Steel Reinforcement Institute of Australia

TECHNICAL NOTE 7

Stress Development and Lap Splicing of Straight D500N Tensile Reinforcing Bars to AS 3600–2009

December 2016

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Cover photograph shows ultimate failure condition with significant concrete spalling, resulting from longitudinal face splits above pairs of lapped N24 tensile bars, superimposed over a regular pattern of deep transverse flexural cracks, in the top surface of the negative uniform moment region in a SRIA bar-bond test performed at Curtin University during the development of AS 3600–2009 [13].

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TECHNICAL NOTE

1 INTRODUCTION

The design rules in AS 3600–2009 [1] for stress development of straight deformed, grade 500 MPa normal ductility (D500N) steel reinforcing bars in tension by end anchorage (Clause 13.1.2), or lap splicing (Clause 13.2.2), are fundamentally important when detailing the interconnected elements or members of concrete building structures. They dictate the additional length of steel bars, and possibly the minimum quantity of fitments, to develop the necessary tensile stress in the bars, in regions at or adjacent to where bars are terminated or lapped.

The design engineers for a project, not the reinforcing steel supplier's schedulers, are normally responsible for making sure that these design rules are applied appropriately to satisfy their structural requirements. The opportunity is taken to remind readers of this design responsibility according to items (j), (k) and (l), Clause 1.4 *Documentation* of AS 3600–2009.

This technical note focuses in detail on the application of the AS 3600–2009 design rules relating to end anchorage or lap splicing of straight deformed bars in tension. These rules give rise to some of the most common, fundamentally important design and detailing issues, and are presented and reviewed in Section 2; proposed improvements follow in Section 3.

Since 1988, when designing to earlier editions of AS 3600, including AS 3600–2001 [2a,b], tensile development length and tensile lapped splice length were normally assumed equal in value [3]. Although some specific conditions had to be satisfied for this to be the case (see Appendix D), this approach greatly simplified design, detailing and site inspection. A simple, standard table of tensile development or lapped splice lengths, usually both designated by $L_{sy.t}$, was normally assumed to suffice on structural drawings, depending on the type of member, e.g. beam, column, slab, wall, etc., as well as other factors such as concrete compressive strength grade, depth of concrete cast below horizontal bars, minimum concrete cover and clear distance between bars developing stress, presence of fitments, etc.

However, satisfying AS 3600–2009 can be more involved than the previous 2001 edition. In particular, tensile development and lap lengths are generally no longer equal for particular situations. A number of additional design issues and reinforcement detailing options are also included, if one elects to develop *refined* instead of *basic* design solutions. Refined design solutions can be more economical, provided they are practical (limited for buildings), and will normally be project specific. They can possibly provide a feasible solution in restrictive cases.

The definition and design of *contact* and *non-contact* types of lapped splices have been usefully clarified in AS 3600–2009. In practice, often it is impossible to ensure that lapped bars will be in direct contact with each other. For example, a range of issues, including normal fabrication and construction tolerances, prevent lapped bars of reinforcing cages like used in the column in Fig. 1 from being in direct contact with each other. However, in accordance with Clause 13.2.2 of AS 3600–2009, provided clear distance, s_b, between adjacent lapped ends (see Fig. A.5) does not exceed three bar diameters ($3d_b$), then in such a column (a narrow member), laps may still be treated in design as contact lapped splices, as would be the case for the relatively congested laps between the cage ends in their final position seen in Fig. 1.

Detailing cogged or hooked ends, to reduce the tensile anchorage length of straight bars, was rationalised in AS 3600–2009 to overcome an anomaly in AS 3600–2001 which required fitment hooks in beams to have a longer extension [4a,b]. Hook and cog geometries are now standardised in Clause 13.1.2.7 of AS 3600–2009 for D500 bars (Ductility Class L or N).

Important new rules have been included in AS 3600–2009 that address alternative means of anchoring or splicing straight D500N bars, by using headed ends or mechanical couplers. Headed ends permit development [1,6] or lap lengths to be significantly reduced. This can be important in confined situations, for example detailing connections, or ends of deep beams [5,6,7,8]. Mechanical couplers eliminate laps and therefore reduce bar congestion.

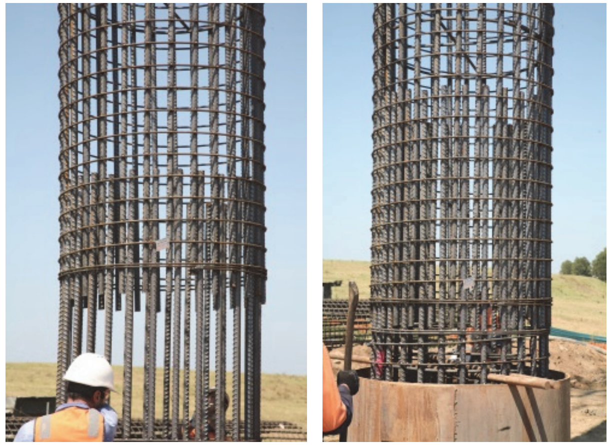

FIGURE 1 – *Lapped bars in narrow elements or members with clear distance $s_b \leq 3d_b$ may be treated in AS 3600–2009 as contact splices for design purposes, as would be the case for these lap-spliced prefabricated pile cages*

An industry survey [9] was conducted by the SRIA while the reinforcement stress development design rules in AS 3600–2009 were being prepared. The standard tables of minimum tensile development and lapped splice lengths for straight D500N bars specified by consulting engineering companies on their General Notes structural drawing were studied. At the time of the survey, most companies would have still been using the rules in AS 3600–2001. Relatively large variations in values were observed for the same design cases, when calculated using the long-standing formula for tensile development or lap length, $L_{sy.t}$, in Clause 13.1.2.1 of AS 3600–2001. An important reason for preparing this technical note is to assist design engineers to improve the consistency of standard design solutions they prepare to satisfy AS 3600–2009.

With the advent of the revised design rules in AS 3600-2009 for stress development of reinforcement, new formulae have to now be used to compute either *basic* or *refined* tensile development lengths, or similarly *basic* or *refined* tensile lap lengths. These formulae incorporate design variables and factors such as those that account directly for the confining effects of transverse compressive pressure or transverse reinforcement, and whether or not lapped bars are in contact with each other, staggered, or in regions of high or low tensile stress. Therefore, the need is even greater than before to assist consulting engineers to develop accurate, condensed design tables. In this technical note, comprehensive sets of General (designated *G*), Cover-Controlled (*CC*) and Spacing-Controlled (*SC*) design tables are developed to satisfy AS 3600-2009, and their application to general design problems is demonstrated. A unified approach for preparing project-specific design tables and notes for structural drawings can readily be adopted – see the relevant worked example in Appendix C.

Alternative Quick-Reference Tables have been assembled in Appendix D, which contain tensile development lengths and tensile lap lengths to AS 3600–2009, and also to AS 3600–2001 with some proposed improvements to these latter design rules applied [3]. These tables provide a realistic way to make practical comparisons between the different requirements of these two editions of AS 3600 for a limited range of design cases.

2 AS 3600–2009 STRESS DEVELOPMENT AND LAP SPLICING DESIGN RULES FOR STRAIGHT D500N TENSILE REINFORCING BARS

Tensile Development Lengths (Basic $L_{sy.tb}$ and Refined $L_{sy.t}$)

In accordance with Clause 13.1.2.1 of AS 3600–2009, the development length to achieve the characteristic yield strength (f_{sy}=500 MPa)[1] of a straight, deformed normal ductility (D500N) bar in tension shall be taken as either the *basic development length* ($L_{sy.tb}$), or if applicable, the *refined development length* ($L_{sy.t}$) taking the beneficial effects of confinement into account.

In accordance with Clause 13.1.2.2 of AS 3600–2009, for normal-density concrete the *basic development length* ($L_{sy.tb}$) shall be calculated using Eq. 1a [2]:

$$L_{sy.tb} = \frac{0.5k_1k_3f_{sy}d_b}{k_2\sqrt{f'_c}} \geq 29k_1d_b \qquad (1a) \qquad (basic)$$

It is important to note that although f_{sy} is included as a variable in Eq. 1a, because the lower limit of $29k_1d_b$ has been derived for f_{sy}=500 MPa, Eq. 1a should only be used for grade 500 MPa reinforcing bars. Otherwise, the lower limit should be adjusted accordingly [2b,6].

Further in accordance with Clause 13.1.2.2 of AS 3600–2009, the value of $L_{sy.tb}$ so calculated using Eq. 1a shall be multiplied by 1.3 (denoted herein as basic factor ξ_{cd}) if lightweight concrete (as defined in AS 3600–2009 – see *Technical Definitions* in Appendix A herein) is used; by 1.3 (basic factor ξ_{sf}) for structural elements built with slip forms; and by 1.5 (basic factor ξ_{bc}) if bars are epoxy-coated, but noting galvanised bars are not penalised.

It follows that Eq. 1a could be written more completely as follows, with the product of these three basic factors, $\xi_{cd}\xi_{sf}\xi_{bc}$, included, noting that each factor equals 1.0 if no penalty applies:

$$L_{sy.tb} = \xi_{cd}\xi_{sf}\xi_{bc}\frac{0.5k_1k_3f_{sy}d_b}{k_2\sqrt{f'_c}} \geq \xi_{cd}\xi_{sf}\xi_{bc}29k_1d_b \qquad (1b) \qquad (basic)$$

Gilbert [10] took the values of these three basic factors in AS 3600–2009 from ACI 318M-05 [11] in the case of ξ_{cd} and ξ_{bc}, and from Part 1.1 of Eurocode 2 [12] in the case of ξ_{sf}.

In Clause 12.2.3 of ACI 318M-05: basic factor ξ_{cd} is represented by the factor λ, and equals 1.3, the same value as in AS 3600–2009; and ξ_{bc} is represented by the factor ψ_e, which in ACI 318M-05 equals 1.5 for epoxy-coated bars with clear cover less than $3d_b$, or clear spacing less than $6d_b$, but otherwise equals 1.2 for epoxy-coated bars. In current ACI 318M-14 [5], factor λ is still used, but it has been moved from the numerator to the denominator of the otherwise unchanged formula for calculating the tensile development length of straight, deformed bars (Eq. 12-1 in ACI 318M-05 versus Eq. 25.4.2.3a in ACI 318M-14), so its new value of 0.75 is effectively the same as the old value of 1.3, noting that 1/0.75=4/3=1.33≈1.3. The definition of factor ψ_e is unchanged in ACI 318M-14, except that it has been broadened to also apply to zinc and epoxy, dual-coated bars. Accordingly, while the definition of basic factor ξ_{cd} should remain unchanged, it is proposed below (see Section 3, *Proposed Improvements to AS 3600–2009*) that the definition of basic factor ξ_{bc} be updated to what is now in Table 25.4.2.4 of ACI 318M-14 for ψ_e. Another condition in ACI 318M-14, that on this basis could be adopted when applying AS 3600–2009, is that $k_1\xi_{bc}$≤1.7 (again, see Section 3, *Proposed Improvements to AS 3600–2009*).

Regarding the application of Eq. 1b to slip-form construction, the penalty basic factors ξ_{sf} and k_1 can both be applied together, with a resultant maximum penalty of $k_1\xi_{sf}$=1.3×1.3=1.69, which in accordance with AS 3600–2009 would arise for all horizontal bars with more than 300 mm of concrete cast below them. However, in accordance with Part 1.1 of Eurocode 2, basic factors ξ_{sf} and k_1 address the same issue, viz. the quality of bond and the position of the bars during concreting, and are dealt with therein (Eq. 8.2) using the factor, η_1, which is either 1.0 for 'good' bond conditions, or 0.7 for 'poor' bond conditions. (In AS 3600–2009, 'good' bond conditions correspond to a basic factor k_1=1.0, and 'poor' bond conditions to k_1=1.3, which is about the inverse of 0.7.) Top horizontal bars with more than 300 mm of concrete cast below the bars, for which k_1=1.3 in AS 3600–2009, are similarly regarded as being under 'poor' bond conditions in Part 1.1 of Eurocode 2. According to Part 1.1 of Eurocode 2, all bars within structural elements built with slip-forms should, unless it can be shown that 'good' bond conditions exist, be treated as if under 'poor' bond conditions, but the penalty is only applied once, irrespective of a bar's position in the concrete. This design approach remains unchanged in the latest *fib* Model Code 2010 [7a], with slip-form construction defined under Special Circumstances in Clause 6.1.5.1 therein. Therefore, it is proposed below (see Section 3, *Proposed Improvements to AS 3600–2009*) that basic factor ξ_{sf} be eliminated from Eq. 1b (to the left and right of the inequality) by broadening the definition of basic factor, k_1, to include the effects of slip-form construction too.

A further proposed correction to Eq. 1b involves the lower limit on the right-hand side of the inequality. Namely, again ignoring basic factor ξ_{sf}, which is to be eliminated by redefining k_1, it is proposed that $\xi_{cd}\xi_{bc}29k_1d_b$ simply stays as $29k_1d_b$, and is not increased by either ξ_{cd} or ξ_{bc}. The lower limit to $L_{sy.tb}$ of $29k_1d_b$ is intended to correspond to an upper limit of bond strength due to bar pull-out rather than concrete splitting failure, but lacks important terms such as concrete strength. Moreover, significantly smaller lower limits are used in ACI 318M-14, and in Part 1.1 of Eurocode 2.

It follows that it is proposed to use Eq. 1c to compute basic development length, $L_{sy.tb}$, in lieu of Eqs 1a or 1b, with k_1 redefined to accommodate possible 'poor' bond conditions in slip-form construction (see *Terminology* in Appendix A), and with $k_1\xi_{bc}$≤1.7:

$$\mathbf{L_{sy.tb} = \xi_{cd}\xi_{bc}\frac{0.5k_1k_3f_{sy}d_b}{k_2\sqrt{f'_c}} \geq 29k_1d_b} \qquad \textbf{(1c)} \qquad \textbf{(basic)}$$

Finally, in accordance with Clauses 13.1.2.2 and 13.1.2.3 of AS 3600–2009, a potentially smaller development length, viz. the *refined development length* ($L_{sy.t}$), may be calculated using Eq. 2, with the basic development length ($L_{sy.tb}$) calculated from Eq. 1c:

$$\mathbf{L_{sy.t} = k_4k_5L_{sy.tb}} \text{ such that } 0.7 \leq k_3k_4k_5 \leq 1.0 \qquad \textbf{(2)} \qquad \textbf{(refined)}$$

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1 For normal design purposes, a designer expects that D500N reinforcing bars anchored or lap spliced in accordance with AS 3600–2009 will be able to reach their design yield stress, f_{sy}. In fact, the bars across a critical section in a real structure must be able to achieve a higher stress than this before the anchorage or lap splice could fail, because the ductility of the reinforcing bars concerned must normally also be maintained [13]. This requirement is already factored into the design Eqs 1, 2 and 3 in Section 2, so does not have to be considered directly in design. However, this ductility principle needs to be considered when designing welded or mechanical splices formed between Ductility Class N reinforcing bars according to Clause 13.2.6 of AS 3600–2009 [6,14].

2 Refer to *Appendix A – Terminology and Technical Definitions* for the definition of all variables used in the equations of the technical note.

It follows from Eqs 1c and 2 that it is sometimes possible that refined development length, $L_{sy.t}$<29$k_1 d_b$, while it is shown below that this is never the case for basic or refined lap lengths.

