

PART X: SPLIT RING AND SHEAR PLATE CONNECTORS

10.1-GENERAL

Background

Split ring and shear plate connectors act like dowels or keys in distributing loads from one member to another in a joint (57). The large diameters of the rings or plates, relative to the diameters of bolts, and the relatively shallow depth of the connectors in the members provide for increased bearing areas without penalizing reductions in net section areas. As a result, these connectors can develop significantly higher design values than those obtainable from bolts alone.

Split ring connectors, the most efficient of timber fastenings, are installed in precut grooves made with a special power-driven drill and cutting tool. They are used in wood-to-wood joints where high lateral joint loads are involved; such as in bowstring trusses, arches and bridges. The bolt or lag screw passing through the center of the ring holds the faces of the joint members in contact.

Similar to split rings, shear plates are installed in precut grooves but are flush to the surface when fully seated. Two shear plates are the equivalent of one split ring, with the load being transferred from one plate to the other in the joint through shear in the bolt or lag screw. Shear plates are primarily used in wood-to-steel connections; such as steel gusset plate joints or column-foundation connections where the metal replaces one of the plates, and in demountable wood-to-wood connections, such as stadium bleachers (179).

The design provisions for split ring and shear plate connectors in the Specification are based on early research (146,159) and have remained essentially unchanged since the 1944 edition. In addition to these connectors, the first edition included allowable design values for claw plates and toothed rings (128). Claw plates, which are similar to shear plates, were dropped in the 1948 edition. Toothed rings, alternates to split rings but made of thinner metal, requiring no grooving and having about one-half the allowable design values, were dropped in the 1973 edition.

Also since the first edition, connector design values were reduced approximately 9 percent in 1962 to increase the level of conservatism in the allowable design values for this type of fastening. The adjustment had the effect of offsetting that portion of the World War II emergency increase of 20 percent authorized for all wood design values that was not subsequently covered by the conversion of all wood design values from a permanent to a normal loading basis (see Commentary for 2.3.2). New in the 1991 edition is the inclusion of a number of additional species and broad species groups in connector Group D (Table 10A of the Specification). The broad species groups (Western Woods, Eastern Species and Northern Species) may include any species produced in the applicable region (see Design Value Supplement).

10.1.1-Terminology

A connector unit is expressed in terms of the metal parts required for a single shear plane. For a split ring connection, one ring is used in matching grooves in the members adjacent to one plane. For shear plate connections, two matching shear plates, one in appropriate grooves in each member, are used in wood-to-wood joints. In a wood-to-metal joint, the steel strap or plate replaces one of the shear plates. In all three cases, the bolt or lag screw tying the joint together is considered loaded in single shear. Where more than one connector unit is on the same bolt, as in the case of a three member joint where the main member has connectors on the same bolt on both faces, an adjusted single shear design value for each shear plane is provided in the design value tables (see Tables 10.2A and 10.2B).

10.1.2-Quality of Split Ring and Shear Plate Connectors

10.1.2.1 The split ring is wedge shaped (beveled toward the edges) to facilitate installation and assure a tight fit when fully seated. The diameter of the inside groove for the split ring is 2 percent larger than the inside diameter of the ring, thus requiring the ring to be sprung slightly when inserted. This provides for any subsequent shrinkage of the members and for simultaneous bearing of the inner surface of the connector against the inner core of wood created by the grooving operation and bearing of the outer surface of the connector on the opposite side against the outside wall of the groove (159,179). The position of the tongue-slot joint in the ring relative to the direction of loading is not significant (159).

The two small perforations in the central portion of pressed steel shear plates serve to facilitate temporary attachment of the connector to the joint member when off-site fabrication is employed and in the erection and dismantling of temporary structures in the field. The perforations, which have been part of the pressed shear plate description since the 1944 edition, do not affect plate load-carrying performance.

10.1.2.2 Dimensions for split rings and pressed steel and malleable iron shear plates have been included in the Specification since the 1944 edition. Dimensions for light gage shear plates were introduced in 1960.

In addition to connector diameter, the depth of the connector in the member and its thickness affect joint load-carrying capacity. It is to be understood that only those split rings that have equivalent or larger inside diameter, metal depth and metal thickness than those given in Appendix K of the Specification qualify for the connector design values provided in Table 10.2A. Similarly, only those shear plates that have equivalent or larger plate diameter, plate depth and plate thickness than those given in Appendix K qualify for the connector design values provided in Table 10.2B.

