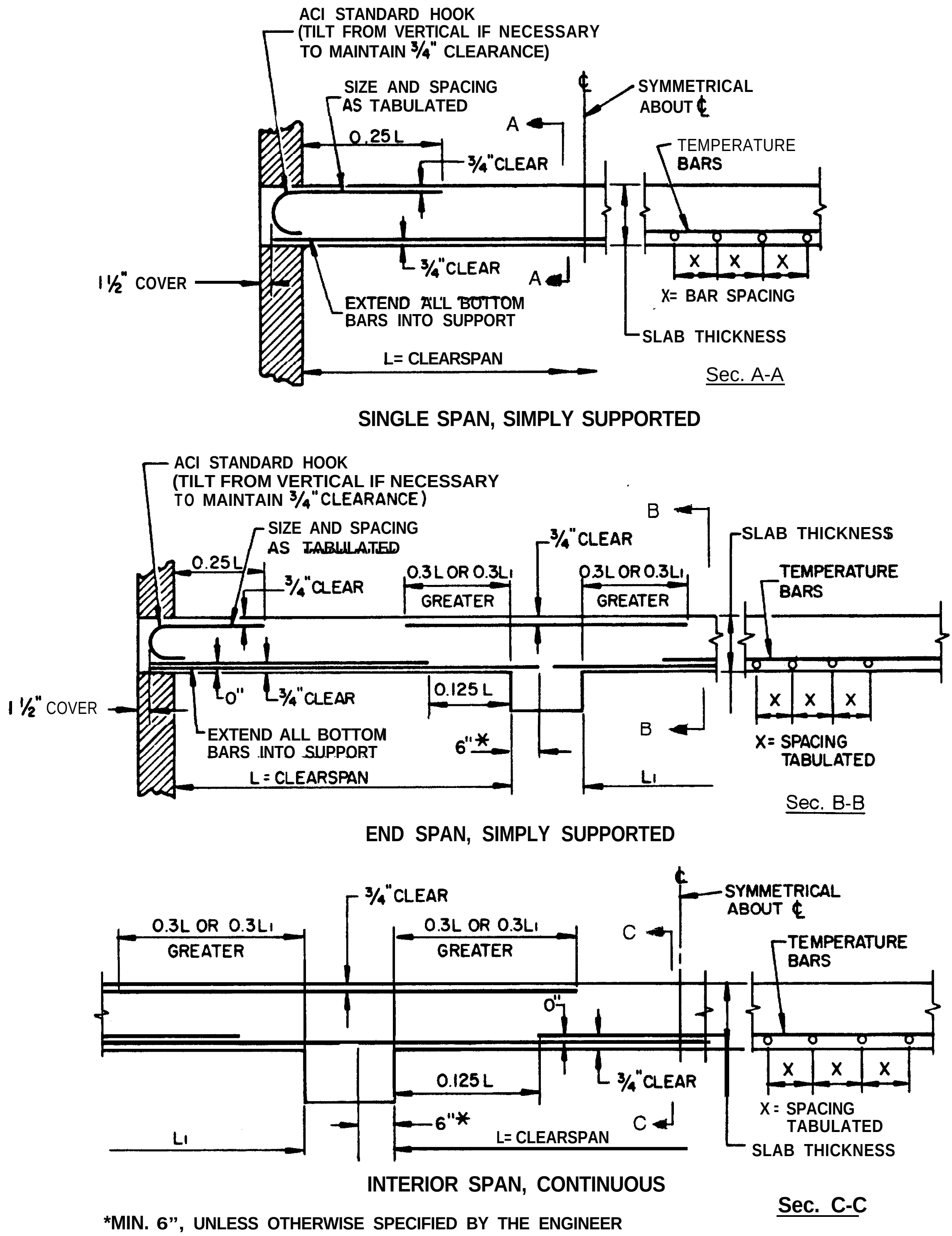
Association for Information and Image Management
1100 Wayne Avenue, Suite 1100
Silver Springs, Maryland 20910

Building Seismic Safety Council
1015 15th Street, N.W., Suite 700
Washington, DC 20005

Concrete Reinforcing Steel Institute
933 North Plum Grove Road
Schaumburg, Illinois 60173

International Conference of Building Officials
5360 South Workman Mill Road
Whittier, California 90601

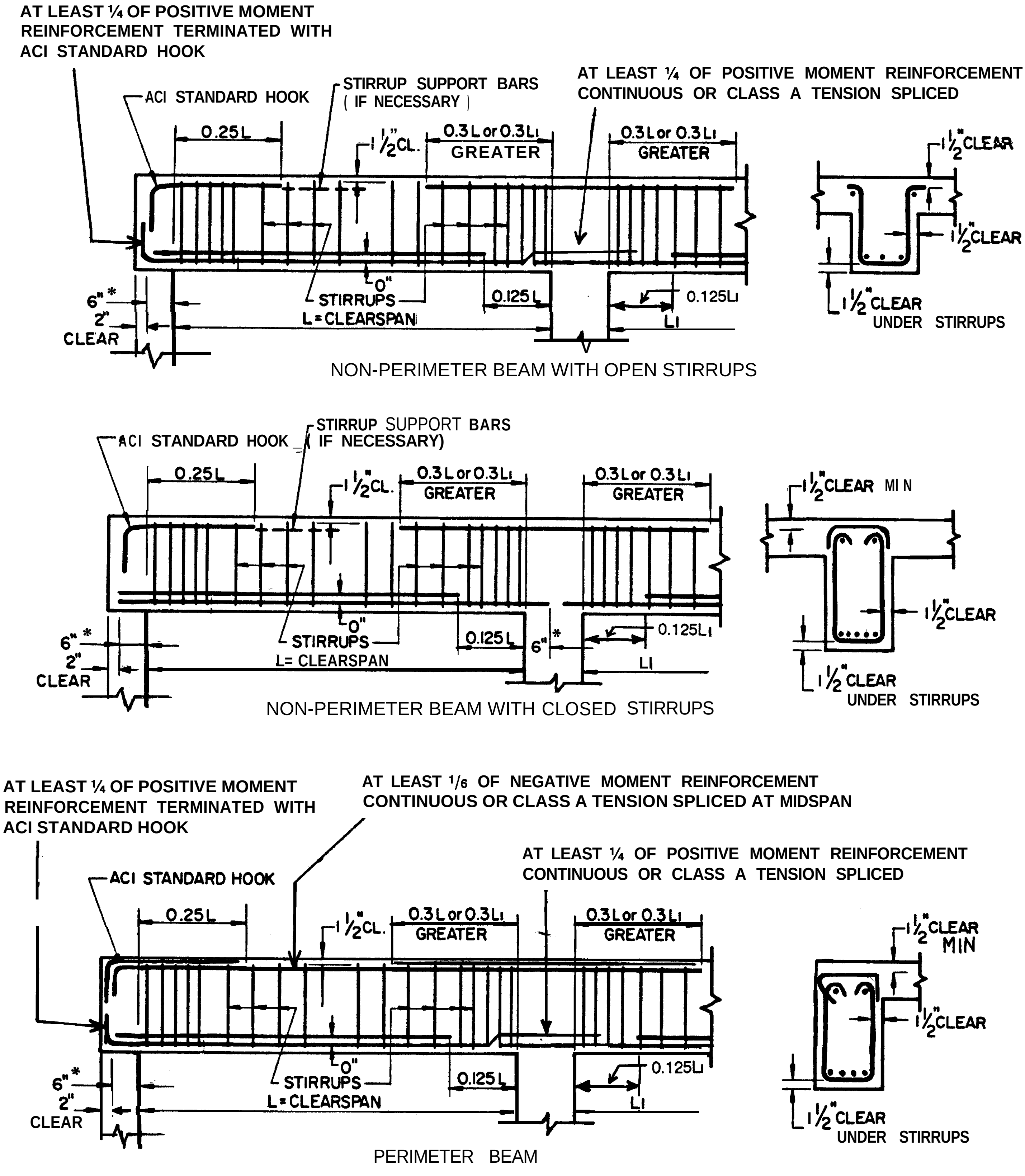
PART C-FIGURES AND TABLES[1]



[1] Unless noted otherwise, tables and figures are based on ACI 318. Concrete cover shown is minimum and should be increased for more severe conditions.

Note: Except for short single span slabs where top steel is unlikely to receive construction traffic, top bars lighter than #4 at 12 in. are not recommended. For a discussion of bar support spacing, see Section 5.4 of this standard. See also Chapter 12 of ACI 318. Bar cutoff details must be verified to provide required development of reinforcement.

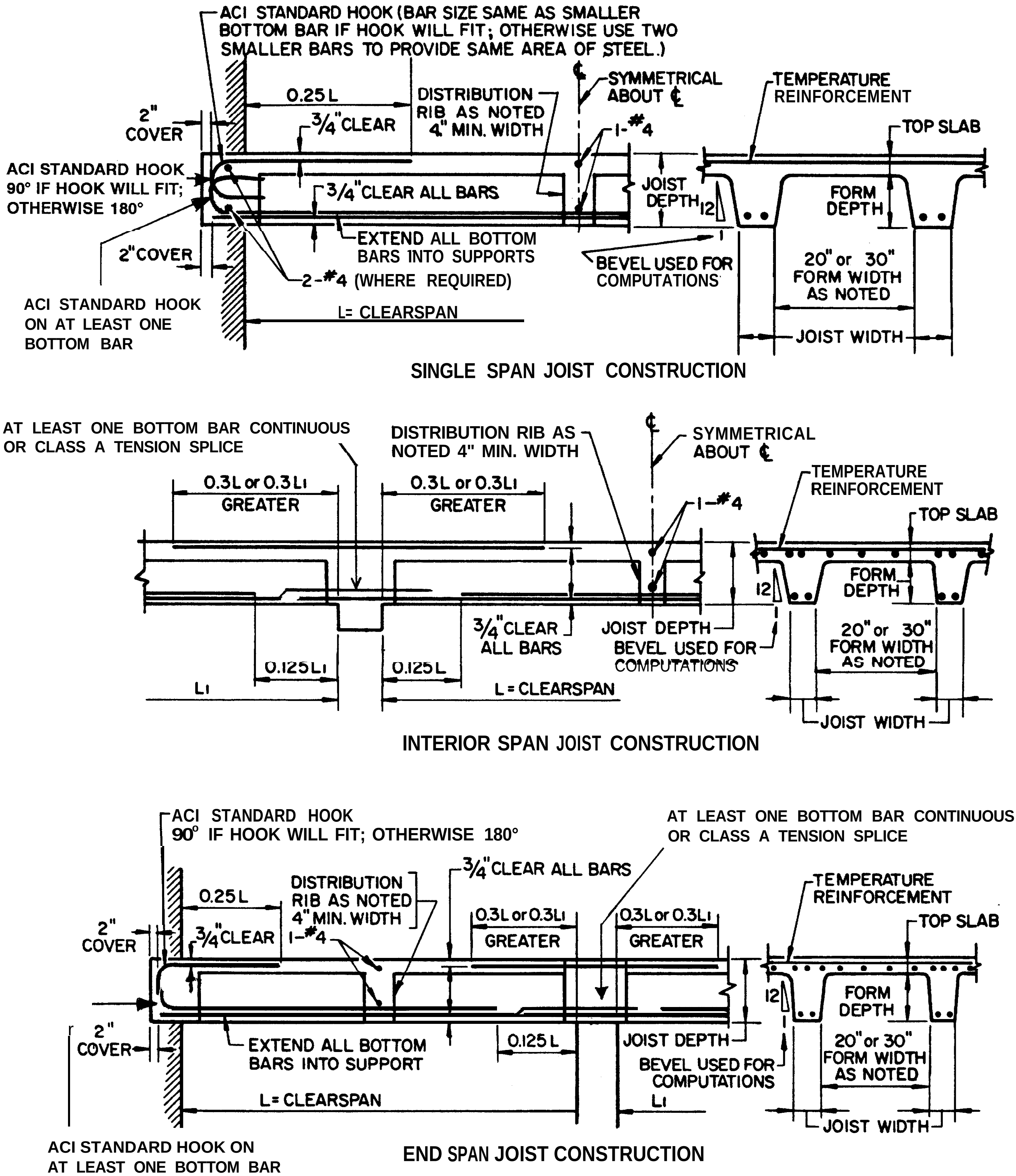
Fig. 1-Typical details for one-way solid slabs



*** MIN. 6", UNLESS OTHERWISE SPECIFIED BY THE ENGINEER**

Note: Check available depth, top and bottom, for required cover on ACI standard hooks. At each end support, add top bar 0.25L in length to equal the area of bars required. See also Chapter 12 and Chapter 21 of ACI 318. Bar cutoff details must be verified to provide required development of reinforcement.

Fig. 2-Typical details for beams



Note: See also Chapter 12 and Section 7.13 of ACI 318.

Bar cutoff details must be verified to provide required development of reinforcement.

Fig. 3-Typical details for one-way joist construction

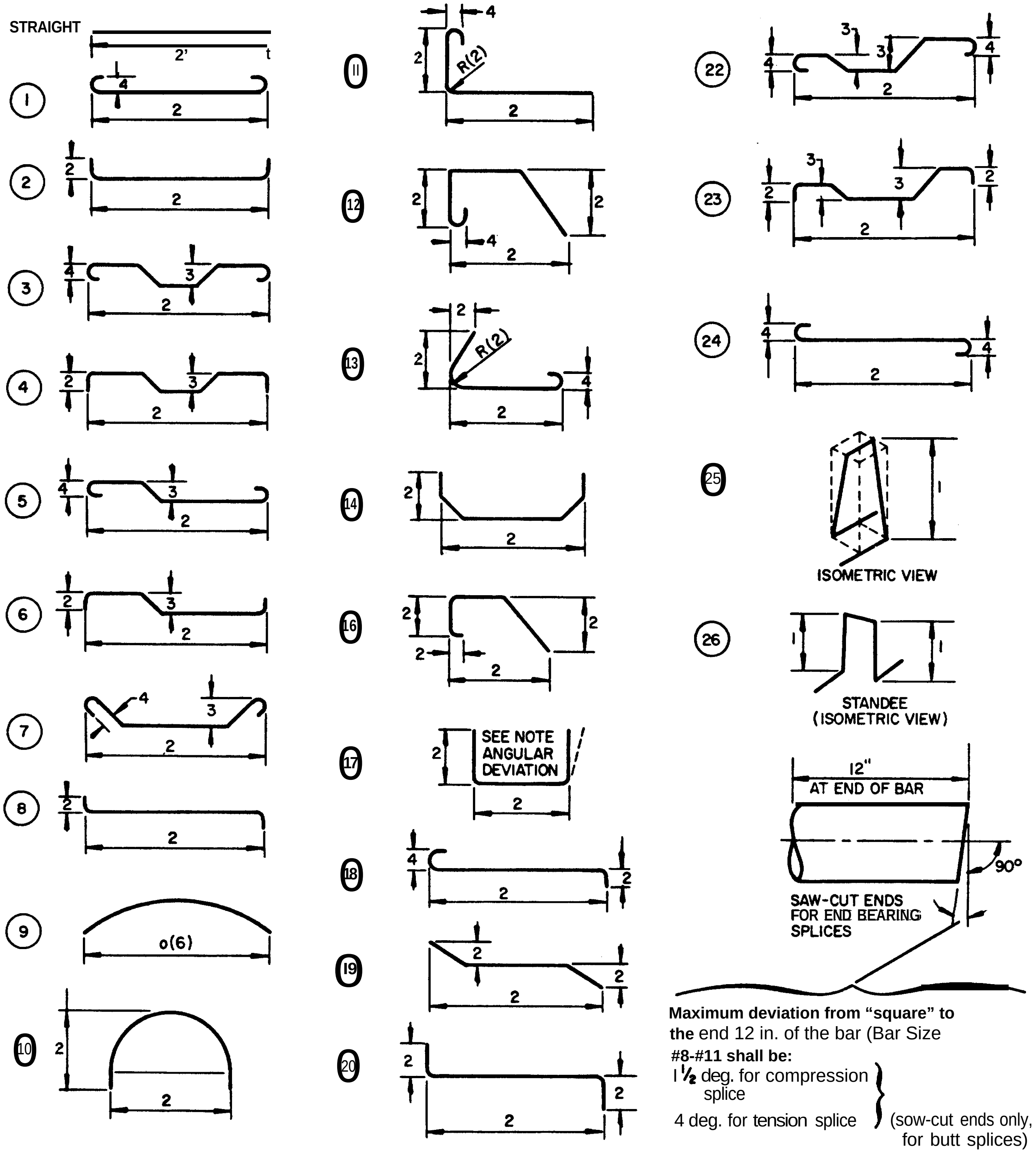
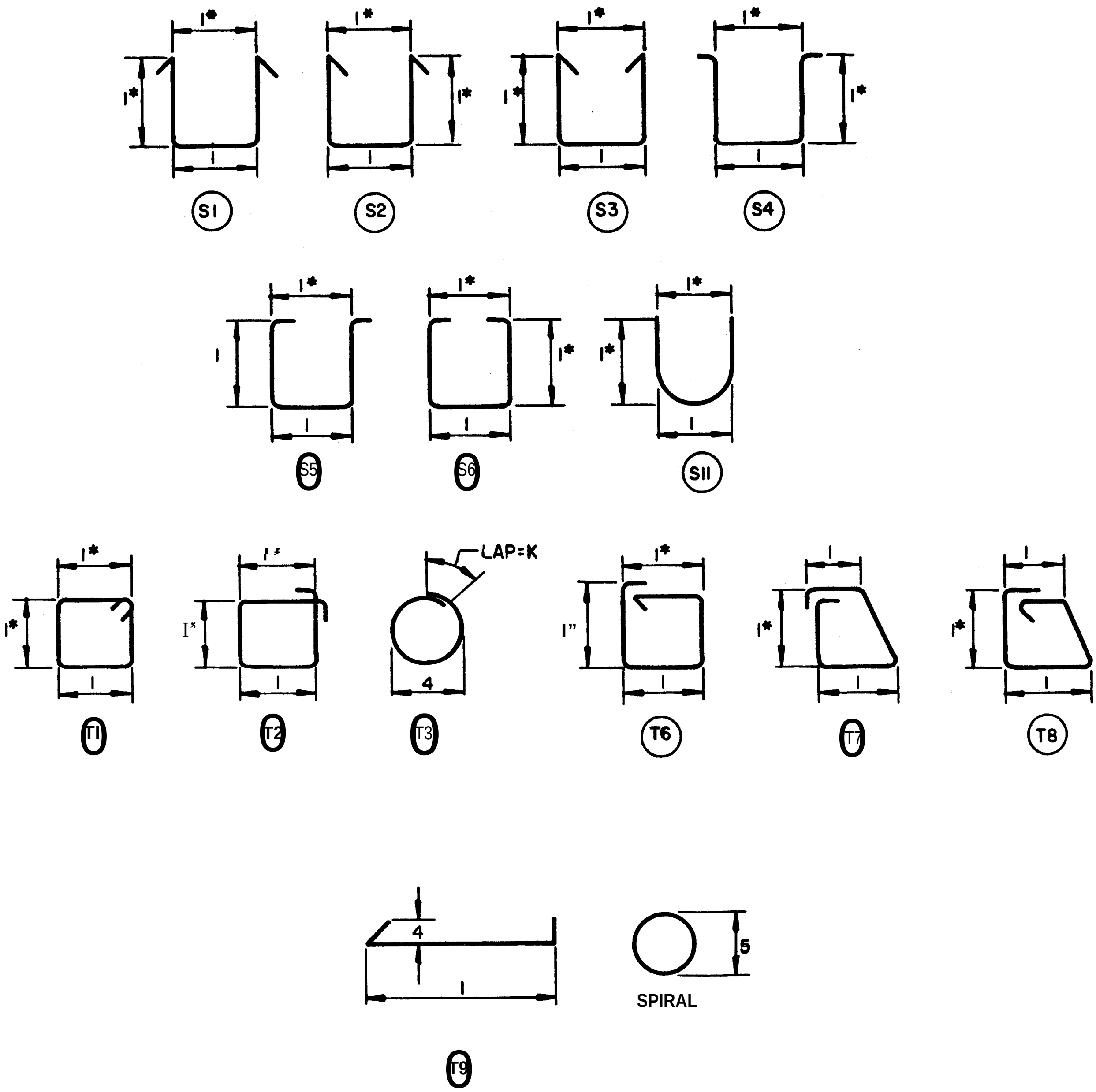


Fig. 4-Standard fabricating tolerances for bar sizes #3 through #11



Notes: Entire shearing and bending tolerances are customarily absorbed in the extension past the last bend in a bent bar.