Tensile Lap Lengths (Basic $L_{sy.tb.lap}$ and Refined $L_{sy.t.lap}$)

In accordance with Clause 13.2.2 of AS 3600–2009, the same formulae (Eqs 1 & 2) shall be used as appropriate to calculate the *basic lap length* ($L_{sy.tb.lap}$) [3] or *refined lap length* ($L_{sy.t.lap}$). Due account shall be taken of the presence of lapped bars when determining clear distance, *a*, to calculate dimension c_d to determine k_3 for use in Eq. 1 – see Fig. A.5 for examples.

In accordance with the notes in Fig. 13.2.2 of AS 3600–2009, observing that this figure is similar to Fig. A.5, for bars lapped in the same plane, clear distance, *a*, shall be determined assuming *contact lapped splices*, i.e. lapped bars shall be assumed to be touching each other, even if they don't and the lapped splices are actually *non-contact*.

A factor k_7 also has to be applied in the calculations, according to Eqs 3a and 3b for *basic lap length* and *refined lap length*, respectively:

$$L_{sy.tb.lap} = k_7 L_{sy.tb} \geq 29 k_1 d_b \qquad \text{(3a)} \quad \textit{(basic)}$$

$$L_{sy.t.lap} = k_7 L_{sy.t} \geq 29 k_1 d_b \qquad \text{(3b)} \quad \textit{(refined)}$$

Note that: (i) consistent with Eq. 1c, the triple basic factors product $\xi_{cd}\xi_{sf}\xi_{bc}$ shown in Eq. 1b has not been included in the right-hand side of Eq. 3a or 3b; (ii) the general formula for basic development length (Eq. 1c) should be used to calculate $L_{sy.tb}$ in Eq. 3a; and (iii) Eq. 2 should be used to calculate $L_{sy.t}$ in Eq. 3b. However, in accordance with Clause 13.2.2 of AS 3600–2009, when calculating $L_{sy.tb}$ for use in Eq. 3a or $L_{sy.t}$ for use in Eq. 3b, the lower limit of 29$k_1 d_b$ in Eq. 1c does not apply.

Factor k_7 accounts for the level of tensile stress in lapped bars at ultimate load, and also the degree of staggering, in the same way Class A or Class B lapped splices are dealt with in ACI 318M-14, except that Class B splices are 1.3 times longer. Nilson et al. [15] explain that "*The effect of these requirements is to encourage designers to locate splices away from regions of maximum stress, to a location where the actual steel area is at least twice that required by analysis, and to stagger splices*". Cairns [16] provides further insight into the common practice of staggering lapped splices, but questions that it is necessarily beneficial. This supports the fact that in AS 3600–2009, staggered lapped splices are not necessarily assumed to be stronger, i.e. for k_7 to equal 1.0, A_s must also be at least twice that required.

Non-contact lapped splices have these same values of lap length ($L_{sy.tb.lap}$ and $L_{sy.t.lap}$) in *wide elements or members* (e.g. T-beam flanges, band beams, slabs, walls and blade columns) [4], and also in narrow elements or members (e.g. beam webs and columns) where the clear distance, s_b, between each pair of bars being spliced does not exceed 3d_b. Otherwise, according to Clause 13.2.2 of AS 3600–2009, in *narrow elements or members*, the calculated lap lengths $L_{sy.tb.lap}$ and $L_{sy.t.lap}$ increase to ($L_{sy.tb}$ +1.5s_b) and ($L_{sy.t}$ +1.5s_b), respectively, if either of these latter two formulae gives rise to a larger value than Eqs 3a and 3b, respectively.

Standard Hook or Cog to Straight D500N Bar End

In accordance with Clause 13.1.2.6 of AS 3600–2009, where an otherwise straight deformed bar ends in a standard hook or cog complying with Clause 13.1.2.7, the tensile development length of that end of the reinforcing bar to develop f_{sy}, measured from the outside of the hook or cog, shall be taken as 0.5$L_{sy.tb}$ or 0.5$L_{sy.t}$, as shown in Fig. 13.1.2.6 of AS 3600–2009.

The dimensions of standard 180° and 135° hooks and 90° cogs, which satisfy the minimum requirements of Clause 13.1.2.7 of AS 3600–2009, are given in Table C13.1.2.7 of the Commentary [6] for uncoated (bare), straight Ductility Class N bars (pin diameter factor, k_p=5, in accordance with Clause 17.2.3.2(b) of AS 3600–2009) [5].

3 PROPOSED IMPROVEMENTS TO AS 3600–2009

Revised formula for basic development length $L_{sy.tb}$

As explained in Section 2, it is proposed to replace Eq. 13.1.2.2 of AS 3600–2009 with Eq. 1c, as it unambiguously shows how to take account of the potentially detrimental effects of reduced concrete density (i.e. lightweight concrete), epoxy coating of bars, or poor bond conditions including the effects of slip-form construction, when calculating basic development length, $L_{sy.tb}$, and does not over penalise the use of these less common construction options.

Broadened definition of basic factor k_1 to include slip-form construction

As explained in Section 2, in accordance with Part 1.1 of Eurocode 2, and *fib* Model Code 2010, unless it can be proven otherwise, it is proposed that all bars in slip-form construction be considered to be under 'poor' bond conditions, which can simply be accounted for by assigning basic factor k_1=1.3 in Eq. 1c. Horizontal bars with more than 300 mm of concrete cast below them should not be penalised further (i.e. twice) in this form of construction.

Updated definition of basic factor ξ_{bc} in-line with ACI 318M-14

As explained in Section 2, in AS 3600–2009 basic factor ξ_{bc}=1.5 if bars are epoxy-coated, which came from ACI 318M-05, but it is proposed that in accordance with the more recent ACI 318M-14, ξ_{bc}=1.5 for epoxy-coated bars or zinc and epoxy dual-coated bars with clear cover less than 3d_b, or clear spacing less than 6d_b, (in which case $k_1\xi_{bc}$≤1.7 in Eq. 1c), but otherwise ξ_{bc}=1.2 for epoxy-coated bars or zinc and epoxy dual-coated bars. (Factor ψ_t denotes k_1 in ACI 318M-14, and like AS 3600–2009 is 1.3 for >300 mm concrete cast below.)

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3 Variable $L_{sy.tb.lap}$ is not used in AS 3600–2009, where instead $L_{sy.t.lap}$ represents either the basic or refined tensile lap length. However, in this technical note it is important to make the determination of the lap length (basic or refined) absolutely clear for the designer when using Appendix B, *Design Tables to AS 3600–2009*, and also in the worked examples in Appendix C. Therefore, the new variable $L_{sy.tb.lap}$ has been added, and correspondingly $L_{sy.t.lap}$ has been redefined. If a designer elects to use refined lap length $L_{sy.t.lap}$, then additional calculations are required to justify this, as shown in Appendix C, *Worked Examples using Design Tables to AS 3600–2009*.

4 In Section 13 of AS 3600, concrete elements and members are loosely distinguished between, according to whether they are "narrow" or "wide". In wide elements or members, clear concrete side cover (c_1) can in practice be completely ignored in design, i.e. side cover effects are insignificant to the average design result.

5 In accordance with Clause 17.2.3.2(a) of AS 3600–2009, for fitments pin diameter factor, k_p=3 and 4 for Ductility Class L and N bars, respectively. L6, L8 and L10 ribbed D500L bars are commonly used for fitments, and their nominal bar diameters are 6.00, 7.60 and 9.50 mm, respectively. Use of R6, R8 and R10 R250N plain bars for fitments is diminishing, noting that design yield stress (f_{sy}) is only half that of D500L or R500L bars.

Improvements to calculation of refined factor k_4

Munter et al. [17a,b] have explained the technical reasons for proposing improvements to the calculation of refined factor k_4 when taking into account the presence of transverse reinforcement to resist longitudinal splitting of the concrete cover. Term K used in the formula for calculating k_4 has been redefined so that more practical design solutions can be calculated, and for a broader range of member types, including circular columns, as shown in Fig. A.3. Further refinements to the three simple cases in Fig. 13.1.2.3(B) of AS 3600–2009, taken from Part 1.1 of Eurocode 2, have subsequently been presented in the *fib* Model Code 2010 [7a,b], which take into consideration the magnitude of the clear distance between adjacent longitudinal bars (see Fig. 6.1-14 in [7a] and Fig. 4-9 in [7b]), thereby reducing the value of K to zero in cases when adjacent bars are spaced close enough together to facilitate an undesirable '*side splitting mode*' (longitudinal cracks pass through adjacent bars, missing the transverse bars) instead of a desirable 'face splitting mode' (longitudinal cracks extend to the nearest concrete surface and must cross through transverse bars nearer the face).

In particular, typical rectangular columns, beams, walls or slabs can incorporate more than one of the details shown in Fig. 13.1.2.3(B) of AS 3600–2009, at a typical transverse cross-section through an anchorage or lapped splice region. As currently shown, each case in Fig. 13.1.2.3(B) has to be treated differently, which can result in different development or lapped splice lengths for adjacent bars. A weighted-average design approach (consistent with Clause 25.4.2.3 of ACI 318M-14, and the calculation of transverse reinforcement index, K_{tr}) is the most practical solution, so that all of the bars being considered with the same cross-section detail and with the same diameter may have the same design development or lapped splice length, and is therefore proposed.

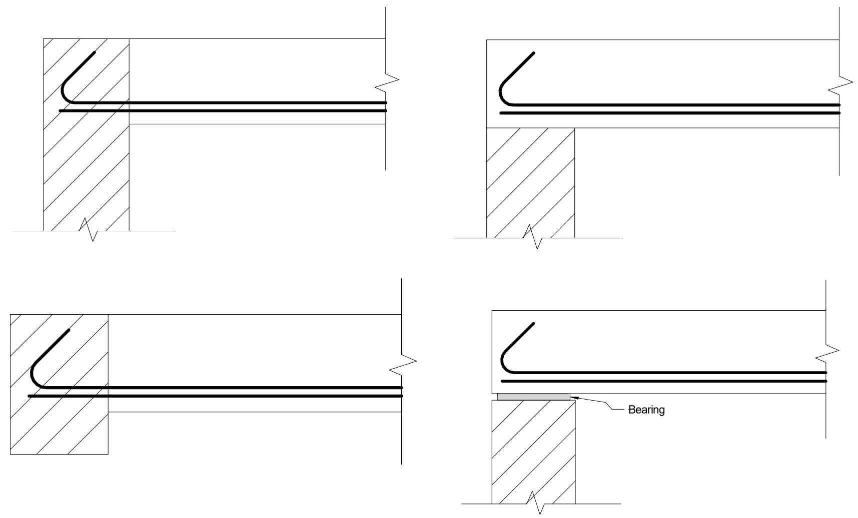
These proposed changes to the present design rules in AS 3600–2009 are included with others in Appendix A, where they are all identified with a preceding hatch (#) to make sure that the reader is aware of their origin. These proposed improvements do not affect any of the solutions contained in Appendix B, *Design Tables to AS 3600–2009*. Their use in normal design is illustrated in Appendix C, *Worked Examples using Design Tables to AS 3600–2009*.

Improvements to calculation of refined factor k_5

Bond strength may be decreased in the presence of tensile stress, and increased in the presence of compressive stress, perpendicular to the bar longitudinal axis [7a], viz.: *"Confinement from transverse pressure initially has a strongly beneficial influence on bond strength where it restrains a splitting failure mode. Once confinement is sufficient to restrain (longitudinal) splitting, the rate of increase reduces. It will usually be beneficial to include the influence of transverse (compressive) pressure when considering anchorage of reinforcement in deep beams and corbels."*

Improved bond strength is restricted to the portion of the end anchorage or lap length where the transverse compressive stress, ρ_p, acts to produce a clamping pressure on the concrete confining the bars along the face where the stress is applied.

For example, consider the different end support arrangements shown in Fig. 2 [18,19]. Confinement of the bottom bars is under consideration here, and therefore other bars have been omitted from the figure. Although not mentioned in AS 3600–2009 or its Commentary [6], the beneficial effects of transverse compressive stress arising from transfer of the support reaction are markedly reduced if a support arrangement is indirect (see two examples to left in Fig. 2(a)) rather than direct (see two examples to right in Fig. 2(b)). It is proposed when designing indirect support arrangements to completely ignore any such beneficial effects, as the support reaction may not significantly confine the bottom bar ends. The straight bottom bars in Fig. 2(b) will have their bond enhanced by transverse pressure, over the supporting wall or bearing where the bars extend. In the case of the hooked bars in Fig. 2(b), with the hook tails vertical, transverse pressure enhancement only occurs over the straight part of the bar, and not over the hooked part, because the tails lie in a plane parallel (not perpendicular) to the direction of the applied compressive stress. However, Park and Paulay [20] show how to enhance end anchorage by placing the hook tails nearly horizontal.



(a) Indirect Support **(b) Direct Support**

FIGURE 2 – *Examples of indirect and direct end support arrangements*

Significant transverse compressive stress can also arise in buildings where load from upper storeys is transferred directly through anchorage zones, in a direction perpendicular to the plane passing through the longitudinal axes of the anchored bars. If this occurs for indirect support arrangements such as in Fig. 2(a), then the stress transferred from above should not be considered as additive to the stress from the floor in question. However, for direct support arrangements like in Fig. 2(b), then at least for the bottom bars, the compressive stress corresponding to the entire reaction acting at the soffit of the floor member can be utilised in design. The same principles can be applied to other cases, including: top bars where pressure from above is applied directly to the top face; and also at internal supports.

Splices between bars of different sizes

In accordance with Clause 25.5.2.2 of ACI 318M-14, where reinforcing bars of different diameter are lap-spliced together in tension, the lapped splice length should equal the larger of the tensile lapped splice length for the smaller bar, or the tensile development length for the larger bar. As stated in the Commentary to AS 3600–2009 [6], this same principle could be applied when designing in accordance with AS 3600–2009 using Eqs 1 to 3 herein, as appropriate.

Minimum clear distance between parallel bars, and minimum concrete cover

Sufficient clear distance between parallel bars is needed to allow the concrete to be placed, and to limit the potential for splitting of the hardened concrete between the bars, which could subsequently cause delamination. It is commonly recommended in practice, e.g. in AS 5100.5 [21], that the absolute minimum clear distance between parallel bars should not be less than 1.5 times the maximum nominal size of aggregate (normally for buildings, maximum aggregate size is 20 mm), or 1.5 times the diameter of the bars, whichever is larger. In Appendix B of this technical note, the limit of 1.5 d_b is increased to 2.0d_b, as this corresponds to the worst possible bond conditions with the minimum value of c_d=d_b, and maximum k_3=1.0 in Eq. 1, provided clear concrete cover is at least d_b. In AS 5100.5, a further requirement is that the clear distance or spacing shall not be less than 40 mm. Also, the clear concrete cover should not be less than the maximum bar diameter.

Upper limit to clear distance s_b in non-contact lapped splices

No upper limit is specified in AS 3600–2009 concerning the clear distance between bars of a non-contact lapped splice, s_b, shown in Fig. A.5. However, in accordance with Clause 25.5.1.3 of ACI 318M-14, for non-contact lapped splices in flexural members, the transverse centre-to-centre spacing of spliced bars should not exceed the lesser of one-fifth the applicable lapped splice length or 150 mm, i.e. the maximum value of clear distance, s_b, equals the minimum of [{$L_{sy.tb.lap}$ or $L_{sy.t.lap}$}/5, 150 mm], less d_b the diameter of the lapped bars.