The projected areas given in Appendix K for split rings are calculated as the sum of the inside groove diameter and twice the groove width times the groove depth. These projected areas are 1.10 and 2.25 square inches for 2-1/2 and 4 inch rings, respectively.

The projected areas for shear plates given in Appendix K are based on the groove diameter times the groove depth for the nominal shear plate dimensions shown. These groove diameters are 2.63 inches and 4.03 inches for 2-5/8 and 4 inch plates respectively. The groove depths assumed to correspond to the plate tabulated flange depths are 0.45, 0.38 and 0.64 inches for 2-5/8 inch pressed steel, 2-5/8 inch light gage and 4 inch malleable iron plates, respectively; giving the tabulated projected area values for these connectors of 1.18, 1.00 and 2.58 square inches. Prior to the 1960 edition, slightly smaller projected areas for the pressed steel and malleable iron plates, based on the actual cross-sectional dimensions of the material cut from the member to accommodate the flanged plate and integral hub and enclosed central bolt hole, were used.

Tabulated projected areas for split ring and shear plate connectors given in Appendix K are to be used in checking for net section in accordance with sections 3.1.2 and 7.1.2 of the Specification.

10.1.2.3 Bolts used with split rings or shear plates are required to meet the quality provisions of 8.1.1.

10.1.2.4 Lag screws used with split rings or shear plates are required to meet the quality provisions of 9.1.1. The provision that only cut thread lag screws be used, a requirement since the 1944 edition, is necessary to establish the basis for the lead hole diameter requirement for the threaded portion of the screw (see Section 10.1.3.2).

10.1.3-Fabrication and Assembly

10.1.3.1 The fabrication and assembly provisions for split rings and shear plates have remained unchanged since the 1944 edition with a few exceptions. The provision requiring cutterheads to be designed specifically for the dimensions provided by the particular connector manufacturer was first introduced in the 1977 edition.

10.1.3.2 The alternative provisions for lead holes for the threaded portion of lag screws of 70 percent of the shank diameter or as required in 9.1.2.1 was introduced in the 1977 edition. This lead hole was set at 75 percent of the shank diameter in earlier editions.

10.1.3.3 Minimum washer sizes given in Appendix K are good practice recommendations that have been part of the Specification since 1944. Washers may be used in shear plate connections involving steel straps and plates when use of a longer bolt or lag screw is necessary to avoid bearing of the threaded portion of the bolt or screw on the strap or plate.

10.1.3.4 Tabulated design values for split ring and shear plate connectors apply to joints in which the members are in contact, are fabricated of wood having a moisture content of 15 percent or lower to a depth of at least 3/4 inches from the surface, and will remain dry in service. Effects of normal variations in moisture content that occur in dry conditions of service are accounted for in the tabulated values.

When connectors are installed in unseasoned or partially seasoned wood intended for use in dry conditions of service, tabulated design values are to be adjusted in accordance with the factors in Table 7.3.3. Such joints will need to be tightened as the members season in service by periodically turning down the nuts on the bolts until service equilibrium moisture content is reached.

It is good practice to exclude visible face knots within a distance of one-half the connector diameter along the grain from the edge of the connector unit (62,159). Where visible knots are included within a one-half connector diameter distance of the critical section, the net section based on the projected area of the connector unit and bolt or screw should be further reduced for the cross-sectional area of such included knots (see Section 3.1.2.3 and Appendix A.12 of the Specification).

10.2-DESIGN VALUES

10.2.1-Tabulated Nominal Design Values

Background

Early connector tests of joints made with Douglas fir, southern pine, white oak and other representative species showed that joint load-carrying capacity was directly related to the specific gravity of the wood members (57,62,146,159). This species effect was accounted for by classifying species into four connector load groups based on their specific gravity. These four groupings, originally established in the 1944 edition, are shown in Table 10A of the Specification. The present listing includes species and species groups that have been added in various subsequent editions since 1944. The 1991 edition includes the addition of several new individual species and three broad regional species groups in Group D, as well as the deletion or reclassification of other species or groups based on changes in commercial importance or specific gravity values. The broad species groups (Western Woods, Eastern Species and Northern Species) may include any species produced in the applicable region (see Design Value Supplement).

The specific gravity ranges of the species in the connector groups of Table 10A are

Group A:	0.67 to 0.73
Group B:	0.49 to 0.58
Group C:	0.42 to 0.47
Group D:	0.31 to 0.41

Specific gravity values for the individual species listed in Table 10A are given in Table 8A or the other dowel bearing strength tables in the Specification. Intermediate specific gravity values for species not listed may conservatively be placed in a lower group.