All tolerances single plane and as shown. Tolerances for types Sl through S6, Sll, T1 through T3, and T6 through T9 apply only to bar sizes #3 'through #8.

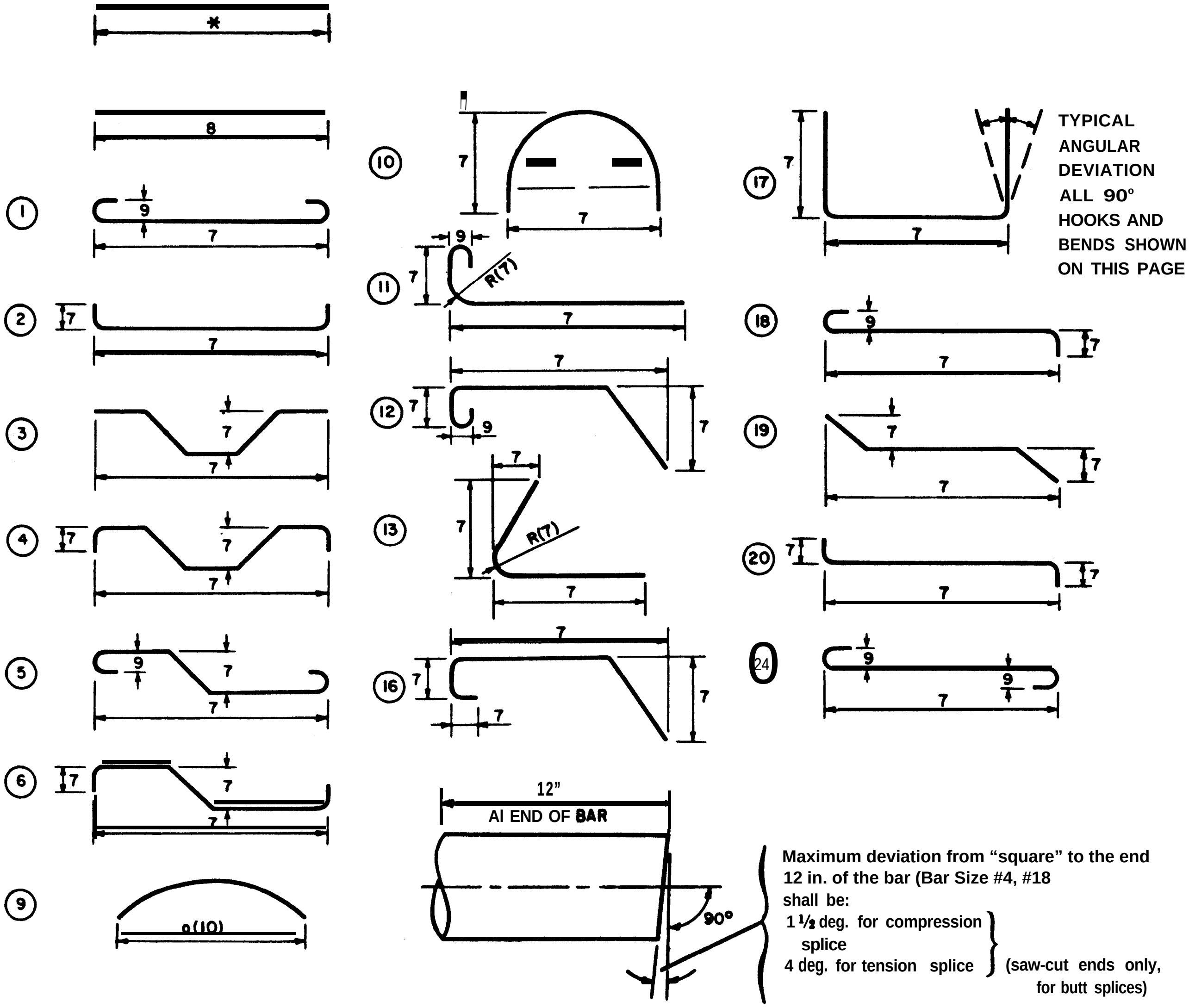
* Dimensions on this line are to be within tolerance shown, but are not to differ from opposite parallel dimension more than ½ in.

Angular deviation-Maximum plus or minus $2^{1}/_{2}$ deg or plus or minus ½ in. per ft, but not less than ½ in., on all 90-deg hooks and bends.

Tolerance symbols:

1. Bar sizes #3, #4, #5:
   = plus or minus 1/2 in. when gross bar length < 12 ft
   = plus or minus 1 in. when gross bar length ≥ 12 ft
   Bar sizes #6 through #1l:
   = plus or minus 1 in.
2. Plus or minus 1 in.
3. Plus 0, minus ½ in.
4. Plus or minus ½ in.
5. Plus or minus ½ in. for diameter ≤ 30 in.
   Plus or minus 1 in. for diameter > 30 in.
6. Plus or minus 1.5 percent of *o* dimension ≥ plus or minus 2 in. minimum. If application of positive tolerance to Type 9 results in a chord length equal to or greater than the arc or bar length, the bar may be shipped straight.

Fig. 4 cont.-Standard fabricating tolerances for bar sizes #3 through #ll



Notes: Entire shearing and bending tolerances are customarily absorbed in the extension past the last bend in a bent bar.

All tolerances single plane and as shown.

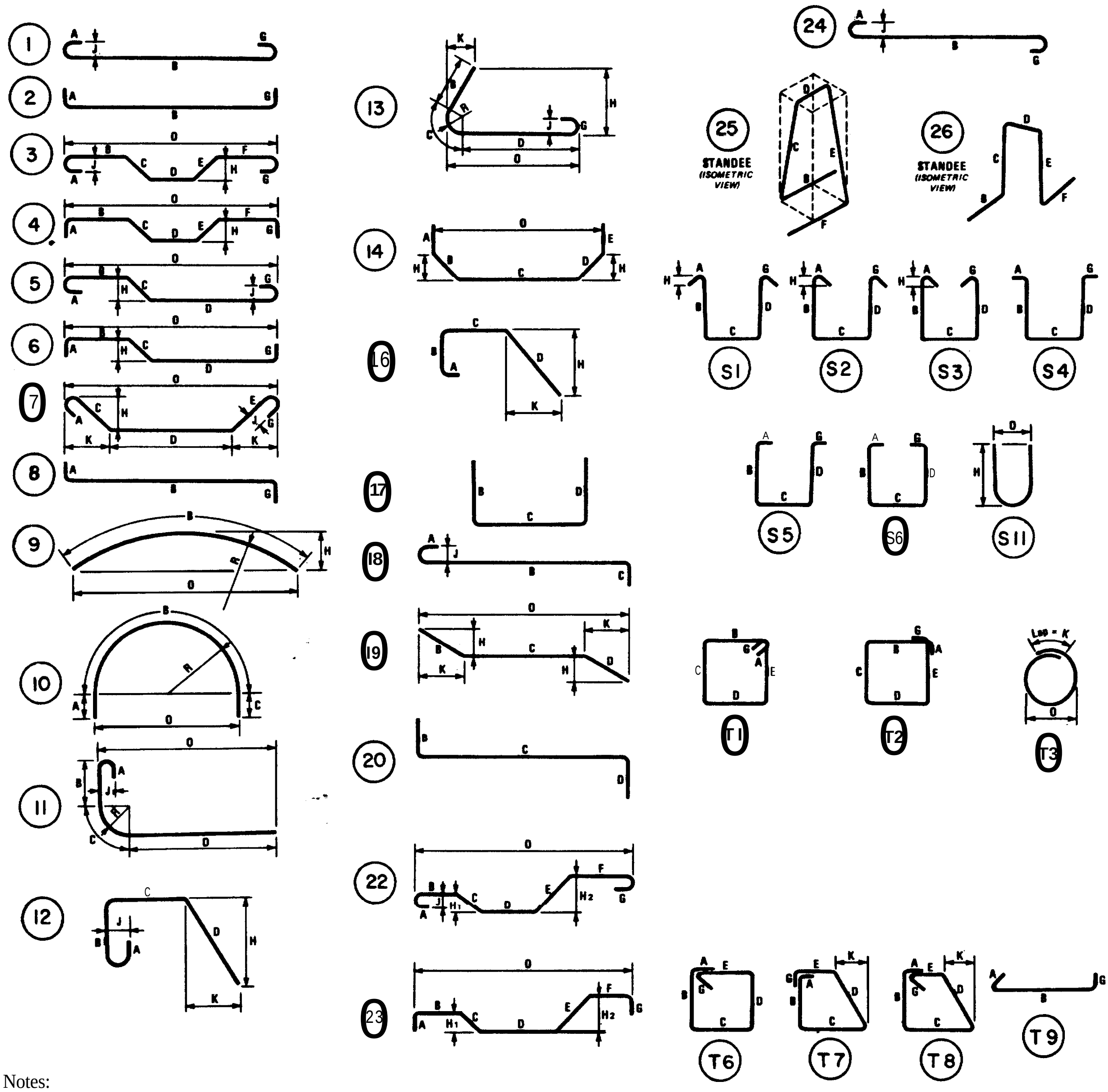
Angular deviation-Maximum plus or minus $2^1/2$ deg or plus or minus ½ in. per ft on all 90-deg hooks and bends.

+ If application of positive tolerance to Type 9 results in a chord length ≥ the arc or bar length, the bar may be shipped straight.

Tolerance symbols:

	#14	#18
7. Plus or minus	2½ in.	3½ in.
8. Plus or minus	2 in.	2 in.
9. Plus or minus	1% in.	2 in.
10. Plus or minus 2 percent x *o* dimension ≥	±2½ in.† min.	±3½ in.+ min.

Fig. 5-Standard fabricating tolerances for bar sizes #14 and #18



Notes:

1. All dimensions are out-to-out of bar except *A* or *G* on standard 180-deg and 135-deg hooks.

2. The *J* dimension on 180-deg hooks to be shown only when necessary to restrict hook size; otherwise standard hooks are to be used.

3. Where *J* is not shown, *J* will be kept equal to or less than *H* on Types 3, 5, and 22. Where *J* can exceed *H*, it should be shown.

4. The *H* dimension on stirrups to be shown where necessary to fit within concrete.

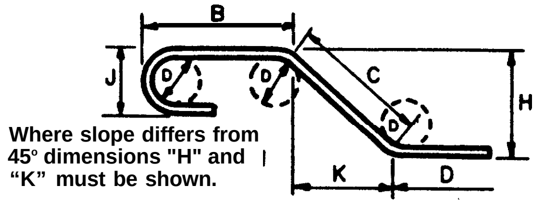
5. Where bars are to be bent more accurately than standard bending tolerances, bending dimensions which require closer fabrication should have limits indicated.

6. Figures in the circles show types.

7. For minimum bend diameters, see Sections 3.7.1 of this standard; for recommended hook dimensions, see Table 1.

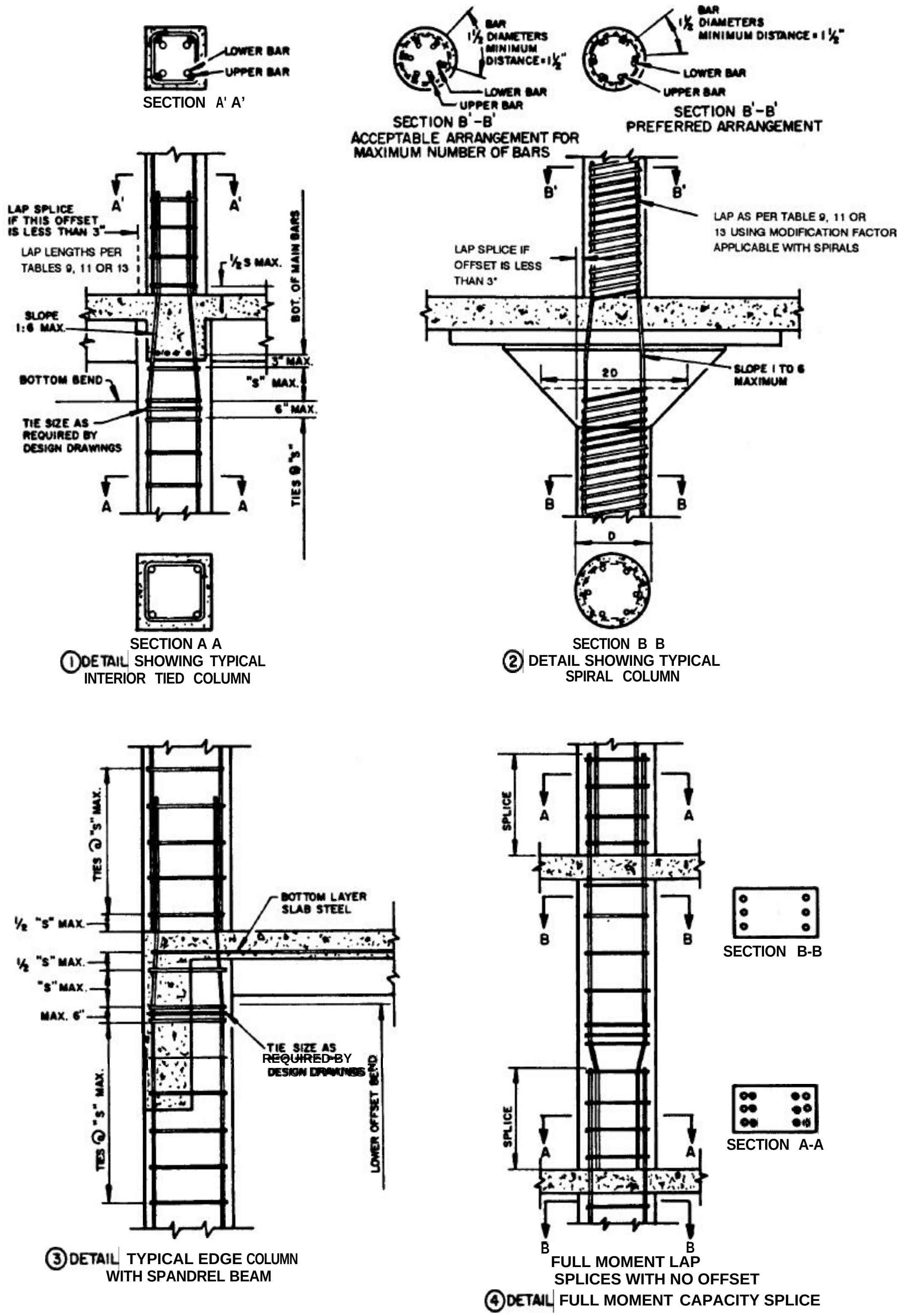
8. Types Sl-S6, Sll, Tl-T3, T6-T9 apply to bar sizes #3-#8 inclusive only.

Unless otherwise noted diameter D is the same for all bends and hooks on a bar.



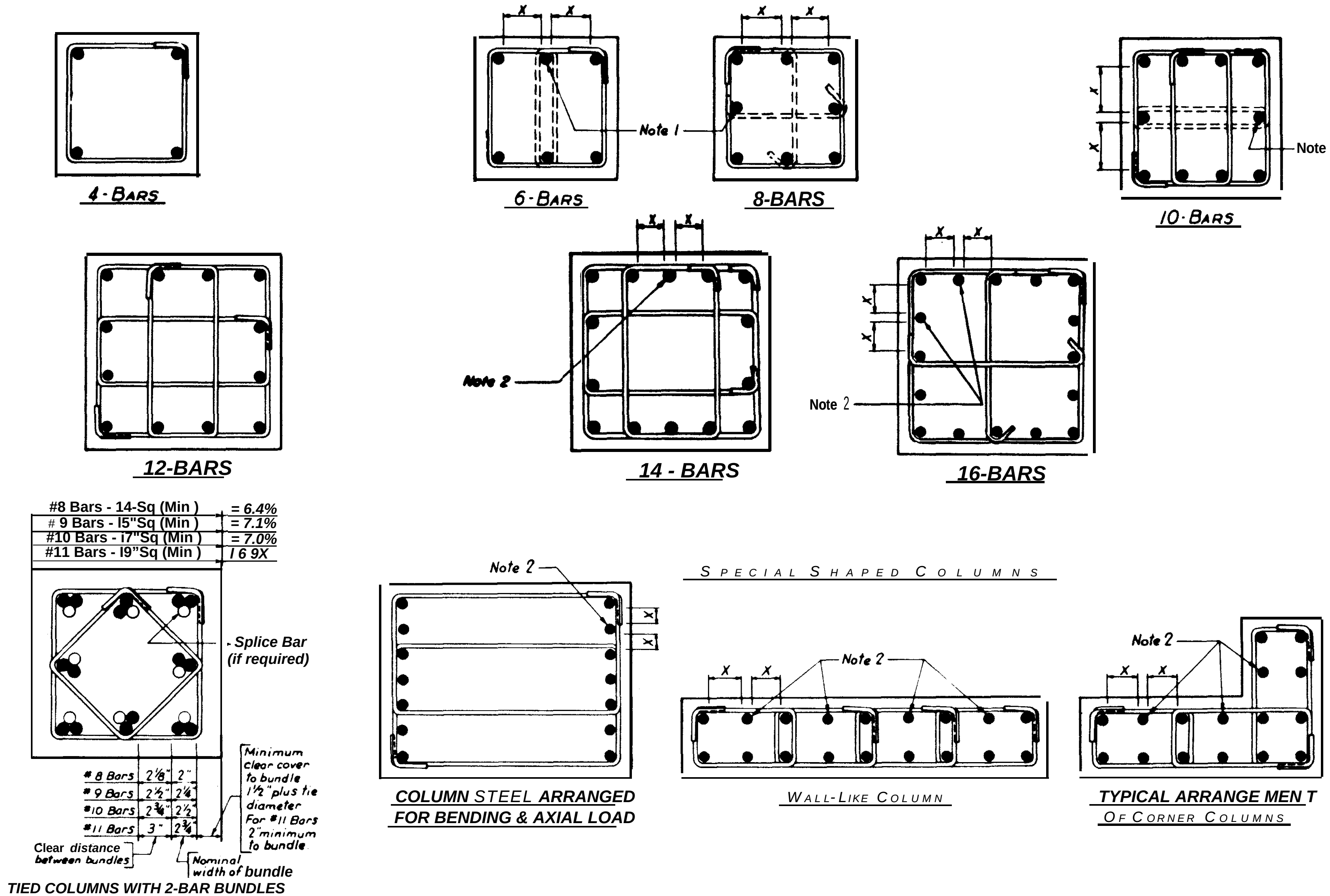
ENLARGED VIEW SHOWING BAR BENDING DETAILS

Fig. 6-Typical bar bends



Where column size above is unchanged from the below, "upside down" offset bars are effective in maintaining the full moment capacity at the end of the column. In U.S. practice, this unusual detail is rare, and should be fully illustrated on design drawings to avoid misunderstandings, whenever its use is deemed necessary.