Splices in columns with offset bars

In accordance with Clause 10.7.5.1.3 of ACI 318M-14, for lapped splices in columns with offset bars, clear distance, s_c, equals the clear spacing shown therein in Fig. R10.7.5.1.3.

4 REFERENCES

[1] Standards Australia, *"Concrete Structures"*, AS 3600–2009 (23 December 2009), 4th Edition with Amdt 1–2010 (15 November 2010) & Amdt 2-2013 (20 March 2013).

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APPENDIX A – TERMINOLOGY AND TECHNICAL DEFINITIONS

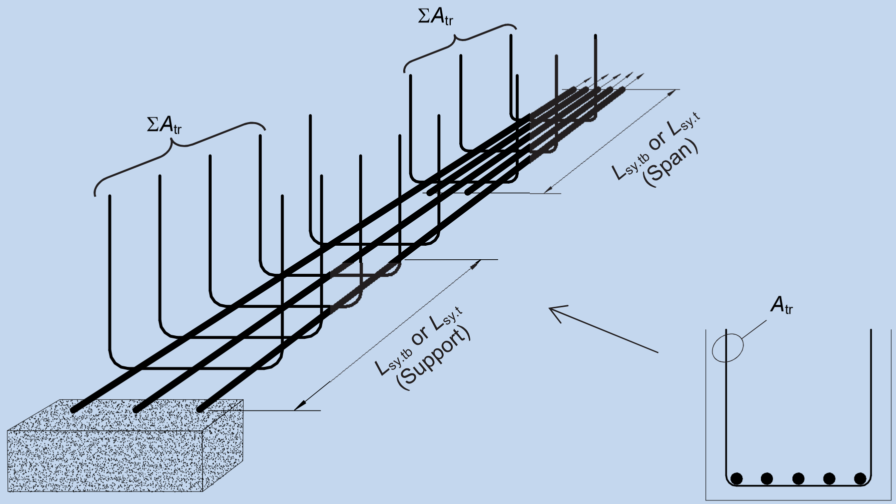
TERMINOLOGY

 # A hatch preceding a symbol or a figure number indicates that the terminology contains a proposed departure or additional information to AS 3600–2009

A_b	=	cross-sectional area of a reinforcing bar	(mm^2)
$A_{b.fit}$	=	cross-sectional area of a reinforcing bar used as a fitment – see Fig. A.3	(mm^2)
A_s	=	cross-sectional area ($\pi d_b^2/4$) of a single (500 MPa) bar of nominal diameter d_b being anchored or lap spliced, with maximum bar area – see formula below for calculating λ, from Part 1.1 of Eurocode 2	(mm^2)
A_{tr}	=	cross-sectional area ($\pi d_{b.tr}^2/4$) of each transverse reinforcing bar spaced along a development or lapped splice length, and located between the layer of anchored or spliced reinforcement and the nearest adjacent concrete surface, across which one or multiple potential splitting cracks can pass – see Figs A.1 and A.3, and also the definitions of ΣA_{tr} and $\Sigma A_{tr.min}$ Note: Transverse reinforcement is only effective if placed between the nearest adjacent concrete surface/s and the bars that are being anchored or spliced. It may also be used for other purposes, e.g. shear, flexure, control of temperature and shrinkage effects, stability of bars in compression, confinement of concrete, etc.	(mm^2)
a	=	clear distance between adjacent parallel bars developing stress – see Figs A.2 & A.4 (development length) and Fig. A.5 (lap length)	(mm)
b_s	=	length of end bearing, measured in longitudinal direction of beam	(mm)
c	=	clear concrete cover to reinforcing bars developing stress – see Fig. A.2	(mm)
c_1	=	clear concrete side cover to reinforcing bars developing stress – see Fig. A.2	(mm)
c_d	=	a dimension equal to either the least clear concrete cover to the bars (c or c_1 in narrow elements or members, or only c in wide elements or members), or half the clear distance between adjacent parallel bars developing stress (a), whichever is the lesser value, noting that the upper and lower bounds on k_3 mean that $d_b \le c_d \le 3d_b$ when substituted into the formula for k_3 – see Fig. A.2 (development length) and Fig. A.5 (lapped splice length)	(mm)
$\bar{c}_d$	=	similar definition to c_d, but used in Appendix D for AS 3600–2001	(mm)
c_{min}	=	minimum allowable value of clear concrete cover, c, equal to max. (c_{req}, $d_{b.5mm}$)	(mm)
c_{req}	=	required concrete cover depending on Exposure Classification, EC – see Table B.4	(mm)

FIGURE A.1 – *Longitudinal distribution of transverse reinforcement*

(a) End anchorages (cases shown: onto *Support*; or within *Span*)



(b) Lapped splices

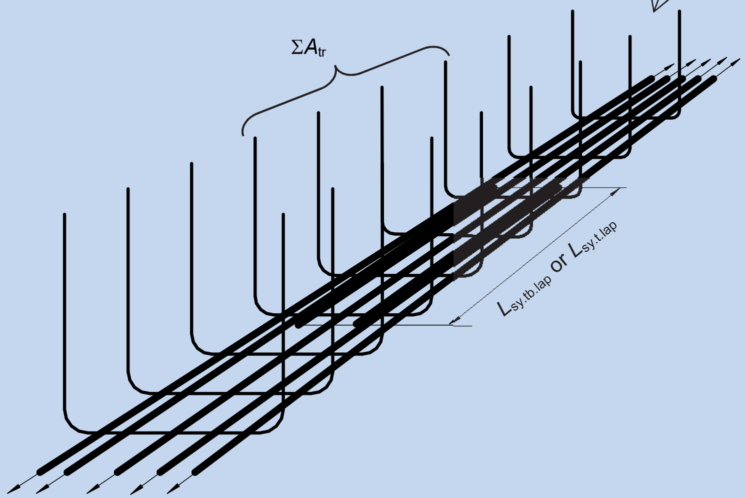
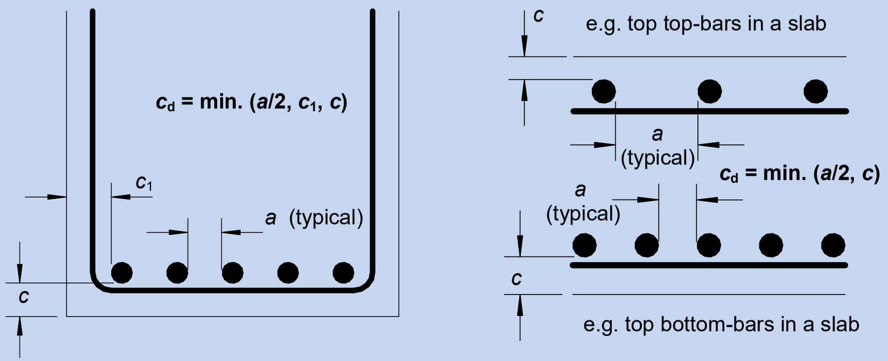


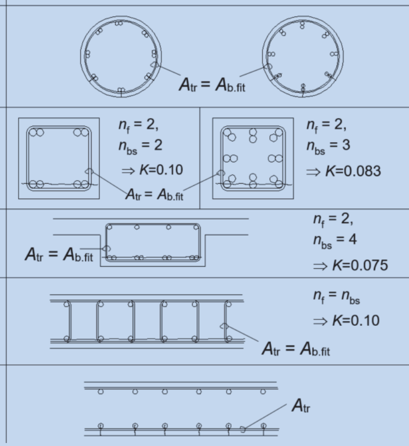
FIGURE A.2 – *Concrete covers and clear distance for straight bars being anchored*



Note: as shown, all of the longitudinal bars in each layer are equi-spaced, and anchored together so they are all developing stress

d	=	effective depth of a cross-section in the plane of bending	(mm)
d_{agg}	=	maximum diameter of coarse aggregate of concrete	(mm)
d_b	=	nominal diameter of a reinforcing bar being anchored or lapped	(mm)
$d_{b.5mm}$	=	nominal diameter of a bar being anchored or lapped, rounded up (if c_{req}<d_b) to the nearest 5 mm, e.g. for N24 bar, $d_{b.5mm}$ = 25 mm	(mm)
$d_{b.tr}$	=	nominal diameter of a transverse reinforcing bar – see A_{tr} above	(mm)
EC	=	Exposure Classification for durability design in accordance with AS 3600–2009	-
# f'_c	=	characteristic compressive cylinder strength of concrete at 28 days, but not less than 15 MPa and not to exceed 65 MPa when substituted into Eq. 1. The lowest value of 15 MPa is explained by the fact that in Table 4.4 *Minimum Strength and Curing Requirements for Concrete* of AS 3600–2009, the minimum average compressive strength at the time of stripping of forms or removal from moulds is defined, and equals 15 MPa for Exposure Classification, EC = A1 or A2. For EC = B1 or B2, the minimum average strengths are 20 and 25 MPa, respectively.	(MPa)
f_{sy}	=	characteristic or design yield strength or stress of the reinforcing bars being anchored or lapped (=500 MPa) (Note: other values of f_{sy} should not be used in Eq. 1, as the lower limit $29k_1d_b$ is derived for grade 500 MPa steel.)	(MPa)
$f_{sy.tr}$	=	characteristic yield strength (stress) of transverse reinforcing bars – see definition of λ below	(MPa)

 # FIGURE A.3 – *Values of K for typical arrangements of transverse reinforcement or fitments for different member types*



Member type	Examples of potential splitting cracks at a tensile face	n_f	n_{bs}	K (see Note 1)
Circular column	$A_{tr} = A_{b.fit}$	1	1	0.10
Rectangular column	n_f = 2, n_{bs} = 2 ⇒ K=0.10; $A_{tr} = A_{b.fit}$; n_f = 2, n_{bs} = 3 ⇒ K=0.083	≥1	≥1	0.05≤K≤0.10
Beam	$A_{tr} = A_{b.fit}$; n_f = 2, n_{bs} = 4 ⇒ K=0.075	≥1	≥1	0.05≤K≤0.10
Slab or wall with fitments	n_f = n_{bs} ⇒ K=0.10; $A_{tr} = A_{b.fit}$	≥1	≥1	0.05≤K≤0.10
Slab or wall without fitments	A_{tr}	0	1 per main bar spacing	0.05 (see Note 2)

Notes:

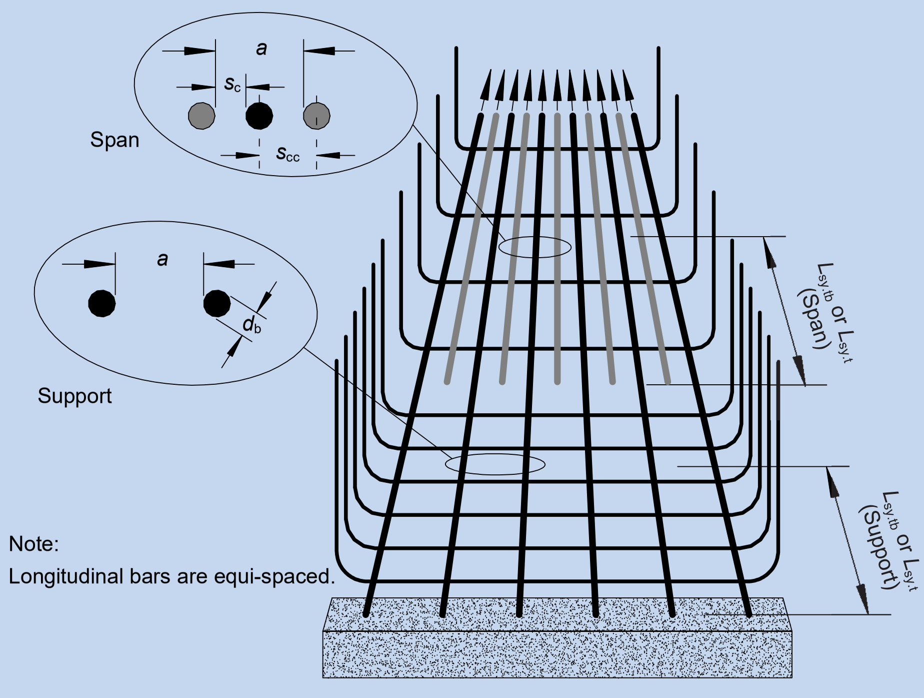
1. The same value of K applies to all of the longitudinal bars being either anchored or lap spliced, i.e. it is a weighted-average value. In the case of a circular column, or a slab or wall without fitments, K=0 if the clear distance between adjacent lapped bars, s_c, is less than 8 times c_d.[6]
2. To be effective, the transverse reinforcement must be located between the longitudinal bars and the concrete tensile face as shown, otherwise K=0.

# K	=	a factor that accounts for the weighted-average effectiveness of transverse reinforcement in controlling potential splitting cracks along a development or lapped splice length, and has a value of between zero and 0.10 inclusive, depending on the position of the anchored or lapped bars with respect to the transverse (confining) reinforcement, as follows:	-
	=	$0.05\times(1 + n_f/n_{bs}) \le 0.10$, with example values of n_f and n_{bs} given in Fig. A.3 for typical arrangements of transverse reinforcement for different member types [6]; or	
	=	0, if transverse reinforcement is not located between the longitudinal bars and the concrete tensile face.	

6 As mentioned in *Improvements to calculation of refined factor k_4* in Section 3, *Proposed Improvements to AS 3600–2009*, according to References 7a,b: in the case of a circular column, or a slab or wall without fitments, K=0 if the clear distance between adjacent parallel bars developing stress, a, is less than 8 times c_d. However, it is left up to design engineers to make their own judgement about this onerous requirement, which is not included in AS 3600–2009 and has been ignored in the worked examples in Appendix C.