Connector design values given in the 1944 edition of the Specification included a 20 percent increase authorized for all wood design values as part of the national war emergency program of World War II. Subsequently, one-half of this emergency increase was codified as part of the conversion of wood design values from a permanent to a normal loading basis (see Commentary for 2.3.2). Based on field experience, the remaining one-half of the war time increase was retained for all wood connection design values, including those for split ring and shear plate connections. In the 1962 edition, in response to changing construction and workmanship practices, design values for joints made with split rings and shear plates were reduced approximately 9 percent. This adjustment had the effect of removing the experience portion of the WW II emergency increase. The 1962 design values have been carried forward unchanged to the 1991 edition.

Design values in Table 10.2A and 10.2B represent maximum joint test loads reduced by a factor of 3.6 that includes adjustments for variability and load duration (57,62,159). These design values, applicable to normal loading conditions, are considered to be less than 70 percent of proportional limit test loads (62,159). Tabulated design values apply only to those joint designs which meet the thickness, end distance, edge distance and spacing requirements for full design value given in Tables 10.2A, 10.2B and 10.3. Net thickness requirements refer to the actual thickness of the member before grooving.

10.2.1.1 Design values for split ring connections in Table 10.2A and for shear plate connections in Table 10.2B are given in terms of the number of faces a member has with a connector on the same bolt and on the thickness of that member. The lowest design value for the two members being joined is the design value for the shear plane. Example C10.2-1 illustrates this provision.

Example C10.2-1

Determine the tabulated allowable design value for a single 2-1/2 inch split ring connector in each shear plane of a three member joint made of two 1 inch thick Group B side members and a 1-1/2 inch thick Group B main member.

Both side and main members loaded parallel to grain:

Side members: Design value from Table 10.2A, row 1, column 6 for connector on one face and 1" thickness = 2270

Main member: Design value from Table 10.2A, row 3, column 6 for connector on two faces and 1-1/2" thickness = 2100

Limiting design value, each shear plane = 2100 lbs

Side members loaded perpendicular to grain and main member loaded parallel to grain:

Side members: Design value from Table 10.2A, row 1, column 10 = 1620

Main member: Design value from Table 10.2A, row 3, column 6 = 2100

Limiting design value, each shear plane = 1620 lbs

10.2.1.2 The limiting design values given in footnote 2 of Table 10.2B are the same as those given in the 1986 edition. The 2900 pound value for the 2-5/8 inch shear plate is the maximum allowable bearing load for a pressed steel plate without a reenforcing hub about the bolt hole. The 4400 and 6000 pound values for the 4 inch plates used with 3/4 and 7/8 inch bolts respectively are the maximum allowable shear design values for A307 bolts of these diameters. The 4 inch plates have integral reenforcing hubs about the central bolt hole. Somewhat higher maximum design values were permitted for 4 inch plates in the 1982 and earlier editions based on higher allowable bolt shear strength.

Because the limiting design values specified in footnote 2 of Table 10.2B are based on metal strength, they are not to be increased by load duration or other adjustment factors given in 7.3.2 for values controlled by wood members.

10.2.2-Thickness of Wood Members

10.2.2.1 The minimum member thicknesses required for use of the split ring and shear plate connector values in Tables 10.2A and 10.2B have been established from the results of joint tests (159).

10.2.2.2 The provision for use of linear interpolation between minimum thicknesses and those required from maximum design values is based on the original connector research (159).

10.2.3-Penetration Depth Factor, C_d

10.2.2.3 The lag screw penetration depth requirements and adjustments for penetrations less than required for full design value given in Table 10.2.3 have been provisions of the Specification since the 1960 edition. Editions prior to 1960 did not have separate penetration requirements for different connector groups, expressed penetration requirements in terms of the anchorage provided by the threaded portion of the screw only, assumed a nonlinear relationship between reduced design value and penetration depth, and did not provide for use of full design value with 2-5/8 inch shear plates at minimum specified penetration when metal side plates were used.

10.2.4-Metal Side Plate Factor, C_{st}

Increases for metal side plates used with 4 inch shear plate connectors given in Table 10.2.4 have been recognized in the Specification since the 1944 edition. The adjustments are based on original connector research involving claw plates (159). Both claw plate and shear plate connectors fit into prebored recesses in wood members and depend upon the bolt to transmit shear between the members being joined. The claw plate differs from the shear plate in having short teeth extending from one side of the plate that are forced into the wood as the bolt nut is tightened. Special note is to be made that the increased values for 4 inch shear plates loaded parallel to grain are permitted only when the maximum metal part design values of footnote 2 of Table 10.2B are not exceeded.