Fig. 7-Column splice details



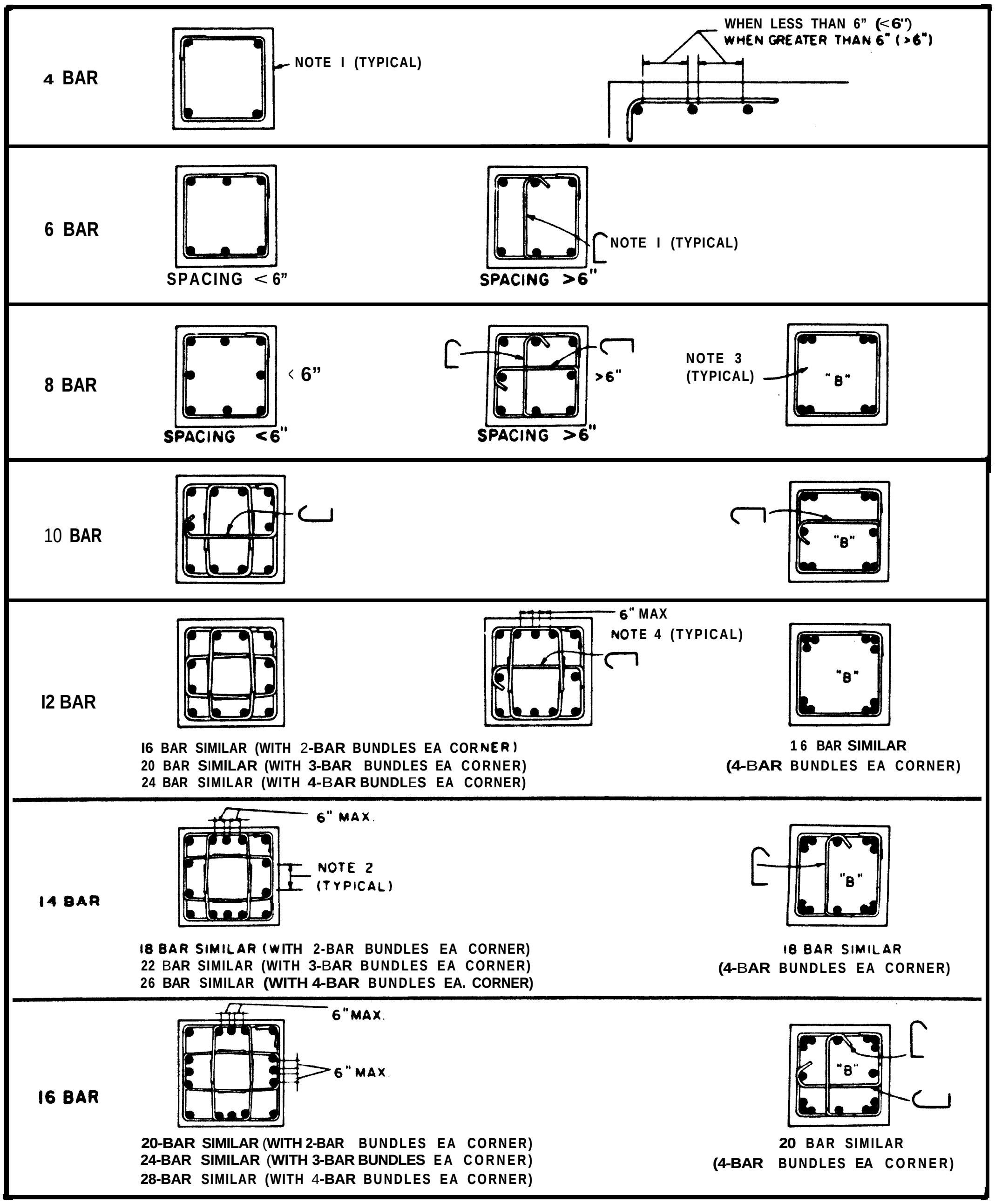
A different pattern of ties may be substituted provided that details of the requirements are shown on the contract drawings. Single-leg tie arrangements in lieu of the one piece diamond tie shown are an acceptable alternate.

Note 1: These bars must be ties as shown by dashed lines when X distance is greater than 6 in.

Note 2: These bars need not be tied when X distance equals 6 in. or less.

Note 3: Minimum cover $1^1/2$ in. to ties.

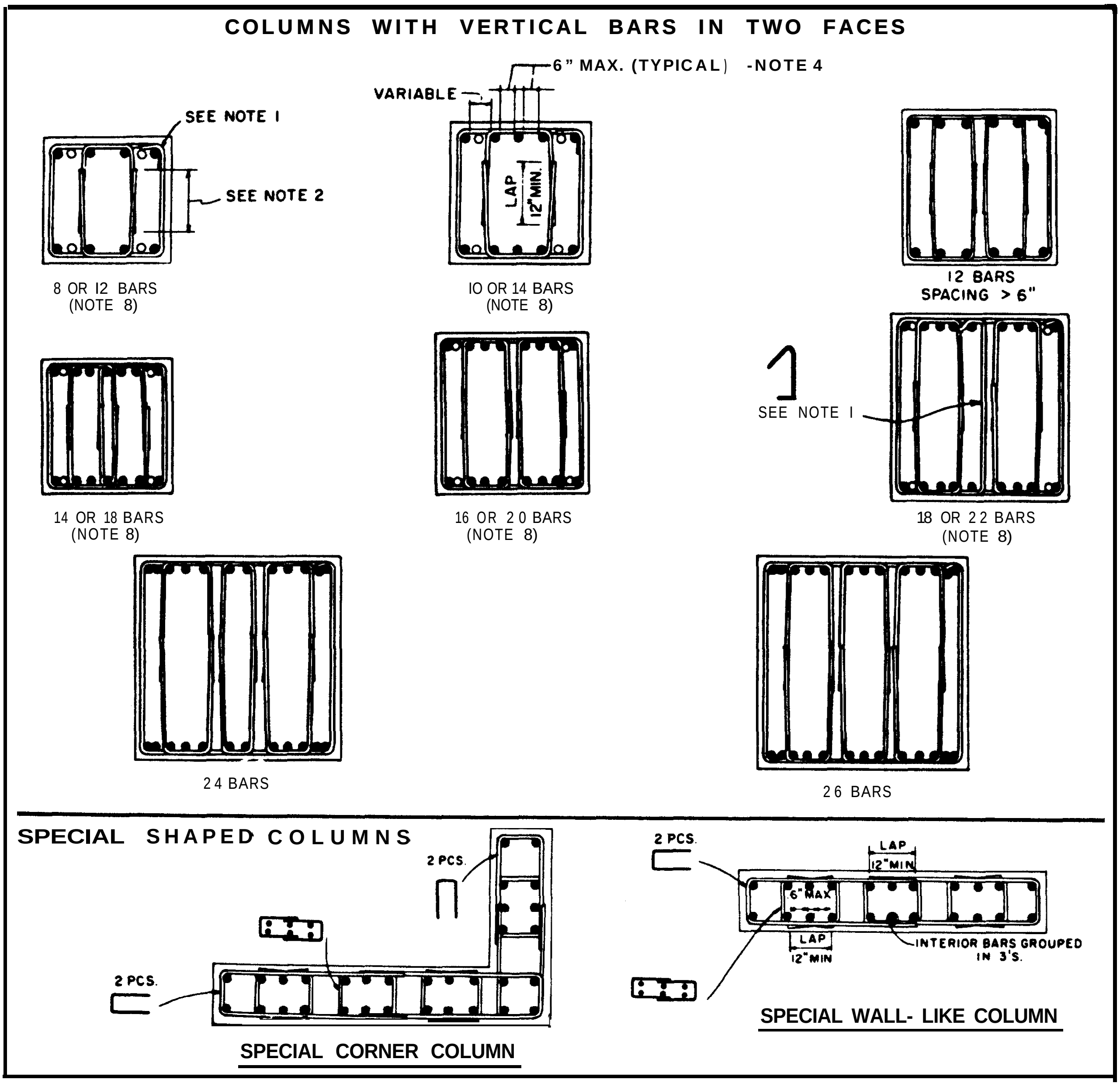
Fig. 8-One-piece column ties applicable for lap-spliced preassembled cages



Notes:

1. Alternate position of hooks in placing successive sets of ties.
2. Minimum lap shall be 12 in.
3. *B* indicates bundled bars. Bundles should not exceed four bars.
4. Elimination of tie for center bar in groups of three limits clear spacing to be 6 in. maximum. Unless otherwise specified, bars should be so grouped.
5. Note to designers: Accepted practice requires that design drawings show all requirements for splicing column verticals, i.e., type of splice, lap length if lapped, location in elevation, and layout in cross section.
6. Note to detailers: Dowel erection details are required for any design employing special large vertical bars, bundled vertical bars, staggered splices, or specially grouped vertical bars as shown.
7. Bars must be securely supported to prevent displacement during concreting.
8. Bars shown as open circles may be accommodated provided clear spaces between bars do not exceed 6 in.
9. Tie patterns shown may accommodate additional single bars between tied groups provided clear spaces between bars do not exceed 6 111.
10. Minimum cover to ties, $1^1/_2$ in. for nonprestressed cast-in-place concrete.
11. Spaces between corner bars and interior groups of three and between interior groups may vary to accommodate average spacing > 6 in.
12. For average spacing < 6 in., one untied bar may be located between each tied group of three and between a tied group and a corner bar.

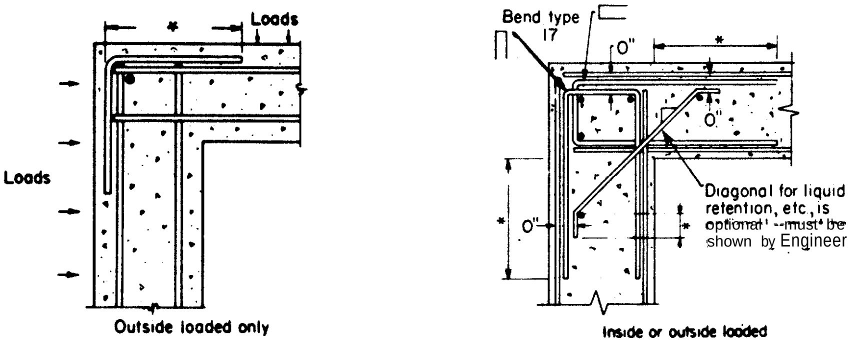
Fig. 9-Universal column ties for standard columns applicable for either. preassembled cages or field erection



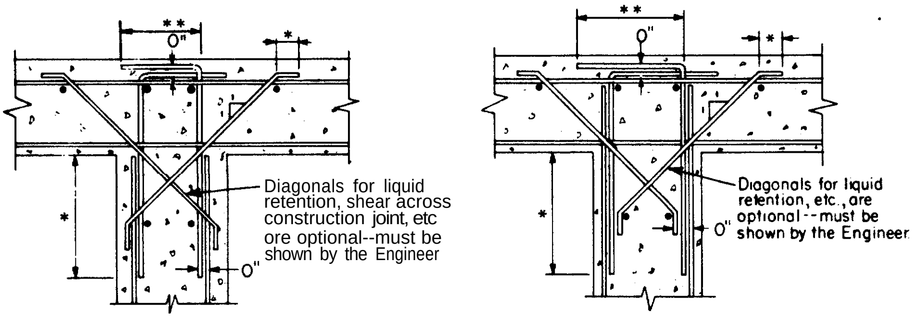
Notes:

1. Alternate position of hooks in placing successive sets of ties.
2. Minimum lap shall be 12 in.
3. *B* indicates bundled bars. Bundles should not exceed four bars.
4. Elimination of tie for center bar in groups of three limits clear spacing to be 6 in. maximum. Unless otherwise specified, bars should be so grouped.
5. Note to designers: Accepted practice requires that design drawings show all requirements for splicing column verticals, i.e., type of splice, lap length if lapped, location in elevation, and layout in cross section.
6. Note to detailers: Dowel erection details are required for any design employing special large vertical bars, bundled vertical bars, staggered splices, or specially grouped vertical bars as shown.
7. Bars must be securely supported to prevent displacement during concreting.
8. Bars shown as open circles may be accommodated provided clear spaces between bars do not exceed 6 in.
9. Tie patterns shown may accommodate additional single bars between tied groups provided clear spaces between bars do not exceed 6 in.
10. Minimum cover to ties, $1^1/_2$ in. for nonprestressed cast-in-place concrete.
11. Spaces between corner bars and interior groups of three and between interior groups may vary to accommodate average spacing > 6 in.
12. For average spacing < 6 in., one untied bar may be located between each tied group of three and between a tied group and a corner bar.

Fig. 10-Universal column ties applicable for either preassembled cages or field erection: special-shaped columns and columns with bars in two faces only



Typical corner details



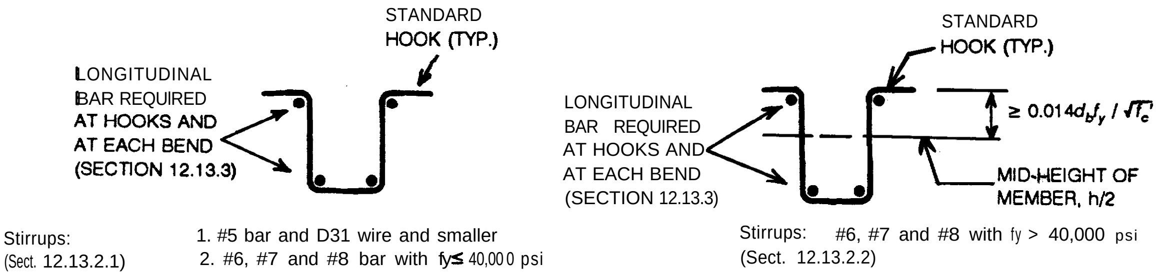
Typical intersection details for double curtain reinforcement

Notes: All 90-deg bends as shown unless otherwise indicated on design drawings. Vertical bars shown at hooks only. Bends are shown as sharp angles for clarity.

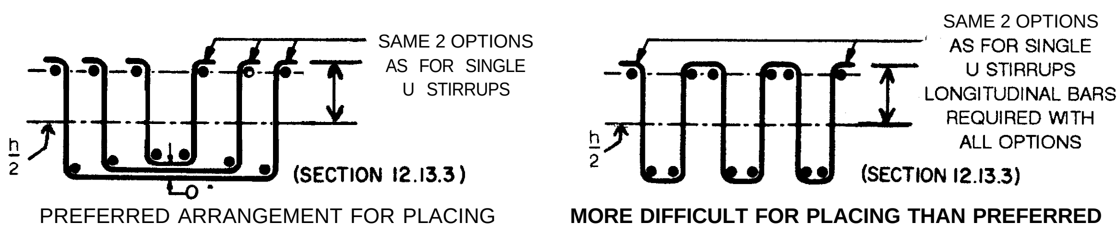
* This dimension must be shown or specified by Engineer.

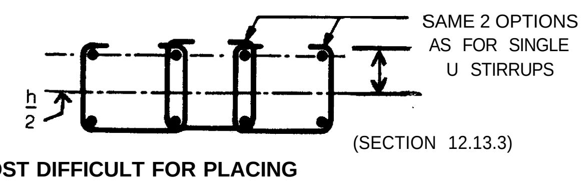
** If other than a standard 90-deg end hook, this dimension must be shown by the Engineer.

Fig. 11-Typical wall details shown in horizontal cross section



SINGLE U-STIRRUPS - ANCHORAGE REQUIREMENTS





Note: Section numbers refer to ACI 318.

Fig. 12-ACI 318 requirements for anchorage of open stirrups

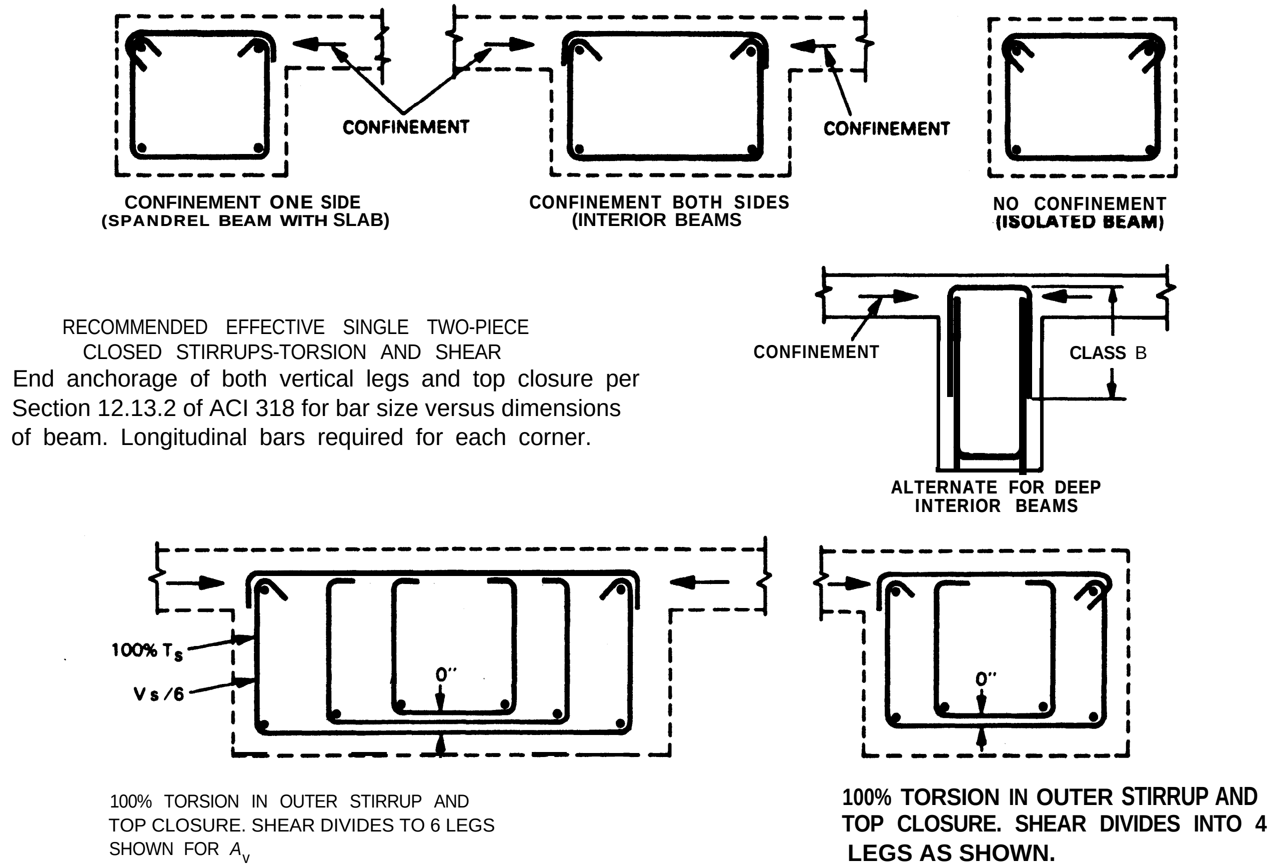
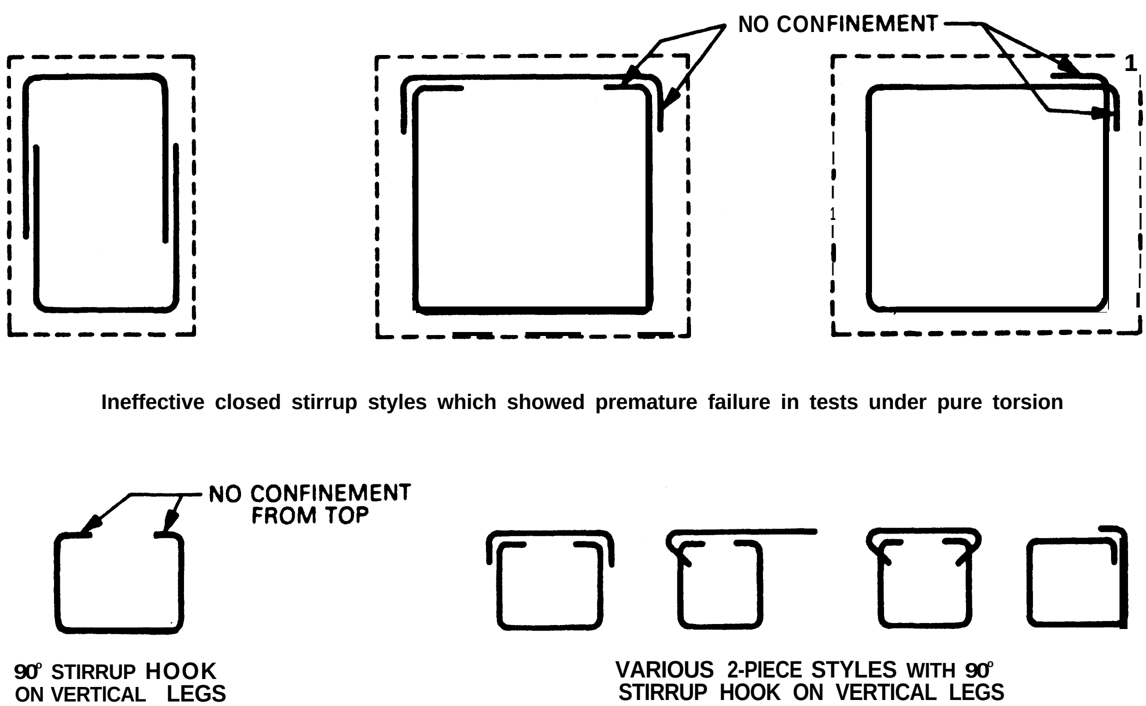