# k_1	=	(basic) factor in Eq. 1 equal to 1.3 for horizontal bars with more than 300 mm of concrete cast below the bars (to account for the possible adverse effects on bond, of aerated concrete due to bleed water and entrapped air underneath horizontal bars close to the top of a concrete member) , or 1.3 for all bars in structural elements built with slip-forms (unless it can be shown that 'good' bond conditions exist), or 1.0 for all other bars;	-
k_2	=	(basic) factor in Eq. 1 equal to (132 - d_b)/100 with no specified upper or lower bounds	-
k_3	=	(basic) factor in Eq. 1 equal to [$0.7 \le \{1.0 - 0.15(c_d - d_b)/d_b\} \le 1.0$] Note: it follows that k_3 equals 1.0 if c_d equals d_b, and 0.7 if $c_d \ge 3d_b$	-
k_4	=	(refined) factor in Eq. 2 equal to [$0.7 \le \{1.0 - K\lambda\} \le 1.0$], which represents the influence of transverse (confining) reinforcement to the anchored or lap spliced bars, in excess of a minimum area	-
k_5	=	(refined) factor in Eq. 2 equal to [$0.7 \le \{1.0 - 0.04\rho_p\} \le 1.0$], which represents the contribution of transverse pressure	-
# k_4k_5	=	refined factors product	-
# $(k_4k_5)_{min}$	=	minimum possible value of refined factors product k_4k_5, corresponding to when $k_3k_4k_5 = 0.7$ – see Table B.2	-
k_7	=	factor in Eq. 3 that accounts for staggered laps, and bar stress levels at ultimate load: k_7=1.25; however, if the cross-sectional area of the bars outside the laps equals at least twice the area required for strength, i.e. a low-stress, non-critical region, and also, no more than half the bars are lapped at any section, e.g. lapped splices are staggered according to Fig. A.5(b), then k_7=1.0, same in principle to Table 10.7.5.2.2 of ACI 318M-14	-
k_p	=	pin diameter factor for bending standard hooks or cogs	-
L_{st}	=	development length of a reinforcing bar for a design ultimate tensile stress (σ_{st}) less than the design yield stress, f_{sy}	(mm)
# $L_{sy.t}$	=	refined tensile development length, to achieve characteristic yield strength or stress (f_{sy}) – see Eq. 2 & Fig. A.4. Note that this symbol is used more generally in AS 3600–2009, as either the basic or refined tensile development length.	(mm)
# $L_{sy.t.min}$	=	minimum possible value of refined tensile development length, $L_{sy.t}$, corresponding to minimum theoretical value of refined factors product, k_4k_5 , i.e. $(k_4\ k_5)_{min}$ – see Table B.2. Note that this symbol is not used in AS 3600–2009, but has been added to show the absolutely minimum possible value of tensile development length.	(mm)
$L_{sy.tb}$		basic tensile development length, to achieve characteristic yield strength or stress (f_{sy}) – see Eq. 1c & Fig. A.4	(mm)

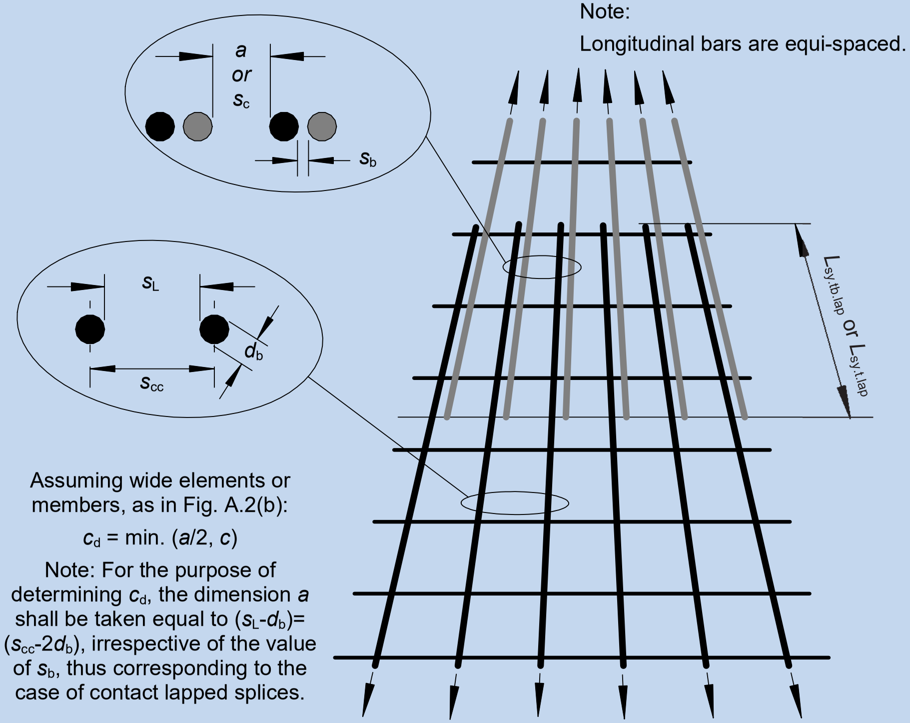
FIGURE A.4 – ***Planar end anchorage details (case of staggered development lengths)***



# $L_{sy.t.lap}$	=	refined tensile lap length (for either contact or non-contact lapped splices), to achieve characteristic yield strength or stress (f_{sy}) – see Eq. 3b & Fig. A.5. Note that this symbol is used more generally in AS 3600–2009, as either the refined tensile lap length, or else it equals the basic tensile lap length if it is simply assumed in design that k_4=k_5=1 in Eq.2, i.e. that there is no benefit due to confinement.	(mm)
# $L_{sy.t.lap.min}$	=	minimum possible value of refined tensile lap length, $L_{sy.t.lap}$, corresponding to minimum theoretical value of refined factors product, k_4k_5 , i.e. $(k_4k_5)_{min}$ – see Table B.2. Note that this symbol is not used in AS 3600–2009, but has been added to show the absolutely minimum possible value of tensile lap length.	(mm)
# $L_{sy.tb.lap}$	=	basic tensile lap length (for either contact or non-contact lapped splices) , to achieve characteristic yield strength (f_{sy}) – see Eq. 3a & Fig. A.5. Note that this symbol is not used in AS 3600–2009, but has been added to make it clear when the tensile lap length is calculated from the basic development length.	(mm)

FIGURE A.5 – *Planar lapped splice details (general case of non-contact splices)*

(a) 100% of bars spliced (no staggered lapped splices)



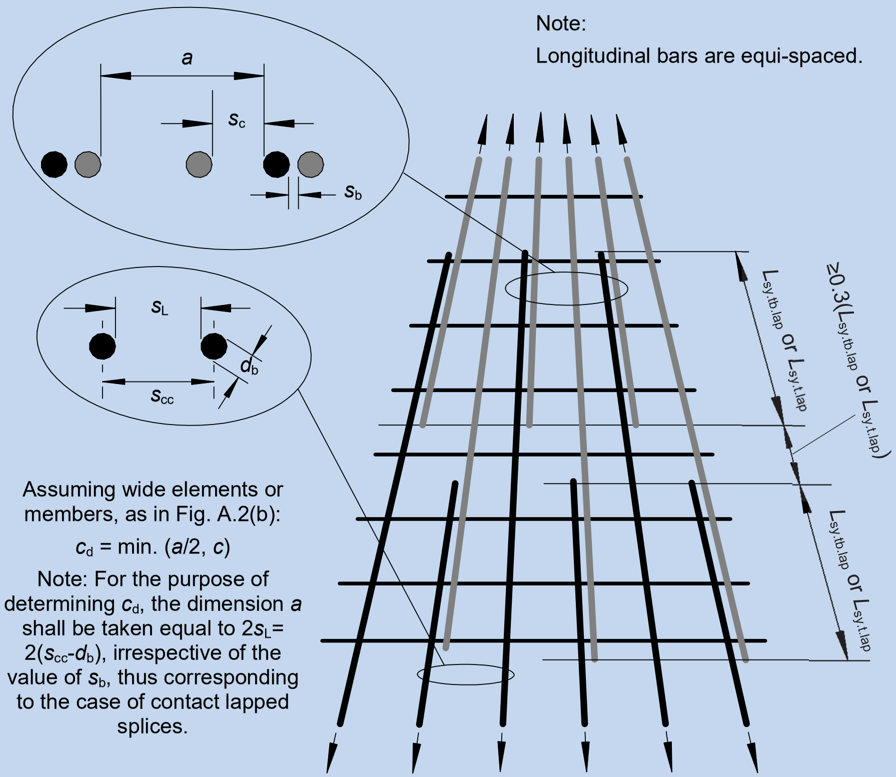
Assuming wide elements or members, as in Fig. A.2(b):

c_d = min. (a/2, c)

Note: For the purpose of determining c_d, the dimension a shall be taken equal to (s_L-d_b)= (s_{cc}-2d_b), irrespective of the value of s_b, thus corresponding to the case of contact lapped splices.

FIGURE A.5 (cont.) – *Planar lapped splice details (general case of non-contact splices)*

(b) 50% staggered lapped splices



Assuming wide elements or members, as in Fig. A.2(b):

c_d = min. (a/2, c)

Note: For the purpose of determining c_d, the dimension a shall be taken equal to 2s_L= 2(s_{cc}-d_b), irrespective of the value of s_b, thus corresponding to the case of contact lapped splices.

# n_{bs}	=	number of longitudinal bars being developed or spliced at which a potential splitting crack can develop – see Fig. A.3	-
# n_f	=	number of fitment bars within longitudinal spacing or pitch s that a potential splitting crack has to cross – see Fig. A.3	-
s	=	centre-to-centre spacing (or pitch) of fitments including shear, torsional or confining reinforcement, measured parallel to the longitudinal axis of a member	(mm)
s_b	=	clear distance between adjacent pairs of parallel bars being spliced – see Fig. A.5. By definition, it has a value of zero for contact lapped splices. For narrow elements or members with non-contact lapped splices, s_b may be assumed to equal zero when calculating the lower limits to tensile lap length $L_{sy.tb.lap}$ or $L_{sy.t.lap}$ in accordance with Clause 13.2.2 of AS 3600–2009, provided s_b does not exceed 3d_b, i.e. Eq. 3 may be used directly.	(mm)
s_c	=	minimum clear distance between adjacent parallel bars, s_b excepted – see Figs A.4 and A.5	(mm)
s_{cc}	=	centre-to-centre spacing of adjacent parallel bars being anchored or lap spliced, measured outside the anchorage or lap region – see Figs A.4 and A.5	(mm)
s_L	=	clear spacing between adjacent parallel bars being lap spliced, measured outside the splice region – see Fig. A.5	(mm)
T^*	=	design axial tensile force	(kN)
V^*	=	design shear force	(kN)
z	=	internal moment lever arm of the section	(mm)

θ_v	=	angle between the axis of the concrete compressive strut and the longitudinal axis of the member	(°)
λ	=	$(\Sigma A_{tr} - \Sigma A_{tr.min}) / A_s \geq 0$ but ΣA_{tr} is multiplied by ($f_{sy.tr}$ / 500) if $f_{sy.tr}$<500 MPa; and A_s equals the cross-sectional area ($\pi d_b^2/4$) of a single (500 MPa) bar of nominal diameter d_b being anchored or lap spliced, with maximum bar area	-
ρ_p	=	transverse compressive pressure or stress at ultimate load, along the development or lap length and perpendicular to the plane of longitudinal splitting (taken as a positive value when compressive)	(MPa)
σ_{st}	=	axial or longitudinal tensile stress in reinforcement under design ultimate load conditions	(MPa)
ϕ	=	capacity reduction factor	-
# ξ_{bc}	=	bar coating (basic) factor in Eqs 1b and 1c, equal to 1.5 for epoxy-coated bars or zinc and epoxy dual-coated bars with clear cover less than 3d_b, or clear spacing less than 6d_b, (noting that $k_1\xi_{bc}$≤1.7 in Eq. 1c), but otherwise equals 1.2 for epoxy-coated bars or zinc and epoxy dual-coated bars, or 1.0 for uncoated (bare) or zinc-coated (galvanised) bars	-
# ξ_{cd}	=	concrete density (basic) factor in Eqs 1b and 1c, equal to 1.3 for lightweight concrete, or 1.0 for normal-density concrete	-
# ξ_{sf}	=	slip form (basic) factor in Eq. 1b, equal to 1.3 for structural elements built with slip forms, or 1.0 otherwise	-
# ΣA_{tr}	=	sum of the cross-sectional areas of the transverse reinforcing bars, each of area A_{tr}, spaced along a development or lapped splice length, and located between the layer of anchored or spliced reinforcement and the nearest adjacent concrete surface, across which one or multiple potential splitting cracks can pass – see Fig. A.1, and also the definition of λ	(mm^2)
# $\Sigma A_{tr.min}$	=	sum of the cross-sectional areas of the minimum transverse reinforcement, required for ductile bond behaviour, which may be taken as 0.25A_s for members with K>0, and zero when K=0 –see the definition of λ	(mm^2)

TECHNICAL DEFINITIONS

Clear distance – width of clear gap between adjacent parallel reinforcing bars (s_b or s_c), or width of gap between adjacent parallel reinforcing bars developing stress (a).

Clear spacing – width of clear gap between adjacent equi-spaced parallel reinforcing bars (s_L).

Contact (lapped) splice – the two stressed parallel reinforcing bars forming the lapped splice are directly in contact with each other at points along the lapped splice.

Cover – minimum straight distance between the outside of the reinforcing bar or bars developing stress, and the relevant permanent surface of the concrete member or element, excluding any applied surface finish.

Development length – length of end anchorage of a bar separated from other parallel bars developing stress.

Exposure Classification, EC – designation indicative of the most severe environment to which a concrete member is to be subjected during its design life, in accordance with Table 4.3 of AS 3600–2009.

Fitment – a form of transverse reinforcement or a reinforcing component used to: laterally support steel reinforcement during construction; laterally restrain longitudinal compressive reinforcement in beams, columns, etc.; laterally confine a concrete column core, etc. Note: also referred to commonly as a stirrup, ligature, tie or helical reinforcement, etc.

Headed reinforcement – steel reinforcing bar that achieves anchorage by means of a suitably sized and designed head or end plate.

Lap length – length of a lapped splice.

Lapped splice – two stressed, parallel reinforcing bars overlapped to create a continuous piece of reinforcement: also see *contact lapped splice,* or *non-contact lapped splice*.

Lightweight concrete – concrete having a saturated surface-dry density in the range of 1800 kg/m^3 to 2100 kg/m^3.

Mechanical splice – two reinforcing bars mechanically connected together at their adjacent ends to create a continuous piece of reinforcement.

Narrow element or member – concrete element or member for which side cover effects cannot be ignored when designing the anchorage or lap splicing of the reinforcing bars, i.e. a significant number of the bars being anchored or lapped could be affected by the side cover, c_1 – see Fig. A.2(a).

Non-contact (lapped) splice – a physical (clear) gap exists in the concrete between the two stressed reinforcing bars forming the lapped splice.

Normal-density concrete – concrete having a saturated surface-dry density in the range of 2100 kg/m^3 to 2800 kg/m^3.

Strength grade – numerical value of the characteristic compressive strength of concrete at 28 days (f'_c), used in design.

Welded splice – two stressed, parallel reinforcing bars welded together at their adjacent ends or end regions to create a continuous piece of reinforcement.

Wide element or member – concrete element or member for which side cover effects can be ignored when designing the anchorage or lap splicing of the reinforcing bars, i.e. for all or most of the bars being anchored or lapped, the effect of cover c only has to be considered – see Fig. A.2(b).

APPENDIX B – DESIGN TABLES TO AS 3600–2009

Three sets of design tables of tensile development lengths (*basic* $L_{sy.tb}$ and minimum *refined* $L_{sy.t.min}$) and tensile lap lengths (*basic* $L_{sy.tb.lap}$ and minimum *refined* $L_{sy.t.lap.min}$) have been derived (with values given in millimetres rounded to the nearest 10 mm, and in some cases also in multiples of nominal bar diameter, d_b, as a useful measure).