10.2.5-Load at Angle to Grain

Use of the standard bearing angle to grain equation (Equation 10.2-1 and Appendix J) to determine allowable design values for split ring and shear plate connectors located in a shear plane that is loaded at an angle to grain between 0° and 90° has been a provision in the Specification since the 1944 edition. The original research showed that maximum design values on claw plate connectors loaded at different angles to grain varied in accordance with the standard angle to grain equation (159). The tests of split ring connectors in this same study showed the relationship between maximum design value and grain angle could be described by a linear relationship without appreciable error. For purposes of conservatism and consistency with the provisions for other fasteners, the standard angle to grain equation is used in the Specification to adjust both split ring and shear plate connector design values for grain angle.

10.2.6-Split Ring and Shear Plate Connectors in End Grain

Prior to the 1977 edition, the Specification contained no provisions for the design of connectors in end grain surfaces. Such provisions were introduced in 1977 to cover joint configurations frequently encountered in practice, such as those at the peak of A-frames or similar arches.

Design values for split ring and shear plate connectors in end grain surfaces are keyed to use of a design value for connectors in square-cut end surfaces equal to sixty percent of the tabulated design value for connectors in side grain surfaces loaded perpendicular to grain, or

$$Q'_{90} = 0.60\,Q' \qquad \text{(C10.2-1)}$$

where:

Q'_{90} = allowable design value for a split ring or shear plate connector unit in a square-cut end surface, loaded in any direction in the plane of the surface (α=90°, 0°$\leq\varphi\leq$90°) calculated from (C10.2-1)

Q' = allowable design value for a split ring or shear plate connector unit in a side grain surface, loaded perpendicular to grain (α=0°, φ=90°).

The Q'_{90} condition is illustrated in Figure 10F of the Specification. The use of 0.60 Q' as the allowable design value for a square-cut end surface was originally based on experience with connector design with glued laminated timber prior to 1977 (4). Available data from a comprehensive study of the capacity of shear plates in sloping grain end surfaces in Douglas fir (107) generally confirm the use of the 0.60 ratio. This ratio is slightly more conservative than the 0.67 value assumed for square-cut end surface design values in Canada (41,101). The end grain connector design provisions in the 1977 edition, which have continued to provide connections of satisfactory field performance, have been carried forward unchanged to the 1991 edition.

Use of the standard bearing angle to grain equation (Appendix J) to establish allowable design values for connectors in sloping end-grain surfaces also has been a basic provision of the Specification since the 1977 edition. When the load on the sloping surface is acting parallel to the axis of cut of the surface (φ=0°), as illustrated in Figure 10G of the Specification, the standard angle to grain equation is entered with the tabulated allowable connector design value for side grain parallel to grain loading and the calculated allowable design value for a square-cut end surface. Thus, for the case of φ=0°, the equation for any slope of surface cut, α, is

$$P'_\alpha = \frac{P'\,Q'_{90}}{P'\,\sin^2\alpha + Q'_{90}\cos^2\alpha} \qquad \text{(C10.2-2)}$$

where:

P'_α = allowable design value for a split ring or shear plate connector unit in a sloping surface, loaded in a direction parallel to the axis of cut (0°<α<90°, φ = 0°)

P' = allowable design value for a split ring or shear plate connector unit in a side grain surface, loaded parallel to grain (α=0°, φ=0°)

Q'_{90} = allowable design value for a split ring or shear plate connector unit in a square-cut end surface, loaded in any direction in the plane of the surface (α=90°, 0°≤φ≤90°) calculated from (C10.2-1)

α = the least angle formed between a sloping surface and the general direction of the wood fibers, from 0° to 90°

When the load on the sloping surface is acting perpendicular to the axis of cut of the surface (φ=90°), as illustrated in Figure 10H of the Specification, the value of P' in equation C10.2-2 is replaced with the tabulated allowable connector design value for side grain perpendicular loading. For this case of φ=90°, the equation for any slope of surface cut, α, is

$$Q'_\alpha = \frac{Q'\,Q'_{90}}{Q'\,\sin^2\alpha + Q'_{90}\cos^2\alpha} \qquad \text{(C10.2-3)}$$

where:

Q'_α = allowable design value for a split ring or shear plate connector unit in a sloping surface, loaded in a direction perpendicular to the axis of cut (0°<α<90°, φ=90°).