Fig. 13-Recommended two-piece closed single and multiple U-stirrups



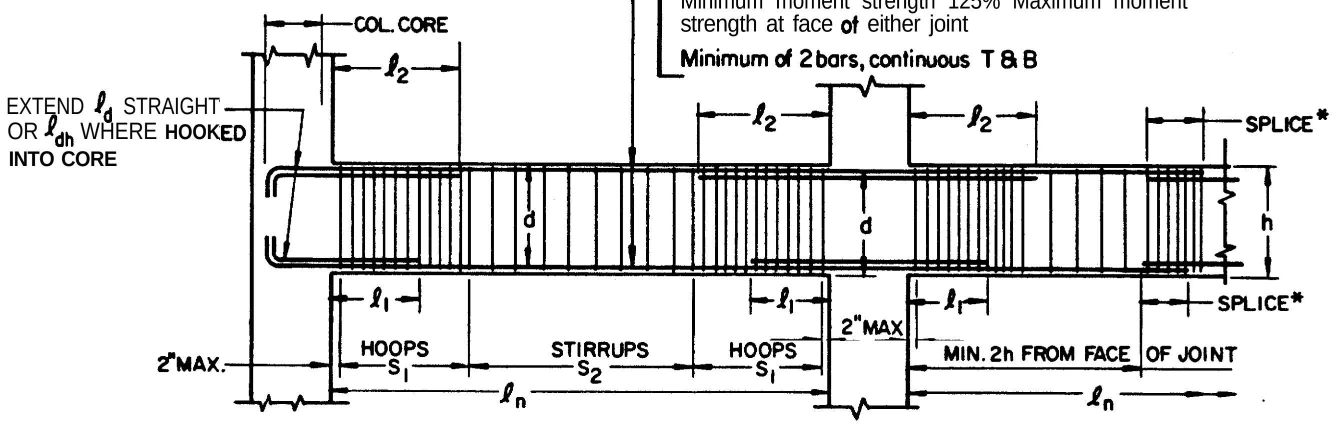
These styles are NOT RECOMMENDED for those members to be subjected to high torsional stress. Note lack of confinement when compared to similar members with confinement shown in Fig. 13.

Fig. 14—Not recommended—Closed stirrup styles considered ineffective for members subjected to high torsion stress (based on tests by Collins and Mitchell)

Terminate all required top and bottom bars at the far face of the column core, providing min. distances, ℓ_{dh} or ℓ_d, for tension per Section 21.6.4 or compression per Section 12.3, ACI 318.

Longitudinal Reinforcement, Top and Bottom

- Minimum $A_s \geq 200\, b_w d/f_y$
- Maximum $p \leq 0.025$
- Minimum moment strength 125% Maximum moment strength at face of either joint
- Minimum of 2 bars, continuous T & B



Engineer must provide dimensions ℓ_1, ℓ_2, S_1, S_2, hoop and stirrup spacing, anchorage length, cut-off points of discontinuous bars, ℓ_d, or ℓ_{dh} if less then across column core.

$\ell_n \geq 4d$

ℓ_1 = distance required by design far moment plus anchorage length

ℓ_2 = distance to point of inflection plus anchorage length

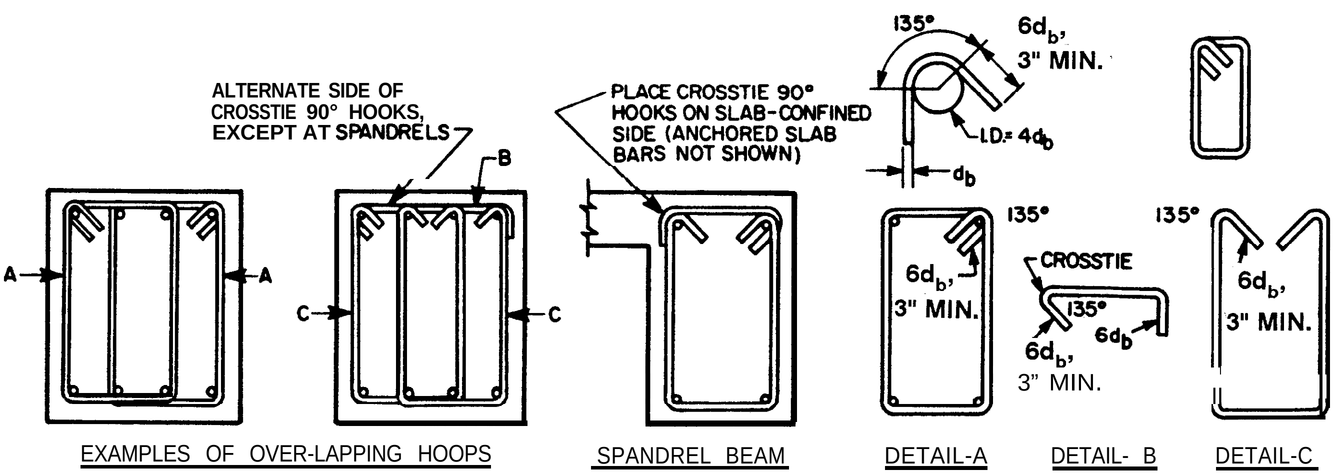
d = design depth for -M and +M

Maximum Hoop/Tie Spacings

In length S_1, spacing for hoops $\leq d/4$; $8d_b$ of smallest bar; $24d_b$ of hoop; or 12 in.

*At lap splices, spacing of hoops $\leq d/4$ but not greater than 4in.

In length S2, spacing strirrups $\leq d/2$



STIRRUPS REQUIRED TO RESIST SHEAR SHALL BE HOOPS. THROUGHOUT THE LENGTH OF FLEXURAL MEMBERS WHERE HOOPS ARE NOT REQUIRED, STIRRUPS MUST BE SPACED AT NO MORE THAN **d/2**

Fig. 15-Typical seismic-resistant details--Flexural members

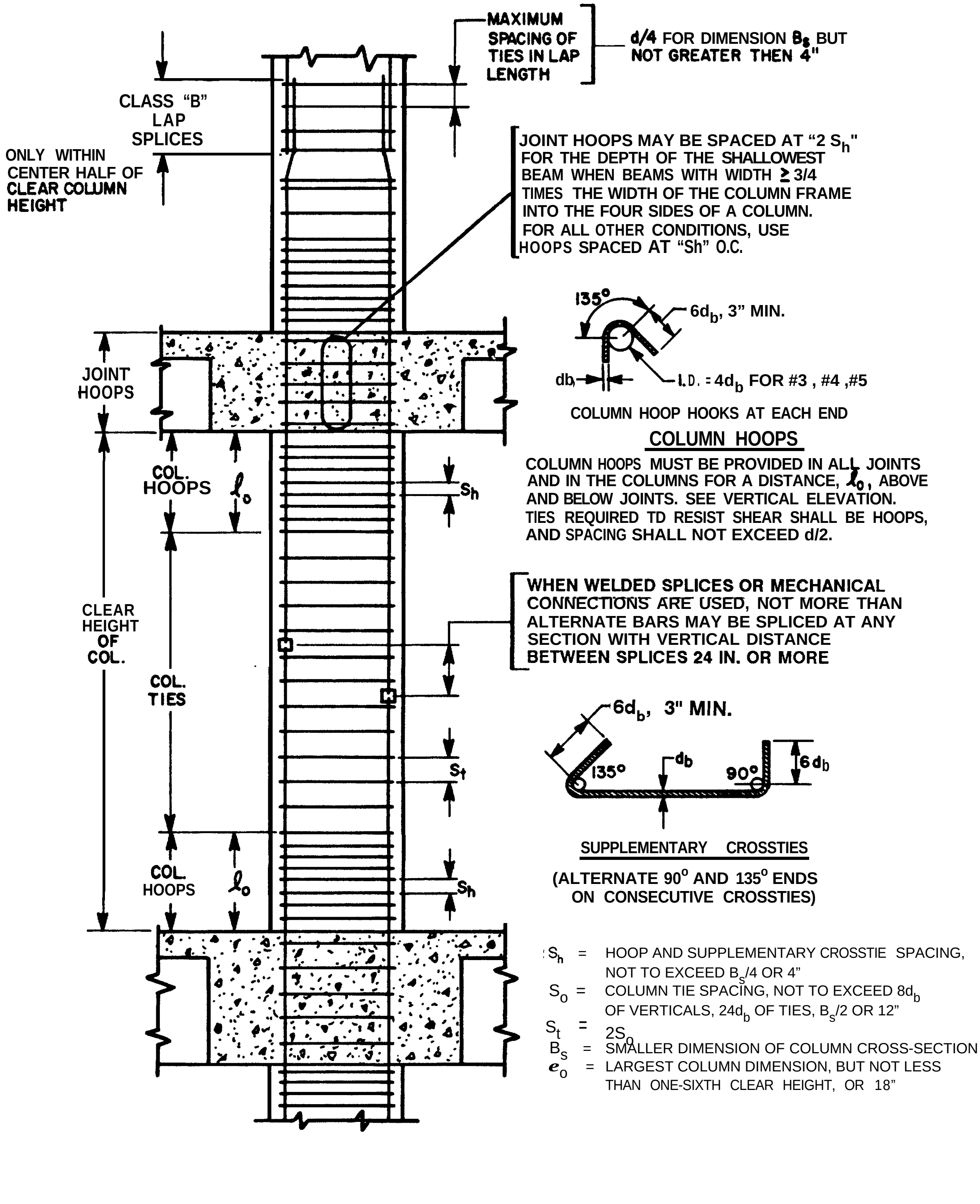


Fig. 16-Typical seismic-resistan details-Columns

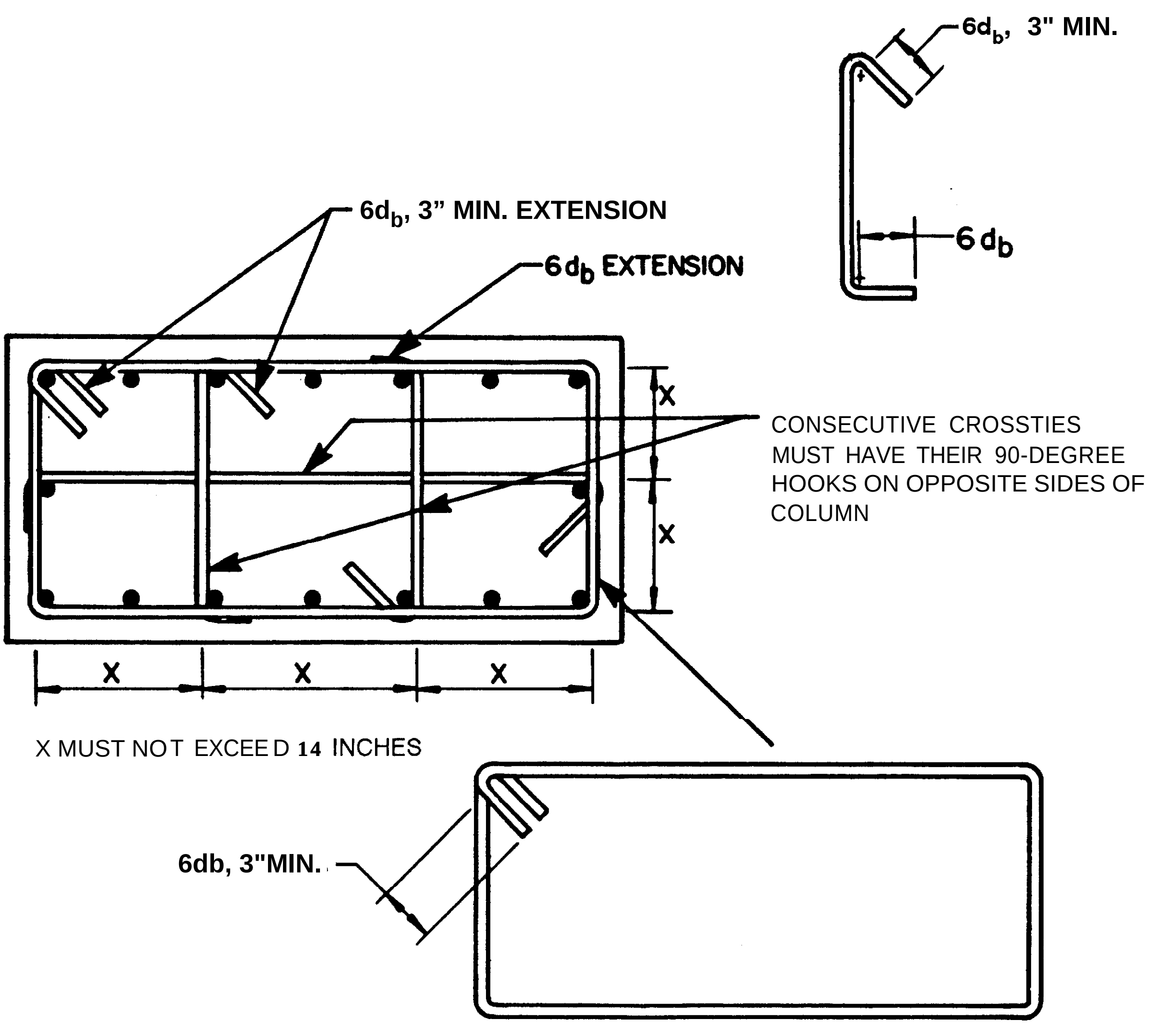
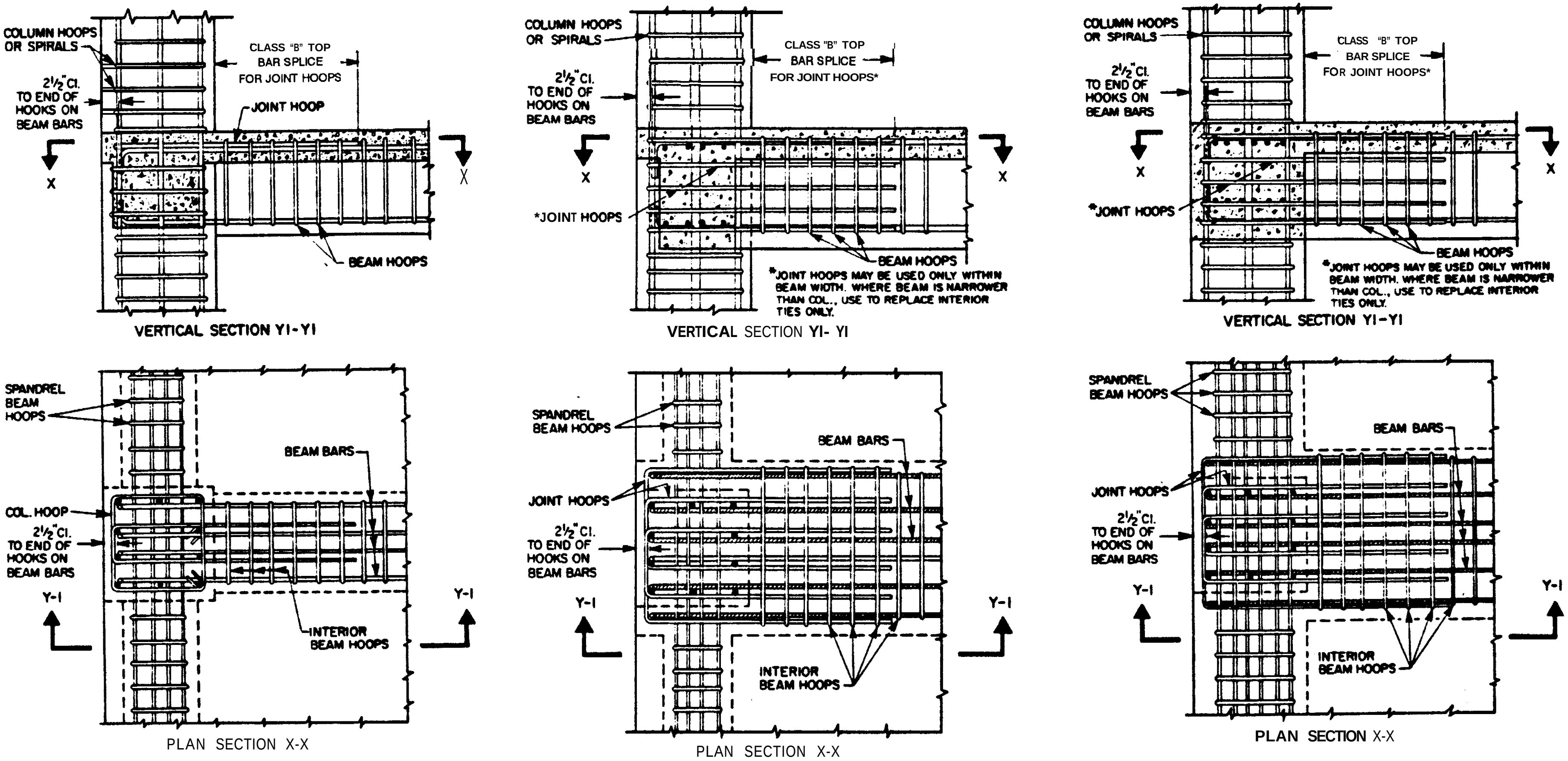