Each set of design tables (viz. *General*, *Cover-Controlled* or *Spacing-Controlled*) is described below. **For all three sets, the following assumptions & conditions of use apply.**

- Minimum refined development and lap lengths ($L_{sy.t.min}$ and $L_{sy.t.lap.min}$, respectively) have been calculated **assuming product $k_3k_4k_5$=0.7**, i.e. the maximum benefit that could possibly be provided by confinement from transverse reinforcement and/or transverse pressure is assumed to be feasible, in accordance with the inequality of Eq. 2. Because in general 0.7≤k_3≤1.0, it follows that with $k_3k_4k_5$=0.7, in general 0.7≤k_4k_5≤1.0, where the product k_4k_5 is referred to herein as the *refined factors product*. For example, for the extreme case of k_3=0.7, then it follows that the refined factors product k_4k_5=1.0, in which case the corresponding basic and refined development lengths, or lap lengths, equal each other, and therefore, no design benefit arises due to confinement from transverse reinforcement and/or pressure. At the other extreme, when k_3=1.0, then it is assumed that the minimum possible value of k_4k_5, i.e. $(k_4k_5)_{min}$, equals 0.7, **but the feasibility of this value of the refined factors product has to be confirmed by separate calculations before it can be adopted in design**.
- More generally, in any case when the minimum refined factors product $(k_4k_5)_{min}$<1.0, **the designer must confirm that the benefit assumed is valid for the particular design case**. Therefore, it is left up to the designer to confirm that there is sufficient transverse reinforcement (accounted for by refined factor k_4) and/or transverse pressure (accounted for by refined factor k_5) to justify using a refined development or lap length ($L_{sy.t}$ or $L_{sy.t.lap}$) that is less than the corresponding basic development or lap length ($L_{sy.tb}$ or $L_{sy.tb.lap}$). Advice regarding this is given below, specific to each set of tables, and the design process is illustrated in Appendix C, *Worked Examples using Design Tables to AS 3600–2009*.
- **The detrimental effects on bond of bar epoxy coating and/or lightweight concrete need to be allowed for separately according to Eq. 1c.** Factors ξ_{bc} and ξ_{cd} have both been assumed to equal 1.0, with twin basic factors product $\xi_{cd}\xi_{bc}$ =1.0. However, bars in slip-form construction can be designed using tables with k_1=1.3, if this penalty is deemed appropriate, i.e. see Tables B.1, B.3 and B.5.
- For beam webs and columns, and other types of "narrow" elements or members, the clear concrete cover, c, should be taken as the minimum distance from the representative bar to any adjacent concrete surface, as shown in Fig. A.2a.
- As stated in the Introduction, **clear concrete cover, *c*, should not be less than bar diameter, d_b**, which also meets the intent of Clause 4.10.2 of AS 3600–2009.
- Lapped splices may be either *contact* or *non-contact*, in either narrow or wide elements or members. This is because, in practice the clear distance between adjacent pairs of bars being spliced, s_b, in narrow elements and members (like columns and rectangular beams) is normally zero (i.e. contact lapped splices) or relatively small (e.g. less than 3d_b, like seen in Fig. 1), and therefore, normally, neither lap length $L_{sy.tb.lap}$ nor $L_{sy.t.lap}$ is controlled (i.e. increased) by the value of $L_{sy.tb}$ +1.5s_b or $L_{sy.t}$ +1.5s_b, respectively. Therefore, all of the design tables may normally be used without being concerned about whether the lapped splices are contact or non-contact.
- **The maximum centre-to-centre spacing between adjacent parallel bars being lap spliced should not exceed 300 mm outside the region of laps.** This general requirement of AS 3600-2009 in effect limits the maximum clear distance between non-contact lapped splices to less than 150 mm, which is considered to be good practice – see Section 3, *Proposed Improvements to AS 3600–2009*, *Upper limit to s_b in non-contact lapped splices*, which has an additional maximum spacing requirement.

General Tables – when c_d is calculated directly by the designer – see INDEX on p.16

Designation: **G** / {f'_c} / {k_1} / {k_7}

The design variables and their ranges that define each General Table are given in Table B.1.

TABLE B.1 – *Design variables for General Tables*

Design Variable	Description	Range
f'_c	Concrete strength grade	f'_c = 20, 25, 32, 40, 50 or ≥65 MPa
k_1	Factor in Eqs 1 and 3 to account for either 'poor' (i.e. k_1=1.3) or 'good' (i.e. k_1=1.0) bond conditions	k_1 = 1.3 for horizontal anchored or lapped bars with more than 300 mm concrete cast below; = 1.3 for all bars in structural elements built with slip-forms (unless it can be shown that 'good' bond conditions exist); or = 1.0 otherwise.
k_7	Factor in Eq. 3 that accounts for effects of staggered laps, and bar stress levels at ultimate load	k_7 = 1.00 if the cross-sectional area of the bars outside the laps equals at least twice the area required for strength, *and* no more than half the bars are lapped at any section; or = 1.25 otherwise.

Each General Table comprises a set of direct solutions of the equations for $L_{sy.tb}$ (Eq. 1c), $L_{sy.t.min}$ (Eq. 2 with k_4k_5=$(k_4k_5)_{min}$), $L_{sy.tb.lap}$ (Eq. 3a) and $L_{sy.t.lap.min}$ (Eq. 3b with k_4k_5=$(k_4k_5)_{min}$), for c_d=20 to 100 mm in increments of 5 mm and for every standard D500N bar size (N10 to N40), **with the following additional assumptions, conditions of use and observations applying**.

- The General Tables are listed according to standard concrete strength grade, f'_c, in the first instance, followed by the values of the factors k_1 and k_7, i.e. feasible combinations of k_1 and k_7, designated by (k_1/k_7) equal (1.0/1.00), (1.3/1.00), (1.0/1.25) and (1.3/1.25).
- In order to select a General Table, the designer first needs to know f'_c, and the values of factors k_1 and k_7, which are both dictated by construction details. Next nominal bar diameter, d_b, has to be known, and c_d has to be determined, which is dictated by the

reinforcement detailing, i.e. c_d equals the least clear concrete cover to the bars (c or c_1 in narrow elements or members, or only c in wide elements or members), or half the clear distance between adjacent parallel bars developing stress, a, whichever is the lesser value. Now knowing c_d, k_3 follows directly, and therefore so does the value of the minimum refined factors product, $(k_4k_5)_{min}$. It follows that for every combination of c_d and d_b in every General Table, there is a unique value of minimum refined factors product, $(k_4k_5)_{min}$, as given in Table B.2. Repeating, when $(k_4k_5)_{min}$=1.0, the basic and refined development lengths are equal to each other, as is also the case for the basic and refined lap lengths, which will be apparent from the General Tables, according to the pattern in Table B.2, noting that values are shown in grey when $(k_4k_5)_{min}$<1.0, while similarly in the General Tables, solutions are also shown in grey when $(k_4k_5)_{min}$<1.0. When minimum refined factors product $(k_4k_5)_{min}$ equals unity in Table B.2, it is shown in blue, and correspondingly, refined development or lap lengths in the General Tables for which $(k_4k_5)_{min}$=1.0 are also printed in blue.

- The minimum refined lap length, $L_{sy.t.lap.min}$, can equal the basic lap length, $L_{sy.tb.lap}$, when $(k_4k_5)_{min}$<1.0, if the identical lower bounds in Eqs 3a and 3b govern in both cases.

- No solutions are provided in the General Tables for values of dimension c_d less than d_b, in which case a dash "-" is shown. This is explained as follows.

  Firstly, as defined it can be written that:

  c_d = min. (c_{min}, a/2) (B1)

  = min. (max. (c_{req}, $d_{b.5mm}$), a/2) (B2)

  and it follows from Eq. B2 that:

  - when $c_{min} \le a/2$, i.e. cover controls the value of c_d:

    c_d = max. (c_{req}, $d_{b.5mm}$) (B3)

    and therefore in no such case is it possible for c_d to be less than d_b; while

  - when $c_{min} > a/2$, i.e. clear distance between bars controls the value of c_d:

    c_d = a/2 (B4)

    while the smallest values of a occur when all bars are anchored or lapped together, in which case a=s_c. Although not stipulated in AS 3600–2009, in practice the minimum clear distance between adjacent parallel bars, s_c, should be limited to max. (2.0d_b, 1.5d_{agg}, 40 mm), where d_{agg} is the maximum diameter of the coarse aggregate, normally 20 mm. It follows from Eq. B4, putting a=s_c, that:

    c_d ≥ max. (2.0d_b, 30 mm, 40 mm) / 2 (B5)

    in which case:

    c_d ≥ max. (d_b, 20 mm) (B6)

    again showing that providing solutions for c_d<d_b would be impractical. (It can also be noted that k_3=1.0, the maximum possible value, when c_d=d_b, e.g. see Table B.2, where correspondingly the value of the minimum refined factors product $(k_4k_5)_{min}$ can be as low as 0.7.)

- For cases when k_3=0.7 (and therefore $(k_4k_5)_{min}$=1.0), the minimum possible value of k_3, which for a particular bar size or diameter, d_b, is more likely to occur for increasingly larger values of c_d, then identical values of basic or refined development length, and basic or refined lap length, are computed. This is shown in each column of the General Tables by a quotation mark ("), which means that the value at the top of all the quotation marks in the particular column applies.

TABLE B.2 – *Unique, minimum values of refined factors product, k_4k_5, which apply to the solutions in every General Table with one-to-one correspondence*

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED FACTORS PRODUCT $(k_4k_5)_{min}$								
20	0.82	0.78	0.73	0.70	0.70	0.70	0.70	0.70	0.70
25	0.90	0.84	0.76	0.73	0.70	0.70	0.70	0.70	0.70
30	1.00	0.90	0.81	0.76	0.73	0.71	0.70	0.70	0.70
35	1.00	0.98	0.85	0.79	0.75	0.73	0.71	0.70	0.70
40	1.00	1.00	0.90	0.82	0.78	0.75	0.73	0.71	0.70
45	1.00	1.00	0.96	0.86	0.81	0.77	0.75	0.73	0.71
50	1.00	1.00	1.00	0.90	0.84	0.79	0.76	0.74	0.73
55	1.00	1.00	1.00	0.95	0.87	0.82	0.78	0.76	0.74
60	1.00	1.00	1.00	1.00	0.90	0.84	0.81	0.78	0.76
65	1.00	1.00	1.00	1.00	0.94	0.87	0.83	0.80	0.77
70	1.00	1.00	1.00	1.00	0.98	0.90	0.85	0.82	0.79
75	1.00	1.00	1.00	1.00	1.00	0.94	0.88	0.84	0.81
80	1.00	1.00	1.00	1.00	1.00	0.97	0.90	0.86	0.82
85	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.88	0.84
90	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.90	0.86
95	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.93	0.88
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.90

Cover-Controlled Tables – when clear concrete cover, c, equals c_{min} and controls the value of c_d (i.e. c_d=c_{min}) with clear distance, $a \ge 2c_{min}$ – see INDEX on p.41

Designation: **CC** / {*EC*} / {k_1} / {k_7}

The design variables and their ranges that define each Cover-Controlled Table are given in Table B.3.

Each Cover-Controlled Table comprises sets of direct solutions of the equations for $L_{sy.tb}$ (Eq. 1c), $L_{sy.t.min}$ (Eq. 2 with k_4k_5=$(k_4k_5)_{min}$), $L_{sy.tb.lap}$ (Eq. 3a) and $L_{sy.t.lap.min}$ (Eq. 3b with k_4k_5=$(k_4k_5)_{min}$), for which the value of c_d is controlled by the concrete cover, c, to the bars being anchored or lapped. **In every case, the concrete cover, *c*, is assumed to equal the minimum allowable value of clear concrete cover, c_{min}**, which equals the maximum of required concrete cover, c_{req}, for Exposure Classification A1, A2 or B1, and $d_{b.5mm}$, the nominal diameter of the bars being anchored or lapped, rounded up to the nearest 5 mm.

It follows that **for all of the solutions in the Cover-Controlled Tables, they can only be applied if clear distance, *a*, is greater than or equal to 2c_{min}, i.e. $a \ge 2c_{min}$**, which can alternatively be written as a≥2×max. (c_{req}, $d_{b.5mm}$). Consequently, **these tables are most likely to be used when designing bars in wide members and elements**, in which bar spacings are more likely to create this condition.

TABLE B.3 – *Design variables for Cover-Controlled Tables*

Design Variable	Description	Range
EC	Exposure Classification for durability	*EC* = A1, A2 or B1, with concrete assumed to be cast in standard formwork complying with AS 3610 [22], and compacted in accordance with Clause 17.1.3 of AS 3600–2009, whereby the minimum allowable clear concrete cover, c_{min} = max. (c_{req}, $d_{b.5mm}$) and thus satisfies Table 4.10.3.2 and Clause 4.10.2 of AS 3600–2009, and depends on the Exposure Classification and value of f'_c – see Table B.4 below for values of c_{req}.
k_1	Factor in Eqs 1 and 3 to account for either 'poor' (i.e. k_1=1.3) or 'good' (i.e. k_1=1.0) bond conditions	k_1 = 1.3 for horizontal anchored or lapped bars with more than 300 mm concrete below; = 1.3 for all bars in structural elements built with slip-forms (unless it can be shown that 'good' bond conditions exist); or = 1.0 otherwise.
k_7	Factor in Eq. 3 that accounts for effects of staggered laps, and bar stress levels at ultimate load	k_7 = 1.00 if the cross-sectional area of the bars outside the laps equals at least twice the area required for strength, and no more than half the bars are lapped at any section; or = 1.25 otherwise.

TABLE B.4 – *Required concrete cover, c_{req}, where standard compaction and formwork are used, in accordance with Table 4.10.3.2 of AS 3600–2009*

Exposure Classification, *EC*	Required cover, c_{req} (mm)				
	Characteristic compressive strength, f'_c (MPa)				
	20	25	32	40	≥50
A1	20	20	20	20	20
A2	50	30	25	20	20
B1	-	60	40	30	25

As defined in Table 4.3 of AS 3600–2009, the Exposure Classifications, *EC*, chosen for the tables, i.e. A1, A2 and B1, include the most common conditions for surfaces of concrete members and elements exposed to interior and exterior environments.

Solutions are given in two parts (a) and (b) in each Cover-Controlled Table, which are grouped according to the Exposure Classification *EC*, and the values of k_1 and k_7, as given in Table B.3. The part (a) tables show all of the solution sets for each combination of f'_c and c_{req} applicable to a particular Exposure Classification, *EC* (as defined in Table B.4), with each solution set covering every standard D500N bar size (N10 to N40). The part (b) tables show more general condensed solution sets, which are the longest development and lap lengths for all of the combinations of f'_c and c_{req} applicable.

The following additional assumptions, conditions of use and observations apply to the Cover-Controlled Tables.

- The part (a) and (b) Cover-Controlled Tables are listed according to Exposure Classification, *EC* (A1, A2 and B1) in the first instance, followed by the values of the factors k_1 and k_7, i.e. feasible combinations of k_1 and k_7, designated by (k_1/k_7) equal (1.0/1.00), (1.3/1.00), (1.0/1.25) and (1.3/1.25).
- In order to select the appropriate Cover-Controlled Table, the designer first needs to know the Exposure Classification, *EC*, concrete strength grade f'_c (although not always), and the values of factors k_1 and k_7, which are dictated by construction details. Next bar diameter, d_b, has to be known.
- **For cases when bar diameter, d_b, exceeds required concrete cover, c_{req}, design solutions have been determined assuming $d_{b.5mm}$= 25, 30, 35, 40 or 40 mm for d_b= 24, 28, 32, 36 or 40 mm, respectively.**
- When checking the feasibility of solutions from the Cover-Controlled Tables, **the centre-to-centre spacing of adjacent parallel, equi-sized bars being anchored or spliced, measured outside the anchorage or lap region, s_{cc}, should (as examples) satisfy the following appropriate inequality:**
  - Development lengths – all bars terminated together, i.e. no staggering:

    $s_{cc} \geq 2c_{min} + d_b$ (B7)
  - Development lengths – every second bar terminated together, i.e. 50% staggering:

    $s_{cc} \geq c_{min} + d_b/2$ (B8)
  - Lap lengths – all bars lapped together in contact, i.e. no staggering:

    $s_{cc} \geq 2(c_{min} + d_b)$ (B9)
  - Lap lengths – every second bar lapped together in contact, i.e. 50% staggering:

    $s_{cc} \geq c_{min} + d_b$ (B10)

  Note: In accordance with AS 3600–2009, in many design situations the maximum allowable centre-to-centre spacing of adjacent parallel bars equals 300 mm, i.e. it is also normally a requirement that s_{cc}≤300 mm.