Q' = allowable design value for a split ring or shear plate connector unit in a side grain surface, loaded perpendicular to grain (α=0°, φ=90°).

When the load on the sloping surface is acting at an angle between 0° and 90° to the axis of cut of the surface (0° ≤ φ ≤ 90°), as illustrated in Figure 10I, the values of P' and Q'_{90} in the equation C10.2-2 are replaced with P'_α and Q'_α, respectively, or

$$N'_\alpha = \frac{P'_\alpha\,Q'_\alpha}{P'_\alpha\sin^2\varphi + Q'_\alpha\cos^2\varphi} \qquad \text{(C10.2-4)}$$

where:

N'_α = allowable design value for split ring or shear plate connector unit in a sloping surface, when direction of load is at an angle φ from the axis of cut.

For split ring and shear plate connectors used in sloping end grain surfaces, the thickness of the member is taken as the distance between the edge of the connector and the nearest point on the outside edge of the member located on a line parallel to the bolt or lag screw axis (see Example C10.2-2). Where the end grain surface is square cut, the thickness of the member may be taken as the length of the lag screw in the member. Example C10.2-2 illustrates the use of provisions for shear plates.

Example C10.2-2

Determine the allowable vertical force with C_D of 1.15 on a 2-5/8 inch shear plate connector unit joining two Douglas fir-larch 4x10 rafters at the ridge where the roof slope is 12 in 8 producing an angle of 33.7° from the vertical at the peak. Use a 3/4-inch bolt with 2 inch diameter wrought iron washers recessed into each rafter (see Figure C10.2-1).

The angle between the direction of load and the axis of cut of the end grain surface, φ, is 0°. The slope of the surface cut, α, or angle between the axis of cut and the direction of grain in the members, is 33.7°.

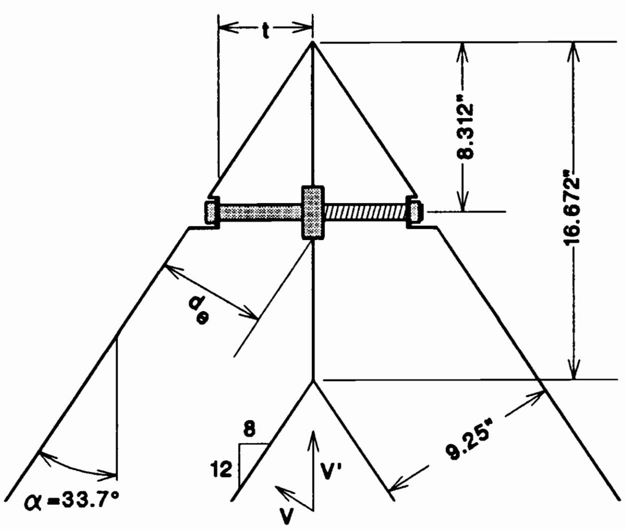

Figure C10.2-1

Assume connectors will be installed in unseasoned wood: from Table 7.3.3, C_M = 0.80

Locate the connector center 8-5/16 inches from the apex. Effective thickness of each member (see Figure C10.2-1) is

$$t = \tan 33.7° \ (8.312 - 2.625/2) = 4.669 \text{ in.}$$

Minimum end distance for full design value from 10.3.6.1 and Table 10.3 = 4 in.; minimum for reduced design value = 2-1/2 in. Actual end distance = 8-5/16 in.

Full design value applies, C_Δ = 1.0

Minimum edge distance for full design value from 10.3.6.1 and Table 10.3 = 1-3/4 in.; minimum for reduced design value = 1-3/4 in.

Actual edge distance = 3.5/2 = 1-3/4 in.

Full design value applies, C_Δ = 1.0

From Table 10.2B for 2-5/8 in. diameter plate with 3/4 in. bolt, 1 face containing connector, minimum member thickness of 1-1/2 in., Group B species:

$$P = 2670, \ P' = (2670 \ C_D \ C_M \ C_\Delta) = 2456$$
$$Q = 1860, \ Q' = (1860 \ C_D \ C_M \ C_\Delta) = 1711$$

From Equation C10.2-1: Q'_{90} = 1027

From Equation C10.2-2 with α = 33.7°: P'_α = 1719

The maximum allowable vertical load that can be transferred from one rafter to the other through the connector unit is 1719 lbs.

10.3-PLACEMENT OF SPLIT RING AND SHEAR PLATE CONNECTORS

10.3.1-Terminology

Edge and end distances and spacings for split ring and shear plate connectors are referenced to the center not the edge of the connectors.