Fig. 17-Example of transverse reinforcement in columns



Case 1: For regions of high seismic risk. Interior and spandrel beams narrower than column

Case 2: For regions of moderate seismic risk in braced frames. Interior beam wider than the column; spandrel beam same width as column

Case 3: For regions of moderate seismic risk in braced frames. Interior beam wider than the column; spandrel beam narrower than column

Fig. 18-Typical ductile frame-spandrel joint details

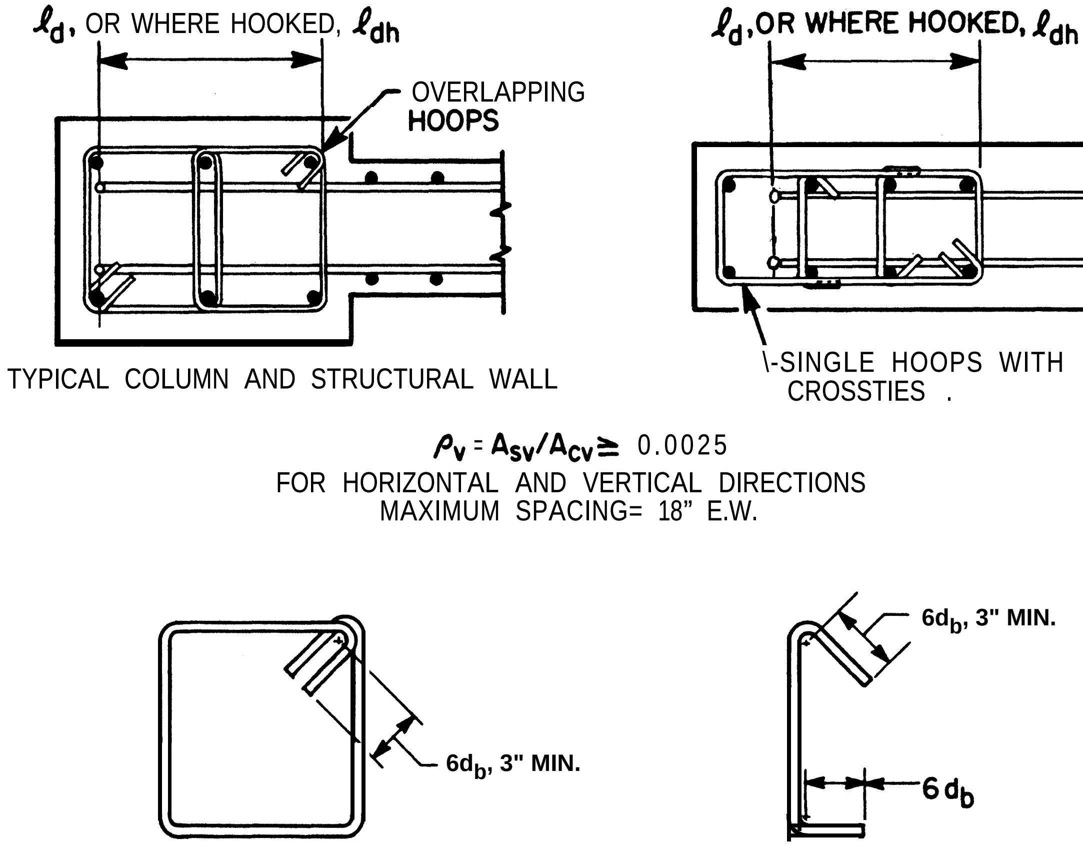


Fig. 19-Boundary members

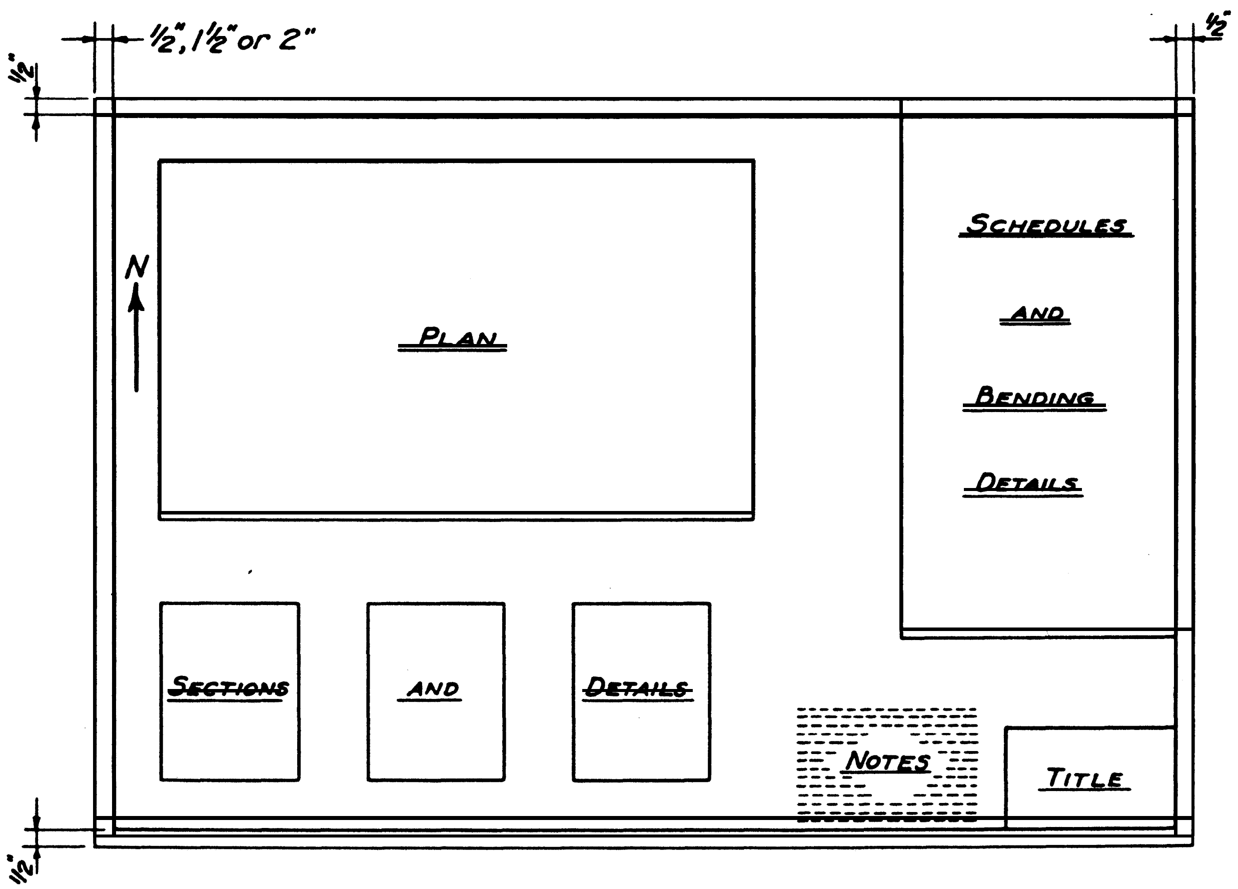


Fig. 20-Recommended layout for placing drawings

ABC PRODUCTS COMPANY
CHICAGO, ILLINOIS

		JOB NO.	**27693**
CUSTOMER	*Jones Bros. Construction Co.*	**DWG. NO.**	*Figs. 18-4a, 18-6a*
PROJECT	*Fieldcrest Apt. Bldg.*	**SHEET**	1 **OF** 2
LOCATION	*Smithville, N. C.*	**DATE**	**3-17-87** **REVISED** *4-7-87*
MATERIAL FOR	*Basement Columns*	**DRAWN BY**	*H.N.H.*

Item	*No.* Pcs.	Size	Length	Mark	Type	A	B	C	D	E	F	G	H	J	K	O	R
1	*STRAIGHT*																
2	4	18	23-11														
3	4	18	18-11														
4	12	18	8-11														
5																	
6	8	14	23-11														
7	4	14	8-11														
8																	
9	12	9	12-8														
10	6	9	4-1														
11	6	9	4-1														
12																	
13	*STRAIGHT SAW CUT BOTH ENDS*																
14	8	18	23-11	18W1													
15	8	18	11-5	18W2													
16																	
17	*HEAVY BENDING*																
18	4	11	20-0	11BC5	5		16-0	1-0	3-0				3		1-0		
19	64	11	13-6	11C16	5		3-0	1-3	9-3				4		1-3		
20																	
21	18	9	12-8	9C4	5		1-11	1-8	9-1				4½		1-8		
22																	
23	*LIGHT BENDING*																
24	22	3	8-4	3T6	T2	4	2-1	1-9	2-1	1-9		4					
25	22	3	7-8	3T9	T2	4	1-11	1-7	1-11	1-7		4					
26	50	3	6-3	3BT1	T2	4	1-4¾	1-4¾	1-4¾	1-4¾		4					
27	26	3	6-3	3BT3	T2	4	1-0¾	1-8¾	1-0¾	1-8¾		4					
28	44	3	3-4	3T10	S10		1-3½	9	1-3½								
29	22	3	2-10	3T23	T5	5	2-1	4									
30	52	3	2-10	3BT4	S10		1-0¼	9¼	1-0¼								
31	22	3	2-8	3T8	T5	5	1-11	4									
32	22	3	2-6	3T20	T5	5	1-9	4									
33																	
34	*SPIRALS*																
35	No. Pcs.	Size	Length	Mark	Diam.	Pitch	Turns	Splices									
36	4	½Φ	8-9	SP5	21	3	38	3									

ALL DIMENSIONS ARE OUT TO OUT
ALL STEEL ASTM <u>A 615</u> GRADE <u>60</u>

FOR TYPICAL BEND TYPES REFER TO ACI DETAILING MANUAL

Note: Fig. 6 identifies typical bend types. All dimensions less than 12 in. are given in inches.

Dimensions 12 in. or greater are given in feet and inches, e.g., 1-3 (except diameter of spirals which is given in inches).

Fig. 21-Typical bar lists for buildings

ABC PRODUCTS COMPANY
CHICAGO, ILLINOIS

		JOB NO.	2 76893
CUSTOMER	*Jones Bros. Construction Co.*	DWG. NO.	*Figs. 18-4a, 18-6a*
PROJECT	*Fieldcrest Apt. Bldg.*	SHEET	2 OF 2
LOCATION	*Smithville, N. C.*	DATE	*3-l 7-87* REVISED *4-7-87*
MATERIAL FOR	*Basement Columns*	DRAWN BY	*H.N.H.*

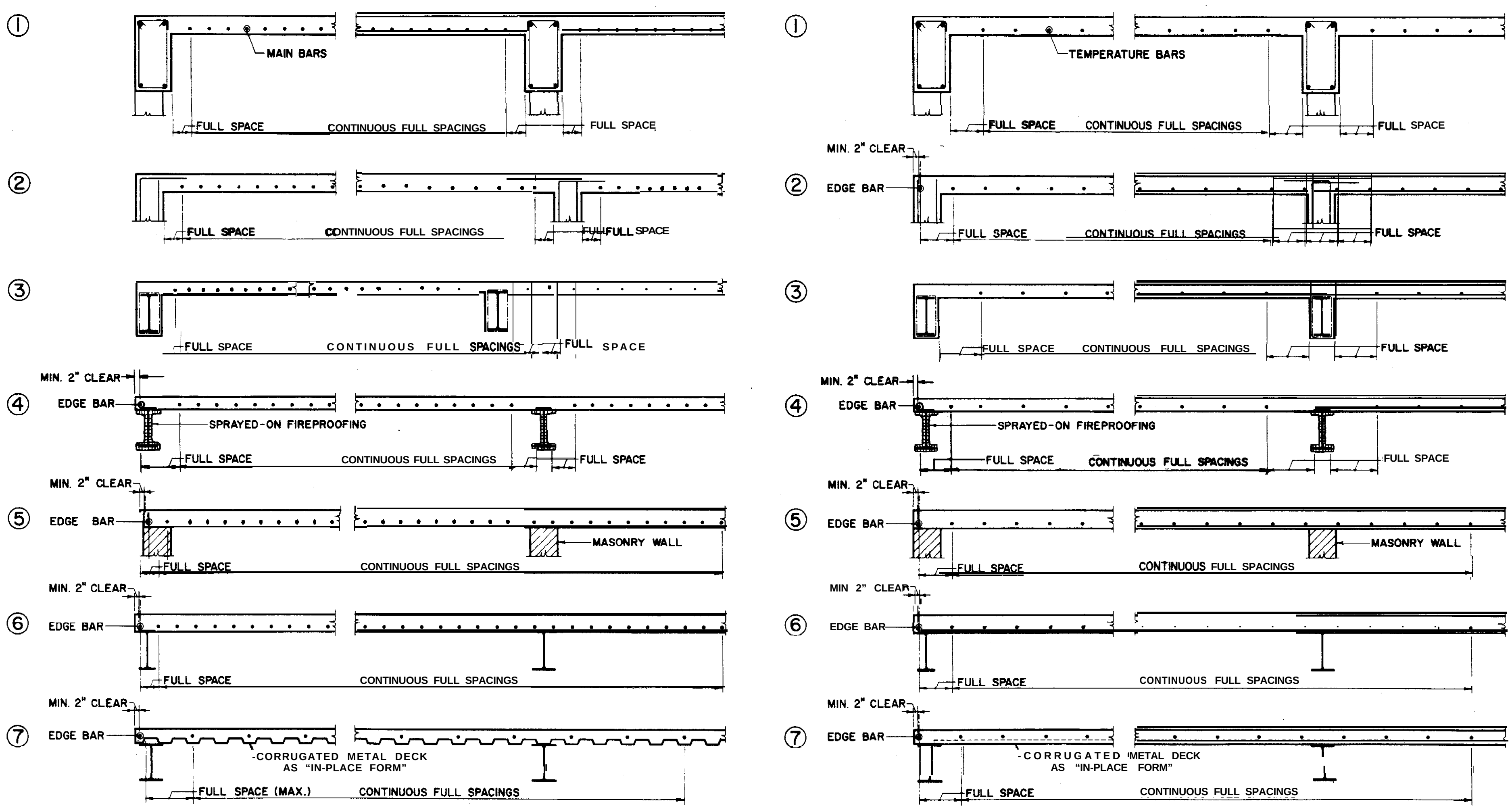
Item	No. Pcs.	Size	Length	Mark	Type	A	B	C	D	E	F	G	H	J	K	O	R
1	*FOOTINGS DECK GIRDER SPAN - Sta. 18 + 4.56*																
2	*STRAIGHT*																
3	116	#6	9-0	F4													
4																	
5	8	#5	17-3	F2													
6	24	#5	11-6	F3													
7																	
8	*64*	*#4*	*3-O*	Fl													
9	*HEAVYBENDING*																
10	*48*	#7	*6-5*	*D3*	1	10	5-7										
11																	
12	48	#6	7-8	D2	1	8	7-0										
13																	
14	72	#5	2-11	D1	1	7	2-4										
15																	
16																	
17	*SLAB BRIDGE AT STA. 4 + 9216*																
18	*STRAIGHT*																
19	*6*	*#4*	*18-3*	*C2*													
20	45	#4	16-9	ST1													
21	*HEAVY BENDING*																
22	27	#8	21-0	S1	3	11	1-2	1-5	14-0	1-5	1-2	11	1-0				18-4
23	52	#8	20-2	S2	1	11	18-4					11					
24																	
25	38	#4	4-10	C1	20		1-9	1-4	1-9								
26																	
27																	
28	*RAIL – RETAINING WALL AT STA. 5 + 440*																
29	*STRAIGHT*																
30	48	#4	17-3	R450													
31	36	#4	3-6	R451													
32	*LIGHT BENDING*																
33	276	#3	3-8	R300	T2	4	10	8	10	8		4					
34	20	#3	2-8	R301	T2	4	6	6	6	6		4					
35	16	#3	2-8	R302	T2	4	4	8	4	8		4					

ALL DIMENSIONS ARE CUT OUT TO OUT
ALL STEEL ASTM A 615 GRADE 60

FOR TYPICAL BEND TYPES REFER TO ACI DETAILING MANUAL

Note: Refer to Fig. 6 for identification of typical bend types. Dimensions less than 12 in. are given in inches; dimensions 12 in. or larger are given in feet and inches, e.g., 14-O.

Fig. 22-Typical bar list for highway structures



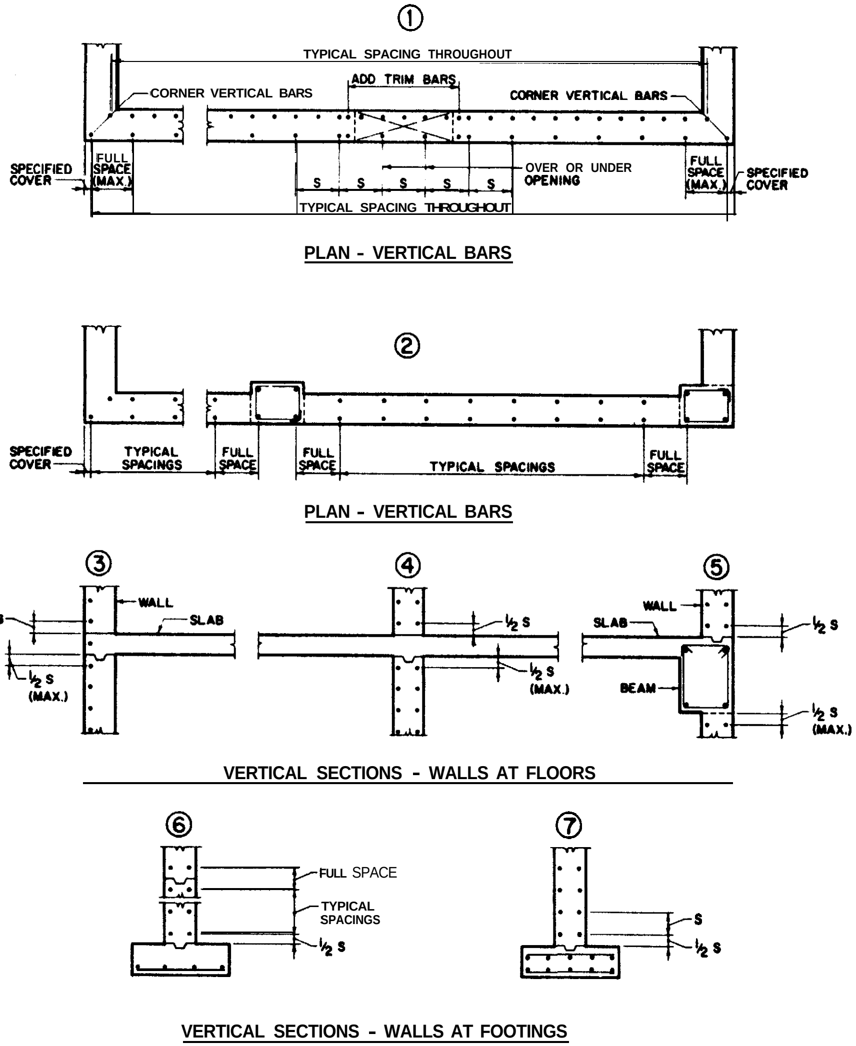
Standard spacing unless otherwise designated