Spacing-Controlled Tables – when clear concrete cover, *c*, equals c_{min} and clear distance, *a*, controls the value of c_d with clear distance, $a \le 2c_{min}$ – **see INDEX on p.66**

Designation: **SC** / {*EC*} / {k_1} / {k_7}

The design variables and their ranges that define each Spacing-Controlled Table are given in Table B.5.

TABLE B.5 – *Design variables for Spacing-Controlled Tables*

Design Variable	Description	Range
EC	Exposure Classification for durability	*EC* = A1, A2 or B1 (i.e. any applies). The concrete is assumed to be cast in standard formwork complying with AS 3610 [14], and compacted in accordance with Clause 17.1.3 of AS 3600–2009. The minimum allowable clear concrete cover, c_{min} equals max. (c_{req}, $d_{b.5mm}$) to satisfy Table 4.10.3.2 and Clause 4.10.2 of AS 3600–2009. The value of c_{req} depends on Exposure Classification *EC* and concrete compressive strength f'_c according to Table B.4.
k_1	Factor in Eqs 1 and 3 to account for either 'poor' (i.e. k_1=1.3) or 'good' (i.e. k_1=1.0) bond conditions	k_1 = 1.3 for horizontal anchored or lapped bars with more than 300 mm concrete below; = 1.3 for all bars in structural elements built with slip-forms (unless it can be shown that 'good' bond conditions exist); or = 1.0 otherwise.
k_7	Factor in Eq. 3 that accounts for effects of staggered laps, and bar stress levels at ultimate load	k_7 = 1.25, as staggered laps are not catered for (see below).
-	Staggered bars, being terminated or lapped	The Spacing-Controlled Tables should NOT be used if the terminated or lapped bars are staggered.

Each Spacing-Controlled Table comprises solutions of the equations for $L_{sy.tb}$ (Eq. 1c), $L_{sy.t.min}$ (Eq. 2 with $k_4k_5=(k_4k_5)_{min}$), $L_{sy.tb.lap}$ (Eq. 3a) and $L_{sy.t.lap.min}$ (Eq. 3b with $k_4k_5=(k_4k_5)_{min}$), for which the value of c_d is controlled by the clear distance, *a*, between the bars being anchored or lapped. **In every case, the clear concrete cover, *c*, is assumed to equal the minimum allowable value of clear concrete cover, c_{min}**, which equals the maximum of required concrete cover, c_{req}, for Exposure Classification A1, A2 and B1 according to Table B.4, and $d_{b.5mm}$, the nominal diameter of the bars being anchored or lapped, rounded up to the nearest 5 mm.

It follows that **solutions in the Spacing-Controlled Tables should only be used if clear distance, *a*, is less than $2c_{min}$, i.e. $a<2c_{min}$**, which can alternatively be written as $a<2\times$max. (c_{req}, $d_{b.5mm}$). Consequently, **these tables are more likely to be used when designing bar end anchorages or laps in narrow concrete members and elements, like beam webs or columns**.

As explained above in the derivation of the General Tables, it is good design practice to define a minimum value for the clear distance between adjacent parallel bars, s_c, e.g. see Figs A.4 and A.5. **For the Spacing-Controlled Tables, it is assumed that $s_c \ge$ max. (2.0d_b, 40 mm)**, the consequence of which is explained as follows. **In the derivation, contact lapped splices are assumed, although non-contact splices may also be used and treated equivalently.**

Firstly, it can be written generally for the Spacing-Controlled Tables that:

$$c_d = a/2 \le c_{min} \quad \text{(B11)}$$

$$c_{min} = \text{max. } (d_{b.5mm}, c_{req}) \quad \text{(B12)}$$

$$s_c \ge \text{max. } (2.0d_b, 40 \text{ mm}) \quad \text{(B13)}$$

- Development or lap lengths – all bars terminated or lapped together, i.e. no staggering:

  If the bars are either all terminated together, or all lapped at one location together, then:

$$s_c = a \quad \text{(B14)}$$

so it follows from Eqs B13 and B14 that:

$$a \ge \text{max. } (2.0d_b, 40 \text{ mm}) \quad \text{(B15)}$$

and then from Eqs B11 and B15 that:

$$c_d \ge \text{max. } (d_b, 20 \text{ mm}) \quad \text{(B16)}$$

whereby, from Eqs B11, B12 and B16:

$$\text{max. } (d_b, 20 \text{ mm}) \le c_d \le \text{max. } (d_{b.5mm}, c_{req}) \quad \text{(B17)}$$

Because $d_b \le d_{b.5mm}$, and referring to Table B.4 it is clear that 20 mm $\le c_{req}$ for any of the Exposure Classifications shown, i.e. A1, A2 and B1, it follows that the lower bound of the inequality given in Eq. B17 defines feasible solutions for the Spacing-Controlled Tables. Therefore, from Eq. B17 it can be deduced that the least feasible value of c_d for the Spacing-Controlled Tables equals:

$$\text{min. } c_d = \text{max. } (d_b, 20 \text{ mm}) \quad \text{(B18)}$$

However, as for the Cover-Controlled Tables, for convenience $d_{b.5mm}$ will be used instead of d_b, resulting in:

$$\text{min. } c_d = \text{max. } (d_{b.5mm}, 20 \text{ mm}) \quad \text{(B19)}$$

It follows from Eq. B19 that for the situations under consideration, i.e. when all bars are either terminated or lapped together, that the **solutions in the Spacing-Controlled Tables are independent of c_{req}, and therefore the Exposure Classification, *EC***.

- Development or lap lengths – every second bar terminated or lapped together, i.e. 50% staggering:

If every second bar is either terminated together or lapped at one location together, then as can be seen from Figs A.4 and A.5(ii):

$$s_c = (a - d_b)/2 \quad \text{(B20)}$$

Transposing Eq. B20:

$$a = 2\, s_c + d_b \quad \text{(B21)}$$

It follows from Eqs B13 and B21 that for feasible solutions:

$$a \geq \max.\ (5d_b,\ 80\text{ mm} + d_b) \quad \text{(B22)}$$

But from Eq. B11, c_d=a/2, so Eq. B22 gives a lower limit:

$$c_d \geq \max.\ (2.5d_b,\ 40\text{ mm} + d_b/2) \quad \text{(B23)}$$

and from Eq. B11 an upper limit to c_d is:

$$c_d \leq \max.\ (d_{b.5mm}, c_{req}) \quad \text{(B24)}$$

while the lower and upper limits normally applying are:

$$d_b \leq c_d \leq 3d_b \quad \text{(B25)}$$

From Eqs B23, B24 and B25 it can be written that:

$$\max.\ [d_b,\ \max.\ (2.5d_b,\ 40\text{ mm} + d_b/2)] \leq c_d \leq \min.\ [3d_b,\ \max.(d_{b.5mm}, c_{req})] \quad \text{(B26)}$$

Solving Eq. B26 over the full range of nominal bar diameters (d_b=10 to 40 mm) and concrete covers (c_{req} for Exposure Classifications A1, A2 and B1) shows that practically all of the solutions are infeasible, i.e. in most cases the lower bound of the inequality exceeds the upper bound. For example, for *EC*=A1 and f'_c =32 MPa, from Table B.4 c_{req}=20 mm, so for d_b = 10 mm, the lower bound of Eq. B26 = max. [d_b, max. (2.5d_b, 40 mm + d_b/2)] = max. [10 mm, max. (25 mm, 40 mm + 5 mm)] = max. [10 mm, 45 mm)] = 45 mm, while the upper bound of Eq. B26 = min. [3d_b, max.($d_{b.5mm}$,c_{req})] = min. [30 mm, max.(10 mm, 20 mm)] = 20 mm, so there is no solution for c_d in this case. In most of the very few cases when solutions to Eq. B26 exist for *EC*=A1, A2 and B1, it can be shown that c_d = c_{min}, which is the condition for which all of the Cover-Controlled Tables have been generated.

It follows that when bars are staggered, the development and lap lengths may be determined from the Cover-Controlled Tables, ignoring the normal requirement to use these tables that $a \geq 2c_{min}$, but of course checking that Eq. B.13 is satisfied. As a result, **no Spacing-Controlled Tables are given for k_7=1.0, as this value can only arise if laps are staggered**.

INDEX: GENERAL TABLES – TENSILE DEVELOPMENT LENGHTHS ($L_{sy.tb}$, $L_{sy.t.min}$) AND LAP LENGTHS ($L_{sy.tb.lap}$, $L_{sy.t.lap.min}$)

Note: To produce the General Tables, it was assumed when using Eq. 1c, that basic factor ξ_{cd}=1.0 (i.e. normal-density concrete) and basic factor ξ_{bc}=1.0 (i.e. uncoated or bare steel bars).

STRESS DEVELOPMENT AND LAP SPLICING OF STRAIGHT D500N TENSILE REINFORCING BARS TO AS 3600–2009

TABLE G/20/1.0/1.00 – Tensile Development and Lap Lengths

f'_c=20 MPa, k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	390	500	740	1000	-	-	-	-	-
25	360	470	710	960	1230	-	-	-	-
30	320	430	670	920	1200	1490	-	-	-
35	"	400	630	890	1160	1450	1760	-	-
40	"	390	600	850	1120	1410	1720	2060	2430
45	"	"	560	810	1080	1370	1680	2020	2380
50	"	"	540	770	1040	1330	1640	1970	2340
55	"	"	"	740	1000	1290	1600	1930	2290
60	"	"	"	700	960	1250	1550	1890	2250
65	"	"	"	"	920	1210	1510	1840	2200
70	"	"	"	"	890	1170	1470	1800	2160
75	"	"	"	"	870	1130	1430	1760	2110
80	"	"	"	"	"	1090	1390	1710	2070
85	"	"	"	"	"	1050	1340	1670	2020
90	"	"	"	"	"	"	1300	1620	1970
95	"	"	"	"	"	"	1260	1580	1930
100	"	"	"	"	"	"	1250	1540	1880

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	320	390	540	700	-	-	-	-	-
25	320	390	540	700	870	-	-	-	-
30	320	390	540	700	870	1050	-	-	-
35	"	390	540	700	870	1050	1250	-	-
40	"	390	540	700	870	1050	1250	1470	1700
45	"	"	540	700	870	1050	1250	1470	1700
50	"	"	540	700	870	1050	1250	1470	1700
55	"	"	"	700	870	1050	1250	1470	1700
60	"	"	"	700	870	1050	1250	1470	1700
65	"	"	"	"	870	1050	1250	1470	1700
70	"	"	"	"	870	1050	1250	1470	1700
75	"	"	"	"	870	1050	1250	1470	1700
80	"	"	"	"	"	1050	1250	1470	1700
85	"	"	"	"	"	1050	1250	1470	1700
90	"	"	"	"	"	"	1250	1470	1700
95	"	"	"	"	"	"	1250	1470	1700
100	"	"	"	"	"	"	1250	1470	1700

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	390	500	740	1000	-	-	-	-	-
25	360	470	710	960	1230	-	-	-	-
30	320	430	670	920	1200	1490	-	-	-
35	"	400	630	890	1160	1450	1760	-	-
40	"	390	600	850	1120	1410	1720	2060	2430
45	"	"	560	810	1080	1370	1680	2020	2380
50	"	"	540	770	1040	1330	1640	1970	2340
55	"	"	"	740	1000	1290	1600	1930	2290
60	"	"	"	700	960	1250	1550	1890	2250
65	"	"	"	"	920	1210	1510	1840	2200
70	"	"	"	"	890	1170	1470	1800	2160
75	"	"	"	"	870	1130	1430	1760	2110
80	"	"	"	"	"	1090	1390	1710	2070
85	"	"	"	"	"	1050	1340	1670	2020
90	"	"	"	"	"	"	1300	1620	1970
95	"	"	"	"	"	"	1260	1580	1930
100	"	"	"	"	"	"	1250	1540	1880

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	320	390	540	700	-	-	-	-	-
25	320	390	540	700	870	-	-	-	-
30	320	390	540	700	870	1050	-	-	-
35	"	390	540	700	870	1050	1250	-	-
40	"	390	540	700	870	1050	1250	1470	1700
45	"	"	540	700	870	1050	1250	1470	1700
50	"	"	540	700	870	1050	1250	1470	1700
55	"	"	"	700	870	1050	1250	1470	1700
60	"	"	"	700	870	1050	1250	1470	1700
65	"	"	"	"	870	1050	1250	1470	1700
70	"	"	"	"	870	1050	1250	1470	1700
75	"	"	"	"	870	1050	1250	1470	1700
80	"	"	"	"	"	1050	1250	1470	1700
85	"	"	"	"	"	1050	1250	1470	1700
90	"	"	"	"	"	"	1250	1470	1700
95	"	"	"	"	"	"	1250	1470	1700
100	"	"	"	"	"	"	1250	1470	1700

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/25/1.0/1.00 – Tensile Development and Lap Lengths

f'_c=25 MPa, k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	350	450	660	890	-	-	-	-	-
25	320	420	630	860	1100	-	-	-	-
30	290	390	600	830	1070	1330	-	-	-
35	"	360	570	790	1030	1300	1580	-	-
40	"	350	530	760	1000	1260	1540	1840	2170
45	"	"	500	730	970	1220	1500	1800	2130
50	"	"	480	690	930	1190	1470	1770	2090
55	"	"	"	660	900	1150	1430	1730	2050
60	"	"	"	630	860	1120	1390	1690	2010
65	"	"	"	"	830	1080	1350	1650	1970
70	"	"	"	"	790	1040	1320	1610	1930
75	"	"	"	"	780	1010	1280	1570	1890
80	"	"	"	"	"	970	1240	1530	1850
85	"	"	"	"	"	940	1200	1490	1810
90	"	"	"	"	"	"	1170	1450	1770
95	"	"	"	"	"	"	1130	1410	1730
100	"	"	"	"	"	"	1120	1380	1680

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	290	350	480	630	-	-	-	-	-
25	290	350	480	630	780	-	-	-	-
30	290	350	480	630	780	940	-	-	-
35	"	350	480	630	780	940	1120	-	-
40	"	350	480	630	780	940	1120	1310	1520
45	"	"	480	630	780	940	1120	1310	1520
50	"	"	480	630	780	940	1120	1310	1520
55	"	"	"	630	780	940	1120	1310	1520
60	"	"	"	630	780	940	1120	1310	1520
65	"	"	"	"	780	940	1120	1310	1520
70	"	"	"	"	780	940	1120	1310	1520
75	"	"	"	"	780	940	1120	1310	1520
80	"	"	"	"	"	940	1120	1310	1520
85	"	"	"	"	"	940	1120	1310	1520
90	"	"	"	"	"	"	1120	1310	1520
95	"	"	"	"	"	"	1120	1310	1520
100	"	"	"	"	"	"	1120	1310	1520