10.3.2-Geometry Factor, C_Δ

The geometry factor has been introduced in the 1991 edition as part of the general conversion of the provisions of the Specification to an equation format. The factor adjusts tabulated design values for use of end distances, edge distances and/or spacings which are less than those required to achieve the full design value capacity of the specified connector unit. The use of reduced connector design values to accommodate imposed geometric design limitations has been a provision of the Specification since the 1944 edition.

It is to be noted that the smallest geometry factor for any split ring or shear plate connector in a joint is to be applied to all connectors in that joint regardless of their alignment relative to one another. This provision for allowing less than full design connector distances to be used only when the total load on the joint or shear plane is reduced in proportion to the reduction in distances was added in the 1982 edition to clarify the intent of requirements for end distance and spacing. The 1991 edition specifically extends the clarification to edge distance requirements.

10.3.3-Edge Distance

10.3.3.1 Connector edge distance requirements and related geometry factors in Table 10.3 are unchanged since the 1944 edition. Specific values are based on the original connector research (159).

10.3.3.2 Determination of edge distance requirements for members loaded at angles to grain between 0° and 90° is simplified by the fact that the edge distance requirement for a given size connector in Table 10.3 is the same for both minimum and full design value for unloaded and loaded edge parallel to the grain and for unloaded edge perpendicular to the grain. Only in the loaded edge perpendicular to grain case is a larger edge distance required to achieve full design value. In this instance, the edge distance required for all other conditions is associated with a reduced minimum design value having a geometry factor, C_Δ, of 0.83. A one inch larger edge distance is required for C_Δ = 1.00. Example C10.3-1 illustrates these provisions.

> **Example C10.3-1**
>
> A 2-1/2 inch split ring connector with 1-3/4 inch unloaded and loaded edge distance. For the unloaded edge, C_Δ = 1.00 under any angle of loading. For the loaded edge, C_Δ = 0.83 under any angle of loading. To obtain a C_Δ = 1.00 for the connector, the loaded edge distance must be increased to **2-3/4 inches** when the angle of loading is 45° or greater and proportionally less for angles between 0° and < 44°. For an angle of loading of 22.5°, the loaded edge distance required for C_Δ = 1.00 is 2.75−(22.5/45)(2.75−1.75) or **2-1/4 inches**.

The edge distance for the loaded edge establishes the geometry factor for edge distance that must be applied, if limiting, to the tabulated values of P and Q to obtain the values of P' and Q' required by the standard angle to grain equation in 10.2.5.1. Example C10.3-2 illustrates these provisions.

> **Example C10.3-2**
>
> For a 2-1/2 inch split ring connector loaded at an angle to grain of 22.5°, the required loaded edge distance for full design value is 2.25 inches, and for minimum reduced design value is 1.75 inches. For an actual loaded edge distance of 2 inches, the geometry factor for the connector based on 10.3.3.1 is by linear interpolation
>
> C_Δ = 0.83 + [(2.00−1.75)(1.00−0.83)/(2.25−1.75)]
> = **0.915**

10.3.4-End Distance

10.3.4.1 The end distance requirements for full and reduced design values in Table 10.3 are based on the original connector research and have been part of the Specification since the 1944 edition. These requirements vary depending upon whether the member is being loaded in tension or compression, with the latter also differing depending upon whether loading is parallel or perpendicular to grain.

10.3.4.2 The use of linear interpolation between tabulated end distances for parallel and perpendicular to grain loading to determine end distance requirements for members loaded at angles to grain between 0° and 90° has been a provision of the Specification since the 1944 edition. Example C10.3-3 illustrates these provisions.

> **Example C10.3-3**
>
> A 2-1/2 inch split ring connector is loaded in compression at an angle to grain of 30° and has an end distance of 3.5 inches. For minimum reduced design value acting at an angle of 30°, the required end distance from 10.3.4.2 is [2.50 + (30/90)(2.75−2.50)], or 2.58 inches. For full design value acting at an angle of 30°, the required end distance is [4.0 + (30/90)(5.50−4.0)], or 4.5 inches. From 10.3.4.1, the end distance geometry factor for the connection is
>
> C_Δ = 0.625 + (3.5−2.58)(1.00−0.625)/(4.5−2.58)]
> = **0.804**

10.3.5-Spacing

10.3.5.1 Spacing requirements in Table 10.3 are based on the original connector research (159) and have remained unchanged since the 1944 edition with two minor exceptions. In 1962, the minimum spacings for reduced design values for parallel to grain loading and parallel to grain spacing were increased from 3-3/8 to the present 3-1/2 inches for the 2-1/2 - 2-5/8 inch connectors and from 4-7/8 to the present 5 inches for the 4 inch connectors.