(a) One-way slab main flexural reinforcing bars

Standard spacing unless otherwise designated

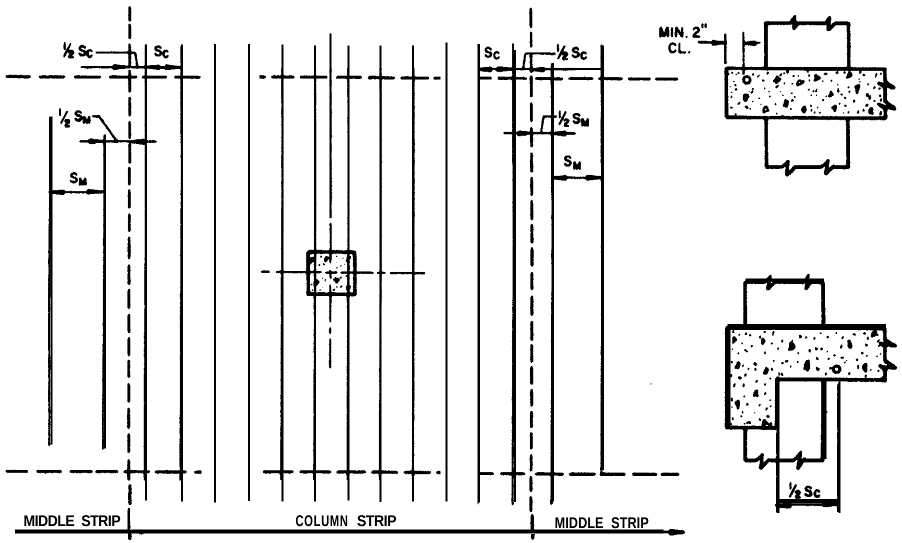
(b) One-way slab shrinkage and temperature reinforcing bars

Fig. 23-Location of bars designated only by size/spacing



Standard spacing unless otherwise designated

(c) Reinforcing bars in walls



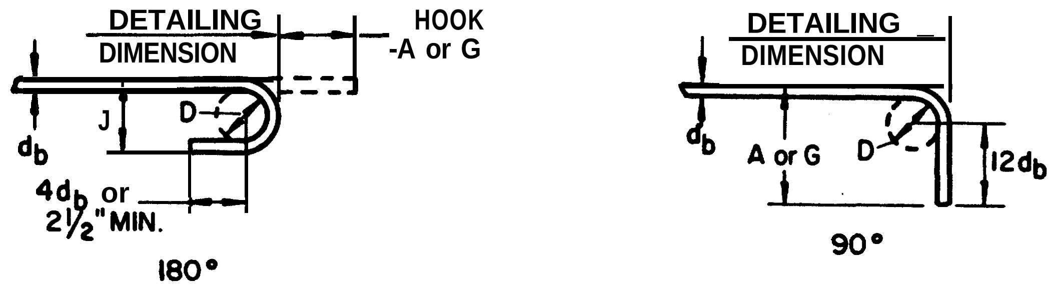
Standard spacing unless otherwise designated

Except for bars parallel to slab edges, space all required bars uniformly across column or middle strips starting at one-half spacing from edges of column strips, middle strips, or spandrel beams. Space the first bars parallel to slab edges with minimum 2 in. clear cover. When design drawing designates separately a number of bars to be uniformly spaced and a number to be concentrated about the column centerline, start the uniformly spaced bars at one-half spacing from the edges of the column strip

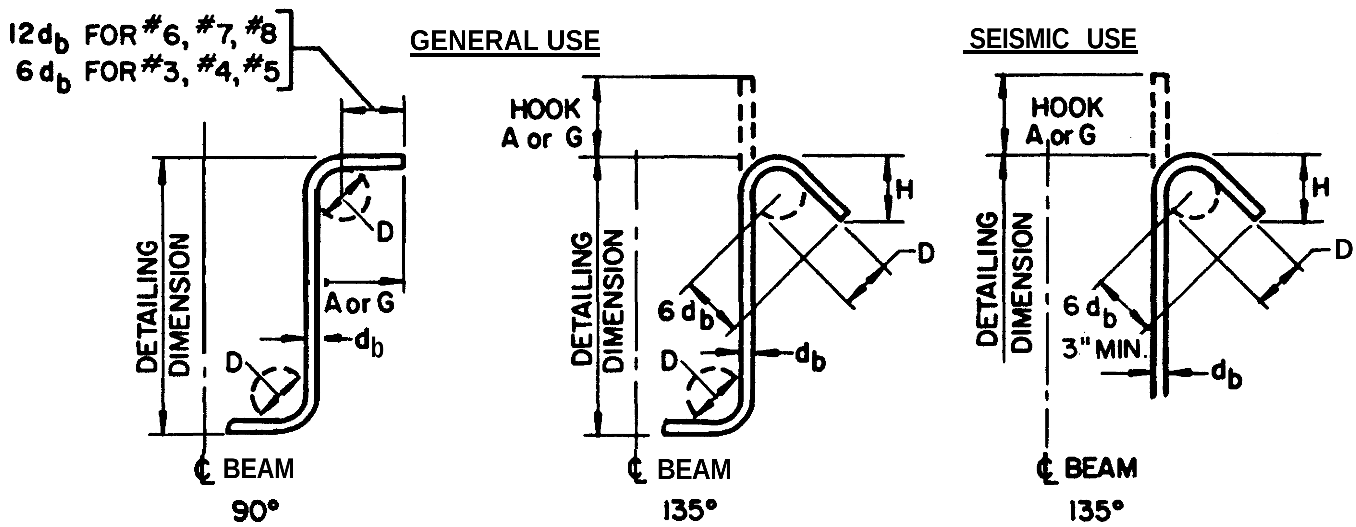
(d) Two-way slab reinforcing bars

Fig. 23 cont.-Location of bars designated only by size/spacing

Table 1-Standard hooks



Recommended end hooks, all grades				
Bar Size	Finished* bend diameter D, in.	180-deg hooks		90-deg hooks
		A or G		A or G
#3	2¼	5"	3"	6"
#4	3	6"	4"	8"
#5	3¾	7"	5"	10"
#6	4½	8"	6"	1-'0"
#7	5¼	10"	7"	1'-2"
#8	6	11"	8"	1'-4"
#9	9½	1'-3"	11¾"	1'-7"
#10	10¾	1'-5"	1 '- 1¼"	1'-10"
#11	12	1'-7"	1'-2¾"	2'-0"
#14	18¼	2'-3"	1'-9¾"	2'-7"
#18	24	3'-0"	2'-4½"	3'-5"



Stirrup and tie hooks, all grades						
		General use			Seismic use	
		90-deg hook	135-deg hook		135-deg hook	
Bar size	D,* in.	A or G	A or G	H, approx.	A or G	H, approx.
#3	1½	4"	4"	2½"	4¼"	3"
#4	2	4½"	4½"	3"	4½"	3"
#5	2½	6"	5½"	3¾"	5½"	3¾"
#6	4½	1'-0"	8"	4½"	8"	4½"
#7	5¼	1'-2"	9"	5¼"	9"	5¼"
#8	6	1'-4"	10½"	6"	10½"	6"

d_b = nominal diameter of bar, in.
* Finished bend diameters include "spring back" effect when bars straighten out slightly after being bent and are slightly larger than minimum bend diameters in 3.7.1

Table 2a-Maximum number of bars as a single layer in beam stems conforming to ACI 318*

¾ in. maximum size aggregate, interior exposure

Size of bar	Beam width b_w (in.)												
	8	10	12	14	16	18	20	22	24	26	28	30	32
#5	2	3	4	5	7	8	9	10	12	13	14	15	17
#6	2	3	4	5	6	7	9	10	11	12	13	14	15
#7	2	3	4	5	6	7	8	9	10	11	12	13	14
#8	2	3	4	5	6	7	8	9	10	11	12	13	14
#9	N/A	2	3	4	5	6	7	8	8	9	10	11	12
#10	N/A	2	3	4	4	5	6	7	8	8	9	10	11
#11	N/A	2	3	3	4	5	5	6	7	8	8	9	10
#14	N/A	2	2	3	3	4	5	5	6	6	7	8	8
#18	N/A	N/A	N/A	N/A	3	N/A	4	4	N/A	5	5	6	6

¾ in. maximum size aggregate, exterior exposure

Size of bar	Beam width b_w (in.)												
	8	10	12	14	16	18	20	22	24	26	28	30	32
#5	2	3	4	5	7	8	9	10	12	13	14	15	17
#6	2	3	4	5	6	7	9	10	11	12	13	14	15
#7	2	3	4	5	6	7	8	9	10	11	12	13	14
#8	2	3	4	5	6	7	8	9	10	11	12	13	14
#9	N/A	N/A	3	4	5	6	7	8	8	9	10	11	12
#10	N/A	N/A	3	4	4	5	6	7	8	8	9	10	11
#11	N/A	N/A	3	N/A	4	5	5	6	7	8	8	9	10
#14	N/A	N/A	N/A	N/A	N/A	N/A	5	N/A	6	N/A	7	8	8
#18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

1 in. maximum size aggregate, interior exposure

Size of bar	Beam width b_w (in.)												
	8	10	12	14	16	18	20	22	24	26	28	30	32
#5	2	3	4	5	6	7	8	9	10	11	12	13	14
#6	N/A	2	3	4	5	6	7	8	9	10	11	12	13
#7	N/A	2	3	4	5	6	7	8	9	10	10	11	12
#8	N/A	2	3	4	5	6	7	7	8	9	10	11	12
#9	N/A	2	3	4	5	5	6	7	8	9	9	10	11
#10	N/A	2	3	4	4	5	6	7	7	8	9	10	10
#11	N/A	2	3	3	4	5	5	6	7	8	8	9	10
#14	N/A	2	2	3	3	4	5	5	6	6	7	8	S
#18	N/A	N/A	N/A	N/A	3	N/A	4	4	N/A	5	5	6	6

1 in. maximum size aggregate, exterior exposure

Size of bar	Beam width b_w (in.)												
	8	10	12	14	16	18	20	22	24	26	28	30	32
#5	2	3	4	5	6	7	8	9	10	11	12	13	14
#6	N/A	2	3	4	5	6	7	8	9	10	11	12	13
#7	N/A	2	3	4	5	6	7	8	9	10	10	11	12
#8	N/A	2	3	4	5	6	7	7	8	9	10	11	12
#9	N/A	N/A	3	4	5	5	6	7	8	9	9	10	11
#10	N/A	N/A	3	4	4	5	6	7	7	8	9	10	10
#11	N/A	N/A	3	N/A	4	5	5	6	7	8	8	9	10
#14	N/A	N/A	N/A	N/A	N/A	N/A	5	N/A	6	N/A	7	8	8
#18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* Minimum concrete cover assumed to be 1½ in. to #4 stirrup.
Note: Beam widths or number of bars that can be placed in a beam are often controlled by other factors than minimum spacing and concrete cover. Table does not consider lap splices or proprietary. mechanical devices.

Table 2b-Maximum number of bars as a single layer in beam stems or columns (bar center-to-center spacing > $3d_b$)

Beam/column width	Maximum number of bars per bar size								
	#5	#6	#7	#8	#9	#10	#11	#14	#18
12	4	3	3	2	2	2	2	2	1
14	5	4	4	3	3	3	2	2	2
16	6	5	4	4	3	3	3	2	2
18	7	6	5	4	4	4	3	3	2
20	8	7	6	5	5	4	4	3	3
22	9	8	7	6	5	5	4	4	3
24	10	8	7	6	6	5	5	4	3
26	11	9	8	7	6	6	5	4	3
28	12	10	9	8	7	6	6	5	4
30	13	11	10	8	8	7	6	5	4
32	14	12	10	9	8	7	7	6	4
34	1s	13	11	10	9	8	7	6	5
36	16	14	12	10	9	8	8	6	5
38	18	15	13	11	10	9	8	7	5
40	19	16	13	12	11	9	9	7	5
42	20	16	14	12	11	10	9	8	6
44	21	17	15	13	12	10	9	8	6
46	22	18	16	14	12	11	10	8	6
48	23	19	16	14	13	12	10	9	7

Notes:

1. Purpose of this table is to avoid Category 1 or 2 tension development or lap splice lengths. See Section 2.7.1. Category 1 or 2 occurs when cover $\leq 1d_b$ or center-to-center bar spacing $\leq 3d_b$.

2. Assumed cover to #4 stirrups or ties was $1^1/_2$ in., which results in a cover to the main steel of at least $1d_b$ for #3 through #14 bars. Minimum cover for beams or columns with #18 bars must be at least $1^1/_2$ in. to the stirrup or tie.

Table 3-Maximum number of bars as a single layer in beam stems conforming to AASHTO “Standard Specifications for Highway Bridges”*

1 in. maximum size aggregate, moderate exposure

Size of bar	Beam width b_w (in.)												
	10	12	14	16	18	20	24	28	32	36	40	44	48
#5	2	3	4	5	6	7	9	11	13	15	17	18	20
#6	2	3	4	5	6	7	9	10	12	14	16	17	19
#7	2	3	4	5	6	6	8	10	11	13	15	17	18
#8	2	3	4	5	5	6	8	9	11	13	14	16	17
#9	2	3	3	4	5	5	7	8	10	11	13	14	15
#10	2	2	3	4	4	5	6	7	9	10	11	12	14
#11	2	2	3	3	4	4	6	7	8	9	10	11	12
#14	N/A	2	N/A	3	3	4	5	6	7	8	9	9	10
#18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

1 in. maximum size aggregate, severe exposure

Size of bar	Beam width b_w (in.)												
	10	12	14	16	18	20	24	28	32	36	40	44	48
#5	N/A	3	4	5	6	7	9	11	13	15	17	18	20
#6	N/A	3	4	5	6	7	9	10	12	14	16	17	19
#7	N/A	N/A	4	5	6	6	8	10	11	13	15	17	18
#8	N/A	N/A	4	5	5	6	8	9	11	13	14	16	17
#9	N/A	N/A	N/A	N/A	N/A	N/A	7	8	10	11	13	14	15
#10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
#11	N/A	N/A	N/A	N/A	N/A	N/A	NIA	N/A	N/A	N/A	N/A	N/A	N/A
#14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
#18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

1½ in. maximum aggregate size, moderate exposure

Size of bar	Beam width b_w (in.)												
	10	12	14	16	18	20	24	28	32	36	40	44	4s
#5	2	3	3	4	5	5	7	S	10	11	12	14	15
#6	2	3	3	4	5	5	7	8	9	11	12	13	15
#7	2	2	3	4	4	5	6	8	9	10	11	13	14
#8	2	2	3	4	4	5	6	7	9	10	11	12	13
#9	2	2	3	3	4	5	6	7	8	9	11	12	13
#10	2	2	3	3	4	4	6	7	8	9	10	11	12
#11	2	2	3	3	4	4	5	7	8	9	10	11	12
#14	N/A	2	N/A	3	3	4	5	6	7	8	9	9	10
#18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

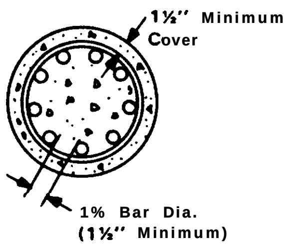
1½ in. maximum aggregate size, severe exposure

Size of bar	Beam width b_w (in.)												
	10	12	14	16	18	20	24	28	32	36	40	44	48
#5	N/A	3	N/A	4	5	5	7	8	10	11	12	14	15
#6	N/A	3	N/A	4	5	5	7	8	9	11	12	13	15
#7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8	9	10	11	13	14
#8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9	10	11	12	13
#9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
#10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
#11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
#14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N / A	N/A
#18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

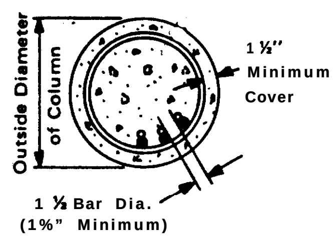
* Minimum concrete cover assumed to be $1^1/_2$ in. to #4 stirrup.
Note: Beam widths or number of bars that can be placed in a beam are often controlled by other factors than minimum spacing and concrete cover. Table does not consider lap splices or proprietary mechanical devices.

Table 4-Maximum number of bars in cast-in-place round columns based on ACI 318 requirements*

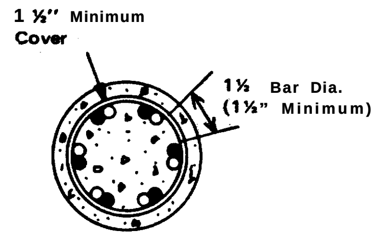
Case I-
Butt splices



Case II-
Radially lapped splices



Case III-Circumferentially lapped
splices or butt spliced two bar bundles



¾ in. maximum size aggregate

Col. diam., in.	Size of bar						Size of bar							Size of bar						
	#8	#9	#10	#1l	#14	#18	#5	#6	#7	#8	#9	#10	#11	#5	#6	#7	#8	#9	#10	#11
12	11	9*	7*	5*	4*	N/A	12	11	9	8	7	6	4	10	9	8	7	6	5	5
14	14	12	9*	7*	5*	N/A	16	14	13	11	9	8	6	13	12	10	9	8	7	6
16	17	15	12*	10*	7*	4*	20	18	16	14	12	10	9	16	14	13	11	lo	9	S
18	20	18	16	13*	9*	5*	24	21	19	17	15	13	11	19	17	15	13	12	lo	9
20	24	21	18	16	11*	6*	27	25	22	20	18	15	13	21	19	17	16	14	12	10
22	27	23	21	18	13*	7*	31	28	26	24	20	18	15	24	22	19	18	15	14	12
24	30	26	23	20	16*	9*	35	32	29	27	23	20	17	27	24	22	20	17	l5	13
26	33	29	26	23	18*	lO*	39	35	32	30	26	22	19	30	27	24	22	19	17	I5
28	36	32	28	25	20	12*	43	39	36	33	29	25	22	33	29	26	24	21	19	16
30	39	35	31	27	22	14*	47	43	39	36	31	27	24	35	32	29	26	23	20	18
32	42	37	33	29	24	16*	51	46	43	39	34	30	26	38	34	31	28	25	22	19
34	46	40	35	31	26	18*	54	50	46	42	37	32	28	41	37	33	30	27	23	21
36	49	43	38	34	28	20	58	53	49	46	40	35	31	44	39	35	32	28	25	22
38	52	46	40	36	30	22	62	57	53	49	43	37	33	46	42	38	34	30	27	24
40	55	48	43	38	31	23	66	61	56	52	45	40	35	49	44	40	36	32	28	25
42	58	51	45	40	33	25	70	64	59	55	48	42	37	52	47	42	39	34	30	27
44	61	54	48	43	35	26	74	68	63	58	51	45	39	55	49	45	41	36	32	28
46	64	57	50	45	37	27	78	71	66	61	54	47	42	58	52	47	43	38	33	30
48	67	60	53	47	39	29	81	75	69	64	56	50	44	60	54	49	45	40	35	31
50	71	62	55	49	41	30	85	79	73	67	59	52	46	63	57	51	47	41	37	33

1 in. maximum size aggregate

Col. Diam., in.	Size of bar						Size of bar							Size of bar						
	#8	#9	#10	#11	#14	#18	#5	#6	#7	#8	#9	#10	#1l	#5	#6	#7	#8	#9	#10	#11
12	10	9	7*	5*	4*	N/A	10	9	8	7	6	5	4	9	8	7	7	6	5	5
14	12	11	9*	7*	5*	N/A	13	12	11	10	9	8	6	11	10	9	8	8	7	6
16	15	14	12*	10*	7*	4*	16	15	13	12	11	10	9	14	12	11	10	9	9	8
18	18	16	15	13*	9*	5*	20	18	16	15	14	12	11	16	15	13	12	11	10	9
20	20	19	18	16	ll*	6*	23	21	19	18	16	15	13	19	17	15	14	13	12	10
22	23	22	20	18	13*	7*	26	24	22	20	19	17	15	21	19	17	16	15	13	12
24	26	24	23	20	16*	9*	29	27	25	23	21	20	17	23	21	19	18	16	15	13
26	28	27	25	23	18*	10*	32	30	28	26	24	22	19	26	23	21	20	1s	17	15
28	31	29	27	25	20	12*	35	33	30	28	26	24	22	28	26	23	21	20	18	16
30	34	32	30	27	22	14*	39	36	33	31	29	21	24	31	28	25	23	22	20	18
32	36	34	32	29	24	16*	42	39	36	34	31	29	26	33	30	27	25	23	21	19
34	39	37	35	31	26	18*	45	42	39	36	34	32	28	36	32	29	27	25	23	21
36	42	39	37	34	28	20	48	45	42	39	36	34	31	38	34	32	29	27	25	22
38	44	42	39	36	30	22	51	48	45	42	39	36	33	40	37	34	31	29	26	24
40	47	44	42	38	31	23	55	51	47	44	42	39	35	43	39	36	33	30	28	25
42	50	47	44	40	33	25	58	54	50	47	44	41	37	45	41	38	35	32	30	27
44	52	50	47	43	35	26	61	57	53	50	47	44	39	48	43	40	37	34	31	28
46	55	52	49	45	37	27	64	60	56	52	49	46	42	50	46	42	38	36	33	30
48	58	55	51	47	39	29	68	63	59	55	52	48	44	53	48	44	40	37	34	31
50	60	57	54	49	41	30	71	66	62	58	54	51	46	55	50	46	42	39	36	33

* Limited to 8 percent vertical reinforcement.