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	350	450	660	890	-	-	-	-	-
25	320	420	630	860	1100	-	-	-	-
30	290	390	600	830	1070	1330	-	-	-
35	"	360	570	790	1030	1300	1580	-	-
40	"	350	530	760	1000	1260	1540	1840	2170
45	"	"	500	730	970	1220	1500	1800	2130
50	"	"	480	690	930	1190	1470	1770	2090
55	"	"	"	660	900	1150	1430	1730	2050
60	"	"	"	630	860	1120	1390	1690	2010
65	"	"	"	"	830	1080	1350	1650	1970
70	"	"	"	"	790	1040	1320	1610	1930
75	"	"	"	"	780	1010	1280	1570	1890
80	"	"	"	"	"	970	1240	1530	1850
85	"	"	"	"	"	940	1200	1490	1810
90	"	"	"	"	"	"	1170	1450	1770
95	"	"	"	"	"	"	1130	1410	1730
100	"	"	"	"	"	"	1120	1380	1680

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	290	350	480	630	-	-	-	-	-
25	290	350	480	630	780	-	-	-	-
30	290	350	480	630	780	940	-	-	-
35	"	350	480	630	780	940	1120	-	-
40	"	350	480	630	780	940	1120	1310	1520
45	"	"	480	630	780	940	1120	1310	1520
50	"	"	480	630	780	940	1120	1310	1520
55	"	"	"	630	780	940	1120	1310	1520
60	"	"	"	630	780	940	1120	1310	1520
65	"	"	"	"	780	940	1120	1310	1520
70	"	"	"	"	780	940	1120	1310	1520
75	"	"	"	"	780	940	1120	1310	1520
80	"	"	"	"	"	940	1120	1310	1520
85	"	"	"	"	"	940	1120	1310	1520
90	"	"	"	"	"	"	1120	1310	1520
95	"	"	"	"	"	"	1120	1310	1520
100	"	"	"	"	"	"	1120	1310	1520

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/32/1.0/1.00 – Tensile Development and Lap Lengths

f'_c=32 MPa, k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	310	400	590	790	-	-	-	-	-
25	290	370	560	760	980	-	-	-	-
30	290	350	530	730	950	1180	-	-	-
35	"	350	500	700	910	1150	1390	-	-
40	"	350	470	670	880	1110	1360	1630	1920
45	"	"	460	640	850	1080	1330	1600	1890
50	"	"	460	610	820	1050	1290	1560	1850
55	"	"	"	580	790	1020	1260	1530	1810
60	"	"	"	580	760	990	1230	1490	1780
65	"	"	"	"	730	950	1200	1460	1740
70	"	"	"	"	700	920	1160	1420	1710
75	"	"	"	"	700	890	1130	1390	1670
80	"	"	"	"	"	860	1100	1350	1630
85	"	"	"	"	"	830	1060	1320	1600
90	"	"	"	"	"	"	1030	1280	1560
95	"	"	"	"	"	"	1000	1250	1530
100	"	"	"	"	"	"	990	1220	1490

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	260	310	430	550	-	-	-	-	-
25	260	310	430	550	690	-	-	-	-
30	290	320	430	550	690	830	-	-	-
35	"	340	430	550	690	830	990	-	-
40	"	350	430	550	690	830	990	1160	1350
45	"	"	440	550	690	830	990	1160	1350
50	"	"	460	550	690	830	990	1160	1350
55	"	"	"	550	690	830	990	1160	1350
60	"	"	"	580	690	830	990	1160	1350
65	"	"	"	"	690	830	990	1160	1350
70	"	"	"	"	690	830	990	1160	1350
75	"	"	"	"	700	830	990	1160	1350
80	"	"	"	"	"	830	990	1160	1350
85	"	"	"	"	"	830	990	1160	1350
90	"	"	"	"	"	"	990	1160	1350
95	"	"	"	"	"	"	990	1160	1350
100	"	"	"	"	"	"	990	1160	1350

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	310	400	590	790	-	-	-	-	-
25	290	370	560	760	980	-	-	-	-
30	290	350	530	730	950	1180	-	-	-
35	"	350	500	700	910	1150	1390	-	-
40	"	350	470	670	880	1110	1360	1630	1920
45	"	"	460	640	850	1080	1330	1600	1890
50	"	"	460	610	820	1050	1290	1560	1850
55	"	"	"	580	790	1020	1260	1530	1810
60	"	"	"	580	760	990	1230	1490	1780
65	"	"	"	"	730	950	1200	1460	1740
70	"	"	"	"	700	920	1160	1420	1710
75	"	"	"	"	700	890	1130	1390	1670
80	"	"	"	"	"	860	1100	1350	1630
85	"	"	"	"	"	830	1060	1320	1600
90	"	"	"	"	"	"	1030	1280	1560
95	"	"	"	"	"	"	1000	1250	1530
100	"	"	"	"	"	"	990	1220	1490

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	290	350	460	580	-	-	-	-	-
25	290	350	460	580	700	-	-	-	-
30	290	350	460	580	700	830	-	-	-
35	"	350	460	580	700	830	990	-	-
40	"	350	460	580	700	830	990	1160	1350
45	"	"	460	580	700	830	990	1160	1350
50	"	"	460	580	700	830	990	1160	1350
55	"	"	"	580	700	830	990	1160	1350
60	"	"	"	580	700	830	990	1160	1350
65	"	"	"	"	700	830	990	1160	1350
70	"	"	"	"	700	830	990	1160	1350
75	"	"	"	"	700	830	990	1160	1350
80	"	"	"	"	"	830	990	1160	1350
85	"	"	"	"	"	830	990	1160	1350
90	"	"	"	"	"	"	990	1160	1350
95	"	"	"	"	"	"	990	1160	1350
100	"	"	"	"	"	"	990	1160	1350

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/40/1.0/1.00 – Tensile Development and Lap Lengths

f'_c=40 MPa, k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	290	360	520	710	-	-	-	-	-
25	290	350	500	680	870	-	-	-	-
30	290	350	470	650	850	1050	-	-	-
35	"	350	460	630	820	1020	1250	-	-
40	"	350	460	600	790	1000	1220	1460	1720
45	"	"	460	580	760	970	1190	1430	1690
50	"	"	460	580	740	940	1160	1400	1650
55	"	"	"	580	710	910	1130	1360	1620
60	"	"	"	580	700	880	1100	1330	1590
65	"	"	"	"	700	850	1070	1300	1560
70	"	"	"	"	700	820	1040	1270	1530
75	"	"	"	"	700	810	1010	1240	1490
80	"	"	"	"	"	810	980	1210	1460
85	"	"	"	"	"	810	950	1180	1430
90	"	"	"	"	"	"	930	1150	1400
95	"	"	"	"	"	"	930	1120	1360
100	"	"	"	"	"	"	930	1090	1330

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	240	280	380	490	-	-	-	-	-
25	260	290	380	490	610	-	-	-	-
30	290	320	380	490	610	740	-	-	-
35	"	340	390	490	610	740	890	-	-
40	"	350	420	490	610	740	890	1040	1200
45	"	"	440	500	610	740	890	1040	1200
50	"	"	460	520	620	740	890	1040	1200
55	"	"	"	550	620	740	890	1040	1200
60	"	"	"	580	630	740	890	1040	1200
65	"	"	"	"	660	740	890	1040	1200
70	"	"	"	"	690	740	890	1040	1200
75	"	"	"	"	700	760	890	1040	1200
80	"	"	"	"	"	790	890	1040	1200
85	"	"	"	"	"	810	880	1040	1200
90	"	"	"	"	"	"	890	1040	1200
95	"	"	"	"	"	"	920	1040	1200
100	"	"	"	"	"	"	930	1040	1200

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	290	360	520	710	-	-	-	-	-
25	290	350	500	680	870	-	-	-	-
30	290	350	470	650	850	1050	-	-	-
35	"	350	460	630	820	1020	1250	-	-
40	"	350	460	600	790	1000	1220	1460	1720
45	"	"	460	580	760	970	1190	1430	1690
50	"	"	460	580	740	940	1160	1400	1650
55	"	"	"	580	710	910	1130	1360	1620
60	"	"	"	580	700	880	1100	1330	1590
65	"	"	"	"	700	850	1070	1300	1560
70	"	"	"	"	700	820	1040	1270	1530
75	"	"	"	"	700	810	1010	1240	1490
80	"	"	"	"	"	810	980	1210	1460
85	"	"	"	"	"	810	950	1180	1430
90	"	"	"	"	"	"	930	1150	1400
95	"	"	"	"	"	"	930	1120	1360
100	"	"	"	"	"	"	930	1090	1330

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	290	350	460	580	-	-	-	-	-
25	290	350	460	580	700	-	-	-	-
30	290	350	460	580	700	810	-	-	-
35	"	350	460	580	700	810	930	-	-
40	"	350	460	580	700	810	930	1040	1200
45	"	"	460	580	700	810	930	1040	1200
50	"	"	460	580	700	810	930	1040	1200
55	"	"	"	580	700	810	930	1040	1200
60	"	"	"	580	700	810	930	1040	1200
65	"	"	"	"	700	810	930	1040	1200
70	"	"	"	"	700	810	930	1040	1200
75	"	"	"	"	700	810	930	1040	1200
80	"	"	"	"	"	810	930	1040	1200
85	"	"	"	"	"	810	930	1040	1200
90	"	"	"	"	"	"	930	1040	1200
95	"	"	"	"	"	"	930	1040	1200
100	"	"	"	"	"	"	930	1040	1200

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/50/1.0/1.00 – Tensile Development and Lap Lengths

f'_c=50 MPa, k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	290	350	470	630	-	-	-	-	-
25	290	350	460	610	780	-	-	-	-
30	290	350	460	580	760	940	-	-	-
35	"	350	460	580	730	920	1120	-	-
40	"	350	460	580	710	890	1090	1300	1540
45	"	"	460	580	700	870	1060	1280	1510
50	"	"	460	580	700	840	1040	1250	1480
55	"	"	"	580	700	810	1010	1220	1450
60	"	"	"	580	700	810	980	1190	1420
65	"	"	"	"	700	810	960	1170	1390
70	"	"	"	"	700	810	930	1140	1360
75	"	"	"	"	700	810	930	1110	1340
80	"	"	"	"	"	810	930	1080	1310
85	"	"	"	"	"	810	930	1060	1280
90	"	"	"	"	"	"	930	1040	1250
95	"	"	"	"	"	"	930	1040	1220
100	"	"	"	"	"	"	930	1040	1190

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	240	270	340	440	-	-	-	-	-
25	260	290	350	440	550	-	-	-	-
30	290	320	370	440	550	670	-	-	-
35	"	340	390	460	550	670	790	-	-
40	"	350	420	480	550	670	790	930	1080
45	"	"	440	500	560	670	790	930	1080
50	"	"	460	520	590	670	790	930	1080
55	"	"	"	550	610	670	790	930	1080
60	"	"	"	580	630	680	790	930	1080
65	"	"	"	"	660	710	790	930	1080
70	"	"	"	"	690	730	790	930	1080
75	"	"	"	"	700	760	820	930	1080
80	"	"	"	"	"	790	840	930	1080
85	"	"	"	"	"	810	870	930	1080
90	"	"	"	"	"	"	890	940	1080
95	"	"	"	"	"	"	920	970	1080
100	"	"	"	"	"	"	930	990	1080

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	290	350	470	630	-	-	-	-	-
25	290	350	460	610	780	-	-	-	-
30	290	350	460	580	760	940	-	-	-
35	"	350	460	580	730	920	1120	-	-
40	"	350	460	580	710	890	1090	1300	1540
45	"	"	460	580	700	870	1060	1280	1510
50	"	"	460	580	700	840	1040	1250	1480
55	"	"	"	580	700	810	1010	1220	1450
60	"	"	"	580	700	810	980	1190	1420
65	"	"	"	"	700	810	960	1170	1390
70	"	"	"	"	700	810	930	1140	1360
75	"	"	"	"	700	810	930	1110	1340
80	"	"	"	"	"	810	930	1080	1310
85	"	"	"	"	"	810	930	1060	1280
90	"	"	"	"	"	"	930	1040	1250
95	"	"	"	"	"	"	930	1040	1220
100	"	"	"	"	"	"	930	1040	1190

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	290	350	460	580	-	-	-	-	-
25	290	350	460	580	700	-	-	-	-
30	290	350	460	580	700	810	-	-	-
35	"	350	460	580	700	810	930	-	-
40	"	350	460	580	700	810	930	1040	1160
45	"	"	460	580	700	810	930	1040	1160
50	"	"	460	580	700	810	930	1040	1160
55	"	"	"	580	700	810	930	1040	1160
60	"	"	"	580	700	810	930	1040	1160
65	"	"	"	"	700	810	930	1040	1160
70	"	"	"	"	700	810	930	1040	1160
75	"	"	"	"	700	810	930	1040	1160
80	"	"	"	"	"	810	930	1040	1160
85	"	"	"	"	"	810	930	1040	1160
90	"	"	"	"	"	"	930	1040	1160
95	"	"	"	"	"	"	930	1040	1160
100	"	"	"	"	"	"	930	1040	1160

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/≥65/1.0/1.00 – Tensile Development and Lap Lengths

f'_c≥65 MPa, k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	290	350	460	580	-	-	-	-	-
25	290	350	460	580	700	-	-	-	-
30	290	350	460	580	700	830	-	-	-
35	"	350	460	580	700	810	980	-	-
40	"	350	460	580	700	810	960	1140	1350
45	"	"	460	580	700	810	930	1120	1320
50	"	"	460	580	700	810	930	1090	1300
55	"	"	"	580	700	810	930	1070	1270
60	"	"	"	580	700	810	930	1050	1250
65	"	"	"	"	700	810	930	1040	1220
70	"	"	"	"	700	810	930	1040	1200
75	"	"	"	"	700	810	930	1040	1170
80	"	"	"	"	"	810	930	1040	1160
85	"	"	"	"	"	810	930	1040	1160
90	"	"	"	"	"	"	930	1040	1160
95	"	"	"	"	"	"	930	1040	1160
100	"	"	"	"	"	"	930	1040	1160

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	240	270	330	410	-	-	-	-	-
25	260	290	350	420	490	-	-	-	-
30	290	320	370	440	510	590	-	-	-
35	"	340	390	460	530	590	690	-	-
40	"	350	420	480	540	610	690	810	940
45	"	"	440	500	560	620	690	810	940
50	"	"	460	520	590	640	710	810	940
55	"	"	"	550	610	660	730	810	940
60	"	"	"	580	630	680	750	820	940
65	"	"	"	"	660	710	770	830	940
70	"	"	"	"	690	730	790	850	940
75	"	"	"	"	700	760	820	870	940
80	"	"	"	"	"	790	840	890	960
85	"	"	"	"	"	810	870	910	980
90	"	"	"	"	"	"	890	940	1000
95	"	"	"	"	"	"	920	970	1020
100	"	"	"	"	"	"	930	990	1050

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	290	350	460	580	-	-	-	-	-
25	290	350	460	580	700	-	-	-	-
30	290	350	460	580	700	830	-	-	-
35	"	350	460	580	700	810	980	-	-
40	"	350	460	580	700	810	960	1140	1350
45	"	"	460	580	700	810	930	1120	1320
50	"	"	460	580	700	810	930	1090	1300
55	"	"	"	580	700	810	930	1070	1270
60	"	"	"	580	700	810	930	1050	1250
65	"	"	"	"	700	810	930	1040	1220
70	"	"	"	"	700	810	930	1040	1200
75	"	"	"	"	700	810	930	1040	1170
80	"	"	"	"	"	810	930	1040	1160
85	"	"	"	"	"	810	930	1040	1160
90	"	"	"	"	"	"	930	1040	1160
95	"	"	"	"	"	"	930	1040	1160
100	"	"	"	"	"	"	930	1040	1160

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	290	350	460	580	-	-	-	-	-
25	290	350	460	580	700	-	-	-	-
30	290	350	460	580	700	810	-	-	-
35	"	350	460	580	700	810	930	-	-
40	"	350	460	580	700	810	930	1040	1160
45	"	"	460	580	700	810	930	1040	1160
50	"	"	460	580	700	810	930	1040	1160
55	"	"	"	580	700	810	930	1040	1160
60	"	"	"	580	700	810	930	1040	1160
65	"	"	"	"	700	810	930	1040	1160
70	"	"	"	"	700	810	930	1040	1160
75	"	"	"	"	700	810	930	1040	1160
80	"	"	"	"	"	810	930	1040	1160
85	"	"	"	"	"	810	930	1040	1160
90	"	"	"	"	"	"	930	1040	1160
95	"	"	"	"	"	"	930	1040	1160
100	"	"	"	"	"	"	930	1040	1160

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ (≥$L_{sy.t.min}$) and/or $L_{sy.t.lap}$ (≥$L_{sy.t.lap.min}$).