However, the reduced design value percentage or geometry factor associated with the minimum spacings in the 1991 edition is more conservative than the percentage used in the earliest editions of the Specification. From 1944 through the 1960 edition, the geometry factor associated with the minimum allowed spacing for parallel to grain loading - parallel to grain spacing was 0.75, and for perpendicular to grain loading - perpendicular to grain spacing was 0.83, the latter factor being that associated with the minimum loaded edge distance for this case. These early factors were based on parallel to grain test results in the original research (159,179). In 1962, the 0.83 factor for the perpendicular loading and spacing case was dropped to 0.75 for purposes of uniformity.

In the 1971 edition, the geometry factor for minimum allowed spacings was reduced from 0.75 to the present 0.50. This change reflected recommendations made previously for simplifying adjustment of connector design values for end distances and longitudinal spacing (62).

The original connector research indicated that the load-carrying capacity of a joint made with two or more connectors aligned parallel to grain and loaded perpendicular to grain was less than the sum of the maximum design values for the same connectors acting singly (62,159). Staggering or offsetting of connectors so that they do not act along the same line along the grain of the transverse loaded member was found to give somewhat higher design values (62). When such offsetting is used, the line connecting the centers of two or more connectors located in the same contact face, the connector axis φ, may not be oriented parallel or perpendicular to the grain of the member or to the direction of load, θ. Spacings intermediate to those given in Table 10.3 for reduced and full design values are applicable to such cases. Because the variables involved are not linearly related, a graphical method has been developed for determining spacing requirements for designs for these cases where the connector axis is at an angle to the grain of the member (4,179). This graphical method is based on numerical procedures given in the 1968 and earlier editions of the Specification. The numerical procedures are given in the Commentary for 10.3.5.2.

Use of linear interpolation to establish geometry factors for spacings intermediate to those associated with tabulated minimum and full design values has been a provision of the Specification since the 1944 edition.

10.3.5.2 The graphical method for determining minimum spacing requirements for members loaded at an angle to grain (4,179) is based on numerical procedures given in the Specification prior to 1971. These procedures, which combine the effects of both variable connector axis angle, φ, and variable angle to grain loading, θ, are given below.

Minimum spacing (R) required for full design value for any connector axis angle (φ) between 0° and 90° and for any angle of load to grain (θ) between 0° and 90° is determined from the equation

$$R = \frac{AB}{\sqrt{A^2 \sin^2\varphi + B^2 \cos^2\varphi}} \qquad \text{(C10.3-1)}$$

where:

A and B are spacing values selected from Table C10.3-1 for the applicable connector type and size and angle of load to grain.

Table C10.3-1 - Connector Spacing Values

Connector type and size	Angle of load to grain, θ	A, in.	B, in.	C (min. for C_Δ=0.5), in.
2-1/2 in. split ring	0°	6-3/4	3-1/2	3-1/2
or	15°	6	3-3/4	3-1/2
2-5/8 in. shear plate	30°	5-1/8	3-7/8	3-1/2
	45°	4-1/4	4-1/8	3-1/2
	60-90°	3-1/2	4-1/4	3-1/2
4 in. split ring	0°	9	5	5
or	15°	8	5-1/4	5
4 in. shear plate	30°	7	5-1/2	5
	45°	6	5-3/4	5
	60-90°	5	6	5

The value of R determined from Equation C10.3-1 is the required spacing for full design value, C_Δ = 1.0. The value of C from Table C10.3-1 is the minimum allowed spacing which is associated with the reduced design value, C_Δ = 0.50. For a load angle of 0°, values of A and B are the spacings from Table 10.3 of the Specification for full design and reduced design value, respectively, for the parallel spacing - parallel loading case. For a load angle of 90°, the values of A and B are the spacings from Table 10.3 of the Specification for reduced design and full design value, respectively for the perpendicular spacing - perpendicular loading case.

For angles of load to grain, θ, intermediate to those tabulated, values of A and B may be obtained by linear interpolation. For actual spacing, S, between R and C, the geometry factor, $C_{\Delta s}$, is determined by linear interpolation or

$$C_{\Delta s} = 0.50 + \frac{(S - C)(1.0 - 0.50)}{(R - C)} \qquad \text{(C10.3-2)}$$

Example C10.3-4 illustrates the use of these provisions.