Note: For bars located in one ring only. Table does not consider lap splices, proprietary mechanical connection devices or offset bends.

Table 5-Maximum number of bars that can be accommodated in a column face, using mechanical end-bearing connections (based on ACI 318)*

Column side dimension, in.	#3 ties, 1½ in. cover					#4 ties, 1% in. cover		
	#6	#7	#8	#9	#10	#11	#14	#18
10	3	3	3	2	2	2	-	-
12	4	4	3	3	3	2	2	-
14	5	4	4	4	3	3	2	-
16	6	5	5	4	4	4	3	2
18	7	6	6	5	5	4	3	3
20	-	7	7	6	5	5	4	3
22	-	-	7	7	6	5	4	3
24	-	-	8	7	6	6	5	4
26	-	-	-	8	7	6	5	4
28	-	-	-	9	8	7	6	4
30	-	-	-	-	8	7	6	5
32	-	-	-	-	9	8	7	5
34	-	-	-	-	10	9	7	5
36	-	-	-	-	10	9	8	6
38	-	-	-	-	11	10	8	6
40	-	-	-	-	12	10	9	7
42	-	-	-	-	12	11	9	7
44	-	-	-	-	13	11	10	7
46	-	-	-	-	13	12	10	8
48	-	-	-	-	14	13	11	8
50	-	-	-	-	15	13	11	8

* Does not include allowance for increased diameter at couplers.

Table 6-Maximum spacing of column ties* per ACI 318, Section 7.10.5.2

Vertical bar size	Size and spacing of ties, in.		
	#3	#4	#5
#5	10	-	
#6	12	-	
#7	14	-	-
#8	16	16	-
#9	18	18	-
#10	18	20	-
#ll	t	22	22
#14	t	24	27
#18	t	24	30

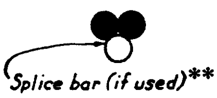
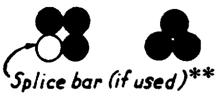
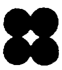
* Maximum spacing not to exceed least column dimension.
† #3 ties not permitted.

Table 7-Minimum requirements for column spiral spacers*

Spiral wire or bar diameter, in.	Spiral core diameter	Minimum number of spacers per spiral
less than ⅝	Less than 20 in. 20 to 30 in. More than 30 in.	2 3 4
⅝ or larger	24 in. or less More than 24 in.	3 4

* Alternate methods are available for maintaining spiral pitch and alignment. If spacers are used, the guidelines above are suggested.

Table 8-Bundled bars as column verticals-Design and detail data*

Bundle	Effective number of bars	Bar size	Total area, in.^{2}	Equivalent diameter, in.	Minimum clear distance, in.	
					Between bundles	Bundle to edge†
	2	#8	1.58	1.42	2⅛	1½
		#9	2.00	1.60	2½	1¾
		#10	2.54	1.80	2¾	2
		#11	3.12	2.00	3	2
	3	#8	2.37	1.74	2¼	1¾
		#9	3.00	1.95	3	2
		#10	3.81	2.20	3½	2¼
		#11	4.68	2.44	3¾	2½
 **	4	#8	3.16	2.01	3¼	2¼
		#9	4.00	2.26	3½	2½
		#10	5.08	2.55	4	2¾
		#11	6.24	2.82	4¼	3

* Bars in a bundle must terminate with at least 40 bar diameters stagger except where the bundle terminates.

† These minimum distances apply to bundles only. Where ties or spirals are present, the **1½-in.** minimum cover to them will control in some cases. 3-in. cover is required where columns are cast against and permanently exposed to earth.

**Splice bars, welding. or posititve connection must be provided for splices required to carry full tension or tension in excess of the capacity of the unspliced portion of the bundle. Compression may be transmitted by-end bearing of square-cut ends.

Note: Minimum clear distances should be increased for structures designed in accordance with AASHTO and AREA specifications.

Table 9-Compression embedment and lap splices for grade 60 bars, bar diameters

Basic embedment	Lap splice
$22d_b$ *	$30d_b$†

* For embedments enclosed by spirals, use $16.5d_b$, but not less than 8 in. (d_b = nominal diameter of bar, in.)

† For use in spirally reinforced columns with spirals conforming to Section 10.9.3, ACI 318, use $22.5d_b$, but not less than 12 in.

Table N-Tension development lengths (in.) for grade 60 uncoated bars in normal weight concrete*

f_c' = 3000 psi

	Top bars						Other bars					
	Category						Category					
Bar size	1	2	3	4	5	6	1	2	3	4	5	6
#3	16	16	16	16	16	16	13	13	13	13	13	13
#4	23	22	22	22	22	22	18	17	17	17	17	17
#5	36	29	27	27	27	27	27	22	21	21	21	21
#6	50	40	35	32	32	32	39	31	27	25	25	25
#7	69	55	48	39	38	38	53	42	37	30	29	29
#8	90	72	63	51	45	43	70	56	49	39	35	33
#9	114	91	80	64	57	48	88	70	62	49	44	37
#10	145	116	102	81	73	58	112	89	78	63	56	45
#11	178	142	125	100	89	71	137	110	96	77	69	55
#14	242	242	170	170	121	121	187	187	131	131	93	93
#18	356	356	250	250	178	178	274	274	192	192	137	137

f_c' = 4000 psi

	Top bars						Other bars					
	Category						Category					
Bar size	1	2	3	4	5	6	1	2	3	4	5	6
#3	14	14	14	14	14	14	12	12	12	12	12	12
#4	20	19	19	19	19	19	15	15	15	15	15	15
#5	31	25	23	23	23	23	24	19	18	18	18	18
#6	44	35	31	28	28	28	34	27	24	22	22	22
#7	59	48	42	33	33	33	46	37	32	26	25	25
#8	78	63	55	44	39	37	60	48	42	34	30	29
#9	99	79	69	56	50	42	76	61	53	43	38	32
#10	126	101	88	70	63	50	97	77	68	54	48	39
#11	154	123	108	86	77	62	119	95	83	67	59	48
#14	210	210	147	147	105	105	162	162	113	113	81	81
#18	309	309	216	216	154	154	237	237	166	166	119	119

f_c' = 5000 psi

	Top bars						Other bars					
	Category						Category					
Bar size	1	2	3	4	5	6	1	2	3	4	5	6
#3	13	13	13	13	13	13	12	12	12	12	12	12
#4	18	17	17	17	17	17	14	13	13	13	13	13
#5	28	22	21	21	21	21	21	17	16	16	16	16
#6	39	31	27	25	25	25	30	24	21	19	19	19
#7	53	43	37	30	29	29	41	33	29	23	23	23
#8	70	56	49	39	35	33	54	43	38	30	27	26
#9	89	71	62	50	44	38	68	55	48	38	34	29
#10	112	90	79	63	56	45	87	69	61	49	43	35
#11	138	110	97	77	69	55	106	85	74	60	53	43
#14	188	188	132	132	94	94	145	145	101	101	72	72
#18	276	276	193	193	138	138	212	212	149	149	106	106

f_c' = 6000 psi

	Top bars						Other bars					
	Category						Category					
Bar Size	1	2	3	4	5	6	1	2	3	4	5	6
#3	12	12	12	12	12	12	12	12	12	12	12	12
#4	16	15	15	15	15	15	13	12	12	12	12	12
#5	25	20	19	19	19	19	20	16	15	15	15	15
#6	36	29	25	23	23	23	28	22	19	18	18	18
#7	49	39	34	27	27	27	37	30	26	21	21	21
#8	64	51	45	36	32	31	49	39	35	28	25	24
#9	81	65	57	45	41	34	62	50	44	35	31	27
#10	103	82	72	58	51	41	79	63	55	44	40	32
#11	126	101	88	71	63	51	97	78	68	54	49	39
#14	171	171	120	120	86	86	132	132	92	92	66	66
#18	252	252	177	177	126	126	194	194	136	136	97	97

f_c' = 7000 psi

	Top bars						Top bars					
	Category						Category					
Bar size	1	2	3	4	5	6	1	2	3	4	5	6
#3	12	12	12	12	12	12	12	12	12	12	12	12
#4	15	14	14	14	14	14	12	12	12	12	12	12
#5	23	19	18	18	18	18	18	15	14	14	14	14
#6	33	27	23	21	21	21	26	20	18	16	16	16
#7	45	36	32	25	25	25	35	28	24	20	19	19
#8	59	47	42	33	30	28	46	37	32	26	23	22
#9	75	60	53	42	38	32	58	46	40	32	29	25
#10	95	76	67	53	48	38	73	59	51	41	37	29
#11	117	93	82	65	58	47	90	72	63	50	45	36
#14	159	159	111	111	80	80	122	122	86	86	61	61
#18	233	233	163	163	117	117	180	180	126	126	90	90

f_c' = 8000 psi

	Top bars						Top bars					
	Category						Category					
Bar size	1	2	3	4	5	6	1	2	3	4	5	6
#3	12	12	12	12	12	12	12	12	12	12	12	12
#4	14	13	13	13	13	13	12	12	12	12	12	12
#5	22	18	17	17	17	17	17	14	13	13	13	13
#6	31	25	22	20	20	20	24	19	17	15	15	15
#7	42	34	30	24	23	23	32	26	23	18	18	18
#8	55	44	39	31	2.8	26	43	34	30	24	21	20
#9	70	56	49	39	35	30	54	43	38	30	27	23
#10	89	71	62	50	45	36	68	55	48	38	34	28
#11	109	87	76	61	55	44	84	67	59	47	42	34
#14	149	149	104	104	74	74	114	114	80	80	57	57
#18	218	218	153	153	109	109	168	168	118	118	84	84

*** Important: See Section 2.7.1 for proper use of this table.**

Table ll-Tension lap splice lengths (in.) for grade 60 uncoated bars in normal weight concrete*

f_c' = 3000 psi

Bar size	Lap class	Top bars Category 1	2	3	4	5	6	Other Bars Category 1	2	3	4	5	6
#3	A	16	16	16	16	16	16	13	13	13	13	13	13
	B	21	21	21	21	21	21	16	16	16	16	16	16
#4	A	23	22	22	22	22	22	18	17	17	17	17	17
	B	30	28	28	28	28	28	23	22	22	22	22	22
#5	A	36	29	27	27	27	27	27	22	21	21	21	21
	B	46	37	35	35	35	35	36	29	27	27	27	27
#6	A	50	40	35	32	32	32	39	31	27	25	25	25
	B	65	52	46	42	42	42	50	40	35	32	32	32
#7	A	69	55	48	39	38	38	53	42	37	30	29	29
	B	89	71	63	50	49	49	69	55	48	39	38	38
#8	A	90	72	63	51	45	43	70	56	49	39	35	33
	B	117	94	82	66	59	56	90	72	63	51	45	43
#9	A	114	91	80	64	57	48	88	70	62	49	44	37
	B	148	119	104	83	74	63	114	91	80	64	57	48
#10	A	145	116	102	81	73	58	112	89	78	63	56	45
	B	188	151	132	106	94	76	145	116	102	81	73	58
#11	A	178	142	125	100	89	71	137	110	96	77	69	55
	B	231	185	162	130	116	93	178	142	125	100	89	71

f_c' = 4000 psi

Bar size	Lap class	Top bars Category 1	2	3	4	5	6	Other bars Category 1	2	3	4	5	6
#3	A	14	14	14	14	14	14	12	12	12	12	12	12
	B	18	18	18	18	18	18	16	16	16	16	16	16
#4	A	20	19	19	19	19	19	15	15	15	15	15	15
	B	26	24	24	24	24	24	20	19	19	19	19	19
#5	A	31	25	23	23	23	23	24	19	18	18	18	18
	B	40	32	30	30	30	30	31	25	23	23	23	23
#6	A	44	35	31	28	28	28	34	27	24	22	22	22
	B	57	45	40	36	36	36	44	35	31	28	28	28
#7	A	59	48	42	33	33	33	46	37	32	26	25	25
	B	77	62	54	43	42	42	59	48	42	33	33	33
#8	A	78	63	55	44	39	37	60	48	42	34	30	29
	B	102	81	71	57	51	48	78	63	55	44	39	37
#9	A	99	79	69	56	50	42	76	61	53	43	38	32
	B	129	103	90	72	64	55	99	79	69	56	50	42
#10	A	126	101	88	70	63	50	97	77	68	54	48	39
	B	163	131	114	92	82	65	126	101	88	70	63	50
#11	A	154	123	108	86	77	62	119	95	83	67	59	48
	B	200	160	140	112	100	80	154	123	108	86	77	62

f_c' = 5000 psi

Bar size	Lap Class	Top bars Category 1	2	3	4	5	6	Other bars Category 1	2	3	4	5	6
#3	A	13	13	13	13	13	13	12	12	12	12	12	12
	B	16	16	16	16	16	16	16	16	16	16	16	16
#4	A	18	17	17	17	17	17	14	13	13	13	13	13
	B	23	22	22	22	22	22	18	17	17	17	17	17
#5	A	28	22	21	21	21	21	21	17	16	16	16	16
	B	36	29	27	27	27	27	28	22	21	21	21	21
#6	A	39	31	27	25	25	25	30	24	21	19	19	19
	B	51	41	36	33	33	33	39	31	27	25	25	25
#7	A	53	43	37	30	29	29	41	33	29	23	23	23
	B	69	55	48	39	38	38	53	43	37	30	29	29
#8	A	70	56	49	39	35	33	54	43	38	30	27	26
	B	91	73	64	51	46	43	70	56	49	39	35	33
#9	A	89	71	62	50	44	38	68	55	48	38	34	29
	B	115	92	81	65	58	49	89	71	62	50	44	38
#10	A	112	90	79	63	56	45	87	69	61	49	43	35
	B	146	117	102	82	73	59	112	90	79	63	56	45
#11	A	138	110	97	77	69	55	106	85	74	60	53	43
	B	179	143	126	101	90	72	138	110	97	77	69	55

f_c' = 6000 psi

Bar Size	Lap Class	Top bars Category 1	2	3	4	5	6	Other bars Category 1	2	3	4	5	6
#3	A	12	12	12	12	12	12	12	12	12	12	12	12
	B	16	16	16	16	16	16	16	16	16	16	16	16
#4	A	16	15	15	15	15	15	13	12	12	12	12	12
	B	21	20	20	20	20	20	16	16	16	16	16	16
#5	A	25	20	19	19	19	19	20	16	15	15	15	15
	B	33	26	25	25	25	25	25	20	19	19	19	19
#6	A	36	29	25	23	23	23	28	22	19	18	18	18
	B	46	37	33	30	30	30	36	29	25	23	23	23
#7	A	49	39	34	27	27	27	37	30	26	21	21	21
	B	63	51	44	35	35	35	49	39	34	27	27	27
#8	A	64	51	45	36	32	31	49	39	35	28	25	24
	B	83	66	58	47	42	40	64	51	45	36	32	31
#9	A	81	65	57	45	41	34	62	50	44	35	31	27
	B	105	84	74	59	53	45	81	65	57	45	41	34
#10	A	103	82	72	58	51	41	79	63	55	44	40	32
	B	133	107	93	75	67	54	103	82	72	58	51	41
#11	A	126	101	88	71	63	51	97	78	68	54	49	39
	B	164	131	115	92	82	66	126	101	88	71	53	51

* Important: See Section 2.7.1 for proper use of this table.

Table 11 cont.-Tension lap splice lengths (in.) for grade 60 uncoated bars in normal weight concrete*

f_c' = 7000 psi

Bar size	Lap class	Top bars Category 1	2	3	4	5	6	Other bars Category 1	2	3	4	5	6
#3	A	12	12	12	12	12	12	12	12	12	12	12	12
	B	16	16	16	16	16	16	16	16	16	16	16	16
#4	A	15	14	14	14	14	14	12	12	12	12	12	12
	B	20	18	18	18	18	18	16	16	16	16	16	16
#5	A	23	19	18	18	18	18	18	15	14	14	14	14
	B	30	24	23	23	23	23	23	19	18	18	18	18
#6	A	33	27	23	21	21	21	26	20	18	16	16	16
	B	43	34	30	28	28	28	33	27	23	21	21	21
#7	A	45	36	32	25	25	25	35	28	24	20	19	19
	B	58	47	41	33	32	32	45	36	32	25	25	25
#8	A	59	47	42	33	30	28	46	37	32	26	23	22
	B	77	62	54	43	39	37	59	47	42	33	30	28
#9	A	75	60	53	42	38	32	58	46	40	32	29	25
	B	97	78	68	55	49	41	75	60	53	42	38	32
#10	A	95	76	67	53	48	38	73	59	51	41	37	29
	B	123	99	86	69	62	50	95	76	67	53	48	38
#11	A	117	93	82	65	58	47	90	72	63	50	45	36
	B	152	121	106	85	76	61	117	93	82	65	58	47

f_c' = 8000 psi

Bar size	Lap class	Top bars Category 1	2	3	4	5	6	Other bars Category 1	2	3	4	5	6
#3	A	12	12	12	12	12	12	12	12	12	12	12	12
	B	16	16	16	16	16	16	16	16	16	16	16	16
#4	A	14	13	13	13	13	13	12	12	12	12	12	12
	B	18	17	17	17	17	17	16	16	16	16	16	16
#5	A	22	18	17	17	17	17	17	14	13	13	13	13
	B	28	23	22	22	22	22	22	18	17	17	17	17
#6	A	31	25	22	20	20	20	24	19	17	15	15	15
	B	40	32	28	26	26	26	31	25	22	20	20	20
#7	A	42	34	30	24	23	23	32	26	23	18	18	18
	B	55	44	38	31	30	30	42	34	30	24	23	23
#8	A	55	44	39	31	28	26	43	34	30	24	21	20
	B	72	58	50	40	36	34	55	44	39	31	28	26
#9	A	70	56	49	39	35	30	54	43	38	30	27	23
	B	91	73	64	51	46	39	70	56	49	39	35	30
#10	A	89	71	62	50	45	36	68	55	48	38	34	28
	B	115	92	81	65	58	46	89	71	62	50	45	36
#11	A	109	87	76	61	55	44	84	67	59	47	42	34
	B	142	113	99	80	71	57	109	87	76	61	55	44

* Important: See Section 2.7.1 for proper use of this table.

Table 12---Tension development lengths (in.) for grade 60 epoxy-coated bars in normal weight concrete*

f_c' = 3000 psi

Bar size	Top bars Category 1	2	3	4	5	6	Other bars Category 1	2	3	4	5	6
#3	21	21	21	21	21	21	19	19	19	19	19	19
#4	30	28	28	28	28	28	27	25	25	25	25	25
#5	46	37	35	35	35	35	41	33	31	31	31	31
#6	66	53	46	42	42	42	58	47	41	37	37	37
#7	90	72	63	50	49	49	79	63	56	44	43	43
#8	118	94	83	66	59	56	104	83	73	58	52	50
#9	149	119	105	84	75	63	132	105	92	74	66	56
#10	190	152	133	106	95	76	167	134	117	94	84	67
#11	233	186	163	130	117	93	205	164	144	115	103	82
#14	317	317	222	222	159	159	280	280	196	196	140	140
#18	466	466	326	326	233	233	411	411	288	288	206	206

f_c' = 4000 psi

Bar size	Top bars Category 1	2	3	4	5	6	Other bars Category 1	2	3	4	5	6
#3	1 81 1	18	18	18	18	16	16	16	16	16	16	
#4	26	24	24	24	24	24	23	22	22	22	22	22
#5	40	32	31	31	31	31	36	29	27	27	27	27
#6	57	46	40	37	37	37	50	40	35	32	32	32
#7	78	62	54	44	43	43	69	55	48	39	38	38
#8	102	82	72	57	51	49	90	72	63	51	45	43
#9	129	104	91	73	65	55	114	91	80	64	57	48
#10	164	131	115	92	82	66	145	116	102	81	73	58
#11	202	161	141	113	101	81	178	142	125	100	89	71
#14	274	274	192	192	137	137	242	242	170	170	121	121
#18	403	403	283	283	202	202	356	356	249	249	178	178

* Important: See Section 2.7.1 for proper use of this table.

Table 12 cont.-Tension development lengths (in.) for grade 60 epoxy-coated bars in normal weight concrete*

f_c' = 5000 psi

Bar Size	Top bars						Other bars					
	Category						Category					
	1	2	3	4	5	6	1	2	3	4	5	6
#3	17	17	17	17	17	17	15	15	15	15	15	15
#4	23	22	22	22	22	22	21	19	19	19	19	19
#5	36	29	27	27	27	27	32	26	24	24	24	24
#6	51	41	36	33	33	33	45	36	32	29	29	29
#7	70	56	49	39	38	38	61	49	43	35	34	34
#8	91	73	64	51	46	44	81	65	57	45	41	38
#9	116	93	81	65	58	49	102	82	72	57	51	43
#l0	147	118	103	82	74	59	130	104	91	73	65	52
#ll	180	144	126	101	90	72	159	127	111	89	80	64
#14	246	246	172	172	123	123	217	217	152	152	108	108
#18	361	361	253	253	181	181	318	318	223	223	159	159

f_c' = 6000 psi

Bar size	Top bars						Other bars					
	Category						Category					
	12	3		4	5	6	12	3		4	5	6
#3	15	15	15	15	15	15	13	13	13	13	13	13
#4	21	20	20	20	20	20	19	18	18	18	18	18
#5	33	26	25	25	25	25	29	23	22	22	22	22
#6	47	37	33	30	30	30	41	33	29	26	26	26
#7	64	51	45	36	35	35	56	45	39	32	31	31
#8	84	67	59	47	42	40	74	59	52	41	37	35
#9	106	85	74	59	53	45	93	75	65	52	47	40
#10	134	107	94	75	67	54	118	95	83	66	59	48
#1l	165	132	115	92	82	66	145	116	102	82	73	58
#14	224	224	157	157	112	112	198	198	139	139	99	99
#18	330	330	231	231	165	165	291	291	204	204	146	146

f_c' = **7000** psi

Bar size	Top bars						Other bars					
	Category						Category					
	1	2	3	4	5	6	1	2	3	4	5	6
#3	14	14	14	14	14	14	12	12	12	12	12	12
#4	20	19	19	19	19	19	18	16	16	16	16	16
#5	31	24	23	23	23	23	27	22	20	20	20	20
#6	43	35	30	28	28	28	38	31	27	25	25	25
#7	59	47	41	33	32	32	52	42	36	29	29	29
#8	77	62	54	43	39	37	68	55	48	38	34	33
#9	98	78	69	55	49	42	86	69	61	48	43	37
#10	124	99	87	70	62	50	110	88	77	62	55	44
#11	152	122	107	86	76	61	135	108	94	75	67	54
#14	208	208	145	145	104	104	183	183	128	128	92	92
#18	305	305	214	214	153	153	269	269	189	189	135	135

f_c' = 8000 psi

Bar size	Top bars						Other bars					
	Category						Category					
	1	2	3	4	5	6	1	2	3	4	5	6
#3	13	13	13	13	13	13	12	12	12	12	12	12
#4	19	17	17	17	17	17	16	15	15	15	15	15
#5	29	23	22	22	22	22	25	20	19	19	19	19
#6	40	32	28	26	26	26	36	29	25	23	23	23
#7	55	44	39	31	30	30	49	39	34	27	27	27
#8	72	58	51	41	36	35	64	51	45	36	32	30
#9	92	73	64	51	46	39	81	65	57	45	41	34
#10	116	93	81	65	58	47	103	82	72	58	51	41
#11	143	114	100	80	71	57	126	101	88	71	63	51
#14	194	194	136	136	97	97	171	171	120	120	86	86
#18	285	285	200	200	143	143	252	252	176	176	126	126

*** Important: See Section 2.7.1 for proper use of this table.**

Table 13-Tension lap splice lengths (in.) for grade 60 epoxy-coated bars in normal weight concrete*

f_c' = 3000 psi

Bar size	Lap class	Top bars						Other bars					
		Category						Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	21	21	21	21	21	21	19	19	19	19	19	19
	B	28	28	28	28	28	28	24	24	24	24	24	24
#4	A	30	28	28	28	28	28	27	25	25	25	25	25
	B	39	37	37	37	37	37	34	32	32	32	32	32
#5	A	46	37	35	35	35	35	41	33	31	31	31	31
	B	60	48	46	46	46	46	53	43	40	40	40	40
#6	A	66	53	46	42	42	42	58	47	41	37	37	37
	B	86	68	60	55	55	55	75	60	53	48	48	48
#7	A	90	72	63	50	49	49	79	63	56	44	43	43
	B	117	93	82	65	64	64	103	82	72	58	56	56
#8	A	118	94	83	66	59	56	104	83	73	58	52	50
	B	153	123	107	86	77	73	135	108	95	76	68	64
#9	A	149	119	105	84	75	63	132	105	92	74	66	56
	B	194	155	136	109	97	82	171	137	120	96	86	73
#10	A	190	152	133	106	95	76	167	134	117	94	84	67
	B	246	197	172	138	123	99	217	174	152	122	109	87
#11	A	233	186	163	130	117	93	205	164	144	115	103	82
	B	302	242	212	169	151	121	267	214	187	150	134	107

f_c' = 4000 psi

Bar size	Lap class	Top bars						Other bars					
		Category						Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	18	18	18	18	18	18	16	16	16	16	16	16
	B	24	24	24	24	24	24	21	21	21	21	21	21
#4	A	26	24	24	24	24	24	23	22	22	22	22	22
	B	34	32	32	32	32	32	30	28	28	28	28	28
#5	A	40	32	31	31	31	31	36	29	27	27	27	27
	B	52	42	40	40	40	40	46	37	35	35	35	35
#6	A	57	46	40	37	37	37	50	40	35	32	32	32
	B	74	59	52	47	47	47	65	52	46	42	42	42
#7	a	78	62	54	44	43	43	69	55	48	39	38	38
	b	101	81	71	57	55	55	89	71	62	50	49	49
#8	A	102	82	72	57	51	49	90	72	63	51	45	43
	B	133	106	93	75	67	63	117	94	82	66	59	56
#9	A	129	104	91	73	65	55	114	91	80	64	57	48
	B	168	134	118	94	84	71	148	119	104	83	74	63
#10	A	164	131	115	92	82	66	145	116	102	81	73	58
	B	213	171	149	120	107	86	188	151	132	106	94	75
#11	A	202	161	141	113	101	81	178	142	125	100	89	71
	B	262	210	183	147	131	105	231	185	162	130	116	93

f_c' = 5000 psi

Bar size	Lap class	Top bars						Other bars					
		Category						Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	17	17	17	17	17	17	15	15	15	15	15	15
	B	21	21	21	21	21	21	19	19	19	19	19	19
#4	A	23	22	22	22	22	22	21	19	19	19	19	19
	B	30	28	28	28	28	28	27	25	25	25	25	25
#5	A	36	29	27	27	27	27	32	26	24	24	24	24
	B	47	38	35	35	35	35	41	33	31	31	31	31
#6	A	51	41	36	33	33	33	45	36	32	29	29	29
	B	66	53	47	42	42	42	59	47	41	38	38	38
#7	A	70	56	49	39	38	38	61	49	43	35	34	34
	B	90	72	63	51	50	50	80	64	56	45	44	44
#8	A	91	73	64	51	46	44	81	65	57	45	41	38
	B	119	95	83	67	60	57	105	84	74	59	53	50
#9	A	116	93	81	65	58	49	102	82	72	57	51	43
	B	150	120	105	84	75	64	133	106	93	74	66	56
#10	A	147	118	103	82	74	59	130	104	91	73	65	52
	B	191	153	134	107	96	77	168	135	118	94	84	68
#11	A	180	144	126	101	90	72	159	127	111	89	80	64
	B	234	188	164	131	117	94	207	165	145	116	104	83

f_c' = 6000 psi

Bar size	Lap class	Top bars						Other bars					
		Category						Category					
		1	2	3	4	5	6	1	2	3	4	5	6
#3	A	15	15	15	15	15	15	13	13	13	13	13	13
	B	20	20	20	20	20	20	17	17	17	17	17	17
#4	A	21	20	20	20	20	20	19	18	18	18	18	18
	B	28	26	26	26	26	26	24	23	23	23	23	23
#5	A	33	26	25	25	25	25	29	23	22	22	22	22
	B	43	34	32	32	32	32	38	30	29	29	29	29
#6	A	47	37	33	30	30	30	41	33	29	26	26	26
	B	61	49	42	39	39	39	53	43	38	34	34	34
#7	A	64	51	45	36	35	35	56	45	39	32	31	31
	B	82	66	58	46	45	45	73	58	51	41	40	40
#8	A	84	67	59	47	42	40	74	59	52	41	37	35
	B	108	87	76	61	54	52	96	77	67	54	48	46
#9	A	106	85	74	59	53	45	93	75	65	52	47	40
	B	137	110	96	77	69	58	121	97	85	68	61	51
#10	A	134	107	94	75	67	54	118	95	83	66	59	48
	B	174	139	122	98	87	70	154	123	108	86	77	62
#11	A	165	132	115	92	82	66	145	116	102	82	73	58
	B	214	171	150	120	107	86	189	151	132	106	95	76

* Important: See Section 2.7.1 for proper use of this table.

Table 13 cont.-Tension lap splice lengths (in.) for grade 60 epoxy-coated bars in normal weight concrete*

f_c' = 7000 psi

Bar size	Lap class	Top bars Category 1	2	3	4	5	6	Other bars Category 1	2	3	4	5	6
#3	A	14	14	14	14	14	14	12	12	12	12	12	12
	B	18	18	18	18	18	18	16	16	16	16	16	16
#4	A	20	19	19	19	19	19	18	16	16	16	16	16
	B	26	24	24	24	24	24	23	21	21	21	21	21
#5	A	31	24	23	23	23	23	27	22	20	20	20	20
	B	40	32	30	30	30	30	35	28	27	27	27	27
#6	A	43	35	30	28	28	28	38	31	27	25	25	25
	B	56	45	39	36	36	36	50	40	35	32	32	32
#7	A	59	47	41	33	32	32	52	42	36	29	29	29
	B	76	61	54	43	42	42	67	54	47	38	37	37
#8	A	77	62	54	43	39	37	68	55	48	38	34	33
	B	100	80	70	56	50	48	89	71	62	50	44	42
#9	A	98	78	69	55	49	42	86	69	61	48	43	37
	B	127	102	89	71	64	54	112	90	79	63	56	48
#10	A	124	99	87	70	62	50	110	88	77	62	55	44
	B	161	129	113	90	81	65	142	114	100	80	71	57
#11	A	152	122	107	86	76	61	135	108	94	75	67	54
	B	198	159	139	111	99	79	175	140	122	98	88	70

f_c' = 8000 psi

Bar size	Lap class	Top bars Category 1	2	3	4	5	6	Other bars Category 1	2	3	4	5	6
#3	A	13	13	13	13	13	13	12	12	12	12	12	12
	B	17	17	17	17	17	17	16	16	16	16	16	16
#4	A	19	17	17	17	17	17	16	15	15	15	15	15
	B	24	23	23	23	23	23	21	20	20	20	20	20
#5	A	29	23	22	22	22	22	25	20	19	19	19	19
	B	37	30	28	28	28	28	33	26	25	25	25	25
#6	A	40	32	28	26	26	26	36	29	25	23	23	23
	B	52	42	37	34	34	34	46	37	33	30	30	30
#7	A	55	44	39	31	30	30	49	39	34	27	27	27
	B	71	57	50	40	39	39	63	51	44	35	35	35
#8	A	72	58	51	41	36	35	64	51	45	36	32	30
	B	94	75	66	53	47	45	83	66	58	47	42	40
#9	A	92	73	64	51	46	39	81	65	57	45	41	34
	B	119	95	83	67	60	50	105	84	74	59	53	45
#10	A	116	93	81	65	58	47	103	82	72	58	51	41
	B	151	121	106	85	76	61	133	107	93	75	67	53
#11	A	143	114	100	80	71	57	126	101	88	71	63	51
	B	185	148	130	104	93	74	164	131	115	92	82	66

* Important: See Section 2.7.1 for proper use of this table.

Table 14-Minimum tension embedment lengths l_{dh} (in.) for standard end hooks on grade 60 in normal weight concrete

General use (nonseismic). 1. Side cover ≥ $2^1/_2$ in. 2. End cover (90-deg hooks) ≥ 2 in.

Bar size	Normal weight concrete, f_c', psi 3000	4000	5000	6000	7ooo	8000	Minimum embedment length for 180-deg hooks
#3	6	6	6	6	6	6	6
#4	8	7	6*	6*	6*	6*	7
#5	10	9	8	7	7	6*	7
#6	12	10	9	8	8	7*	8
#7	14	12	11	10	9	9	9
#8	16	14	12	11	10	10	10
#9	18	15	14	13	12	11*	12
#10	20	17	15	14	13*	12*	14
#1l	22	19	17	16	14*	14*	15
#14	37	32	29	27	25	23	20
#18	50	43	39	35	33	31	25

• For 180-deg hooks at right angles to exposed surfaces, see minimum lengths to provide 2 in. minimum cover to tail, far right column.

Table 14 cont.-Minimum tension embedment lengths l_{dh} (in.) for standard end hooks on grade 60 bars in normal weight concrete

Special confinement (nonseismic). 1. Side cover ≥ 2½ in. 2. End cover (90-deg hooks) ≥ 2 in. 3. Confining reinforcement $s \leq 3d_b$

Bar size	Normal weight concrete, f_c', psi						Minimum embedment length for 180-deg hooks
	3000	4000	5000	6000	7000	8000	
#3	6	6	6	6	6	6	6
#4	6*	6*	6*	6*	6*	6*	7
#5	8	7	6’	6*	6*	6*	7
#6	10	8	7*	7*	6’	6*	8
#7	11	10	9	8*	7*	7*	9
#8	13	11	10	9*	8*	8*	10
#9	14	12	11*	10*	9*	9*	12
#10	16	14	12*	11*	11*	10*	14
#l1	18	15	14*	13*	12*	12*	15

Seismic frames-90-deg hooks. 1. Side cover ≥ 2½ in. 2. End cover (90-deg hooks) ≥ 2 in. 3. Inside confined core

Bar size	Normal weight concrete, f_c', psi						Minimum embedment length for 180-deg hooks
	3000	4000	5000	6000	7000	8000	
#3	7	6	6	6	6	6	6
#4	9	8	7	6*	6*	6*	7
#5	11	9	8	8	7	7	7
#6	13	11	10	9	9	8	8
#7	15	13	12	11	10	9	9
#8	17	15	13	12	11	11	10
#9	19	17	15	14	13	12	12
#10	22	19	17	15	14	13*	14
#11	24	21	19	17	16	15	15

* For 180-deg hooks at right angles to exposed surfaces, see minimum lengths to provide 2 in. minimum cover to tail, far right column.

Table 15-Minimum tension embedment lengths l_{dh} (in.) for standard end hooks on grade 60 bars in lightweight aggregate concrete

General use (nonseismic). 1. Side cover ≥ 2½ in. 2. End cover (90-deg hooks) ≥ 2 in.

Bar size	Lightweight aggregate concrete, f_c', psi				Minimum embedment length for 180-deg hooks
	3000	4000	5000	6000	
#3	8	7	6	6	6
#4	10	9	8	7	7
#5	13	11	10	9	7
#6	15	13	12	11	8
#7	18	15	14	13	9
#8	20	18	16	14	10
#9	23	20	18	16	12
#10	26	22	20	18	14
#l1	28	25	22	20	15
#14	49	42	38	34	20
#18	65	56	50	46	25

Table 15 cont.-Minimum tension embedment lengths l_{db} (in.) for standard end hooks on grade 60 bars in light-weight aggregate concrete

Special confinement (nonseismic). 1. Side cover ≥ 2 1/2 in. 2. End cover (90-deg hooks) ≥ 2 in. 3. Confining reinforcement, $s \leq 3d_b$

Bar size	Lightweight aggregate concrete, f_c', psi				Minimum embedment length for 180-deg hooks
	3000	4000	5000	6000	
#3	6	6	6	6	6
#4	8	7	6*	6*	7
#5	10	9	8	7	7
#6	12	11	10	9	8
#7	14	12	11	10	9
#8	16	14	13	12	10
#9	18	16	14	13	12
#10	21	18	16	15	14
#11	23	20	18	16	15

Seismic frames-90-deg hooks. 1. Side cover ≥ 2½ in. 2. End cover (90-deg hooks) ≥ 2 in. 3. Inside confined core

Bar size	Lightweight aggregate concrete, f_c', psi		Minimum embedment length for 180-deg hooks
	3000	4000	
#3	8	8	6
#4	11	9	7
#5	13	12	7
#6	16	14	8
#7	19	16	9
#8	21	19	10
#9	24	21	12
#10	27	23	14
#11	30	26	15

* For 180-deg hooks at right-angles to exposed surfaces, see minimum lengths to provide 2 in. minimum cover to tail, far right column.