10.3.6-Split Ring and Shear Plate connectors in End Grain

10.3.6.1 Procedures for establishing minimum and full design value spacing and edge and end distances

Example C10.3-4

Two 2-1/2 inch split ring connectors spaced 4.0 inches apart on a connector axis angle, φ, of 30° are loaded at an angle to grain, θ, of 22.5°. Determine the spacing geometry factor, C_Δ.

From Equation C10.3-1 and Table C10.3-1:

$$A = 6 - (6 - 5.125)/2 = 5.562$$
$$B = 3.75 + (3.875 - 3.75)/2 = 3.812$$
$$R = 4.541 \text{ for } C_\Delta = 1.00$$
$$C = 3.5 \text{ for } C_\Delta = 0.50$$
$$C_\Delta\ (s=4.0) = 0.50 + (4 - 3.5)(1.0 - 0.50)/(4.541 - 3.5) = \mathbf{0.76}$$

for connectors in end grain surfaces follow the same logic as that employed to establish allowable design values for such configurations in 10.2.6. The procedures have been part of the Specification since provisions for connectors in end grain were introduced in the 1977 edition.

10.3.6.2 Special attention should be given to the requirement for checking the shear capacity of members supported by connectors in end grain surfaces. Where the slope of the surface cut, α, is other than 90°, the component of the vertical force on the connector shear plane that is normal to the outside or uncut edge of the member should be taken as the shear force, V, in Equation 3.4-5 of the Specification. The effective depth of the member, d_e, should be taken as the component of the distance from the loaded edge of the member to the unloaded edge of the connector that is normal to the outside or uncut edge of the member (see Figure C10.2-1). Example C10.3-5 illustrates these provisions.

10.3.7-Multiple Split Ring or Shear Plate Connectors

10.3.7.1 The inclusion of same bolt axis connectors with connectors in a row in 10.3.7.1 of the 1991 edition is an inadvertent carryover of language introduced in the 1977 edition when the adjustment for fasteners in a row was first added to the Specification.

The group action factor, C_g, of 7.3.6 applies only to a row of two or more connectors which are in the same shear plane, are aligned in the direction of load and are on separate bolts or lag screws (see Commentary for 7.3.6). The factor need not be applied to connections involving two or more connector units on two or more contact faces concentric to the same bolt axis.

It is to be noted that the definitive criterion for application of the group action factor is alignment of two or more connectors in the direction of load on the shear plane. Two or more connectors which are aligned parallel or perpendicular to the grain of a member are not subject to the group action factor if such connectors are not also aligned with the resultant force on the shear plane. Design values for the connectors in the joint illustrated in Figure 10J of the Specification are not adjusted for group action.

10.3.7.2 The provision for handling two sizes of split ring grooves cut concentrically on the same wood surface has been part of the Specification since the 1944 edition. When this occurs and rings are installed in both grooves as required, the total load on the joint is limited to the allowable design value for the larger ring only.

Example C10.3-5

Check the shear at the end of the rafter in the end grain connector from Example C10.2-2. The joint consists of a 2-5/8 inch shear plate connector unit joining two Douglas fir-Larch 4x10 rafters at the ridge where the roof slope is 12 in 8 producing an angle of 33.7° from the vertical at the peak. The allowable connector design value for a C_D of 1.15 on the end grain surface is 1719 pounds.

$$V = V' \sin\alpha = (1719)\sin 33.7° = 954 \text{ lbs}$$
$$d_e = (8.312 + 2.625/2)\sin 33.7° = 5.34 \text{ in.}$$

From Equation 3.4-5:

$$f_v = [3(954)(9.25)]/[2(3.5)(5.34)^2] = 133 \text{ psi}$$

Allowable shear for Douglas fir-Larch 4x10:

$$F_v' = 95\ C_D = 95(1.15) = 109 < 133$$

The design does not check for shear at the connection. Either limit V' to

$$V = [109(2)(3.5)(5.34)^2]/[3(9.25)] = 784 \text{ lbs}$$
$$V' = (784)/\sin 33.7° = \mathbf{1413\ lbs}$$

or increase the distance, d_c, from the apex to the center of the connector to

$$d_e = [(3(954)(9.25))/(2(3.5)(109))]^{1/2} = 5.89 \text{ in.}$$
$$d' = (5.89)/\sin 33.7° = 10.615 \text{ in.}$$
$$d_c = (10.615 - 2.625/2) = \mathbf{9.30\ in.}$$