SRIA Steel Reinforcement Institute of Australia

TECHNICAL NOTE 7

STRESS DEVELOPMENT AND LAP SPLICING OF STRAIGHT D500N TENSILE REINFORCING BARS TO AS 3600–2009

TABLE G/20/1.3/1.00 – Tensile Development and Lap Lengths

f'_c=20 MPa, k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	510	650	960	1300	-	-	-	-	-
25	460	610	920	1250	1600	-	-	-	-
30	420	560	870	1200	1550	1940	-	-	-
35	"	520	820	1150	1500	1880	2290	-	-
40	"	510	780	1100	1450	1830	2240	2680	3160
45	"	"	730	1050	1400	1780	2180	2620	3100
50	"	"	700	1010	1350	1730	2130	2570	3040
55	"	"	"	960	1300	1670	2070	2510	2980
60	"	"	"	910	1250	1620	2020	2450	2920
65	"	"	"	"	1200	1570	1970	2400	2860
70	"	"	"	"	1150	1520	1910	2340	2800
75	"	"	"	"	1130	1460	1860	2280	2740
80	"	"	"	"	"	1410	1800	2230	2690
85	"	"	"	"	"	1370	1750	2170	2630
90	"	"	"	"	"	"	1690	2110	2570
95	"	"	"	"	"	"	1640	2060	2510
100	"	"	"	"	"	"	1630	2000	2450

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	420	510	700	910	-	-	-	-	-
25	420	510	700	910	1130	-	-	-	-
30	420	510	700	910	1130	1370	-	-	-
35	"	510	700	910	1130	1370	1630	-	-
40	"	510	700	910	1130	1370	1630	1910	2210
45	"	"	700	910	1130	1370	1630	1910	2210
50	"	"	700	910	1130	1370	1630	1910	2210
55	"	"	"	910	1130	1370	1630	1910	2210
60	"	"	"	910	1130	1370	1630	1910	2210
65	"	"	"	"	1130	1370	1630	1910	2210
70	"	"	"	"	1130	1370	1630	1910	2210
75	"	"	"	"	1130	1370	1630	1910	2210
80	"	"	"	"	"	1370	1630	1910	2210
85	"	"	"	"	"	1370	1630	1910	2210
90	"	"	"	"	"	"	1630	1910	2210
95	"	"	"	"	"	"	1630	1910	2210
100	"	"	"	"	"	"	1630	1910	2210

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	510	650	960	1300	-	-	-	-	-
25	460	610	920	1250	1600	-	-	-	-
30	420	560	870	1200	1550	1940	-	-	-
35	"	520	820	1150	1500	1880	2290	-	-
40	"	510	780	1100	1450	1830	2240	2680	3160
45	"	"	730	1050	1400	1780	2180	2620	3100
50	"	"	700	1010	1350	1730	2130	2570	3040
55	"	"	"	960	1300	1670	2070	2510	2980
60	"	"	"	910	1250	1620	2020	2450	2920
65	"	"	"	"	1200	1570	1970	2400	2860
70	"	"	"	"	1150	1520	1910	2340	2800
75	"	"	"	"	1130	1460	1860	2280	2740
80	"	"	"	"	"	1410	1800	2230	2690
85	"	"	"	"	"	1370	1750	2170	2630
90	"	"	"	"	"	"	1690	2110	2570
95	"	"	"	"	"	"	1640	2060	2510
100	"	"	"	"	"	"	1630	2000	2450

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	420	510	700	910	-	-	-	-	-
25	420	510	700	910	1130	-	-	-	-
30	420	510	700	910	1130	1370	-	-	-
35	"	510	700	910	1130	1370	1630	-	-
40	"	510	700	910	1130	1370	1630	1910	2210
45	"	"	700	910	1130	1370	1630	1910	2210
50	"	"	700	910	1130	1370	1630	1910	2210
55	"	"	"	910	1130	1370	1630	1910	2210
60	"	"	"	910	1130	1370	1630	1910	2210
65	"	"	"	"	1130	1370	1630	1910	2210
70	"	"	"	"	1130	1370	1630	1910	2210
75	"	"	"	"	1130	1370	1630	1910	2210
80	"	"	"	"	"	1370	1630	1910	2210
85	"	"	"	"	"	1370	1630	1910	2210
90	"	"	"	"	"	"	1630	1910	2210
95	"	"	"	"	"	"	1630	1910	2210
100	"	"	"	"	"	"	1630	1910	2210

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/25/1.3/1.00 – Tensile Development and Lap Lengths

f'_c=25 MPa, k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	450	590	860	1160	-	-	-	-	-
25	410	540	820	1120	1440	-	-	-	-
30	380	500	780	1070	1390	1730	-	-	-
35	"	460	740	1030	1350	1680	2050	-	-
40	"	460	690	990	1300	1640	2000	2400	2830
45	"	"	650	940	1250	1590	1950	2350	2770
50	"	"	630	900	1210	1540	1900	2300	2720
55	"	"	"	860	1160	1500	1860	2240	2670
60	"	"	"	810	1120	1450	1810	2190	2610
65	"	"	"	"	1070	1400	1760	2140	2560
70	"	"	"	"	1030	1360	1710	2090	2510
75	"	"	"	"	1010	1310	1660	2040	2460
80	"	"	"	"	"	1260	1610	1990	2400
85	"	"	"	"	"	1230	1560	1940	2350
90	"	"	"	"	"	"	1510	1890	2300
95	"	"	"	"	"	"	1470	1840	2240
100	"	"	"	"	"	"	1460	1790	2190

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	370	460	630	810	-	-	-	-	-
25	370	460	630	810	1010	-	-	-	-
30	380	460	630	810	1010	1230	-	-	-
35	"	460	630	810	1010	1230	1460	-	-
40	"	460	630	810	1010	1230	1460	1710	1980
45	"	"	630	810	1010	1230	1460	1710	1980
50	"	"	630	810	1010	1230	1460	1710	1980
55	"	"	"	810	1010	1230	1460	1710	1980
60	"	"	"	810	1010	1230	1460	1710	1980
65	"	"	"	"	1010	1230	1460	1710	1980
70	"	"	"	"	1010	1230	1460	1710	1980
75	"	"	"	"	1010	1230	1460	1710	1980
80	"	"	"	"	"	1230	1460	1710	1980
85	"	"	"	"	"	1230	1460	1710	1980
90	"	"	"	"	"	"	1460	1710	1980
95	"	"	"	"	"	"	1460	1710	1980
100	"	"	"	"	"	"	1460	1710	1980

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	450	590	860	1160	-	-	-	-	-
25	410	540	820	1120	1440	-	-	-	-
30	380	500	780	1070	1390	1730	-	-	-
35	"	460	740	1030	1350	1680	2050	-	-
40	"	460	690	990	1300	1640	2000	2400	2830
45	"	"	650	940	1250	1590	1950	2350	2770
50	"	"	630	900	1210	1540	1900	2300	2720
55	"	"	"	860	1160	1500	1860	2240	2670
60	"	"	"	810	1120	1450	1810	2190	2610
65	"	"	"	"	1070	1400	1760	2140	2560
70	"	"	"	"	1030	1360	1710	2090	2510
75	"	"	"	"	1010	1310	1660	2040	2460
80	"	"	"	"	"	1260	1610	1990	2400
85	"	"	"	"	"	1230	1560	1940	2350
90	"	"	"	"	"	"	1510	1890	2300
95	"	"	"	"	"	"	1470	1840	2240
100	"	"	"	"	"	"	1460	1790	2190

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	380	460	630	810	-	-	-	-	-
25	380	460	630	810	1010	-	-	-	-
30	380	460	630	810	1010	1230	-	-	-
35	"	460	630	810	1010	1230	1460	-	-
40	"	460	630	810	1010	1230	1460	1710	1980
45	"	"	630	810	1010	1230	1460	1710	1980
50	"	"	630	810	1010	1230	1460	1710	1980
55	"	"	"	810	1010	1230	1460	1710	1980
60	"	"	"	810	1010	1230	1460	1710	1980
65	"	"	"	"	1010	1230	1460	1710	1980
70	"	"	"	"	1010	1230	1460	1710	1980
75	"	"	"	"	1010	1230	1460	1710	1980
80	"	"	"	"	"	1230	1460	1710	1980
85	"	"	"	"	"	1230	1460	1710	1980
90	"	"	"	"	"	"	1460	1710	1980
95	"	"	"	"	"	"	1460	1710	1980
100	"	"	"	"	"	"	1460	1710	1980

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/32/1.3/1.00 – Tensile Development and Lap Lengths

f'_c=32 MPa, k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	400	520	760	1030	-	-	-	-	-
25	380	480	730	990	1270	-	-	-	-
30	380	450	690	950	1230	1530	-	-	-
35	"	450	650	910	1190	1490	1810	-	-
40	"	450	610	870	1150	1450	1770	2120	2500
45	"	"	600	830	1110	1410	1730	2070	2450
50	"	"	600	800	1070	1360	1680	2030	2400
55	"	"	"	760	1030	1320	1640	1980	2360
60	"	"	"	750	990	1280	1600	1940	2310
65	"	"	"	"	950	1240	1550	1890	2260
70	"	"	"	"	910	1200	1510	1850	2220
75	"	"	"	"	900	1160	1470	1800	2170
80	"	"	"	"	"	1120	1420	1760	2120
85	"	"	"	"	"	1080	1380	1710	2080
90	"	"	"	"	"	"	1340	1670	2030
95	"	"	"	"	"	"	1300	1620	1980
100	"	"	"	"	"	"	1290	1580	1940

MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	330	400	550	720	-	-	-	-	-
25	340	400	550	720	890	-	-	-	-
30	380	410	550	720	890	1080	-	-	-
35	"	440	550	720	890	1080	1290	-	-
40	"	450	550	720	890	1080	1290	1510	1750
45	"	"	580	720	890	1080	1290	1510	1750
50	"	"	600	720	890	1080	1290	1510	1750
55	"	"	"	720	890	1080	1290	1510	1750
60	"	"	"	750	890	1080	1290	1510	1750
65	"	"	"	"	890	1080	1290	1510	1750
70	"	"	"	"	890	1080	1290	1510	1750
75	"	"	"	"	900	1080	1290	1510	1750
80	"	"	"	"	"	1080	1290	1510	1750
85	"	"	"	"	"	1080	1290	1510	1750
90	"	"	"	"	"	"	1290	1510	1750
95	"	"	"	"	"	"	1290	1510	1750
100	"	"	"	"	"	"	1290	1510	1750

BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	400	520	760	1030	-	-	-	-	-
25	380	480	730	990	1270	-	-	-	-
30	380	450	690	950	1230	1530	-	-	-
35	"	450	650	910	1190	1490	1810	-	-
40	"	450	610	870	1150	1450	1770	2120	2500
45	"	"	600	830	1110	1410	1730	2070	2450
50	"	"	600	800	1070	1360	1680	2030	2400
55	"	"	"	760	1030	1320	1640	1980	2360
60	"	"	"	750	990	1280	1600	1940	2310
65	"	"	"	"	950	1240	1550	1890	2260
70	"	"	"	"	910	1200	1510	1850	2220
75	"	"	"	"	900	1160	1470	1800	2170
80	"	"	"	"	"	1120	1420	1760	2120
85	"	"	"	"	"	1080	1380	1710	2080
90	"	"	"	"	"	"	1340	1670	2030
95	"	"	"	"	"	"	1300	1620	1980
100	"	"	"	"	"	"	1290	1580	1940

MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	380	450	600	750	-	-	-	-	-
25	380	450	600	750	900	-	-	-	-
30	380	450	600	750	900	1080	-	-	-
35	"	450	600	750	900	1080	1290	-	-
40	"	450	600	750	900	1080	1290	1510	1750
45	"	"	600	750	900	1080	1290	1510	1750
50	"	"	600	750	900	1080	1290	1510	1750
55	"	"	"	750	900	1080	1290	1510	1750
60	"	"	"	750	900	1080	1290	1510	1750
65	"	"	"	"	900	1080	1290	1510	1750
70	"	"	"	"	900	1080	1290	1510	1750
75	"	"	"	"	900	1080	1290	1510	1750
80	"	"	"	"	"	1080	1290	1510	1750
85	"	"	"	"	"	1080	1290	1510	1750
90	"	"	"	"	"	"	1290	1510	1750
95	"	"	"	"	"	"	1290	1510	1750
100	"	"	"	"	"	"	1290	1510	1750

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/40/1.3/1.00 – Tensile Development and Lap Lengths

f'_c=40 MPa, k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	380	460	680	920	-	-	-	-	-
25	380	450	650	880	1130	-	-	-	-
30	380	450	620	850	1100	1370	-	-	-
35	"	450	600	810	1060	1330	1620	-	-
40	"	450	600	780	1030	1290	1580	1890	2230
45	"	"	600	750	990	1260	1540	1850	2190
50	"	"	600	750	960	1220	1510	1810	2150
55	"	"	"	750	920	1180	1470	1770	2110
60	"	"	"	750	900	1150	1430	1730	2070
65	"	"	"	"	900	1110	1390	1690	2020
70	"	"	"	"	900	1070	1350	1650	1980
75	"	"	"	"	900	1060	1310	1610	1940
80	"	"	"	"	"	1060	1270	1570	1900
85	"	"	"	"	"	1060	1240	1530	1860
90	"	"	"	"	"	"	1210	1490	1820
95	"	"	"	"	"	"	1210	1450	1770
100	"	"	"	"	"	"	1210	1410	1730

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	310	360	500	640	-	-	-	-	-
25	340	380	500	640	800	-	-	-	-
30	380	410	500	640	800	970	-	-	-
35	"	440	510	640	800	970	1150	-	-
40	"	450	540	640	800	970	1150	1350	1560
45	"	"	580	650	800	970	1150	1350	1560
50	"	"	600	680	800	970	1150	1350	1560
55	"	"	"	710	800	970	1150	1350	1560
60	"	"	"	750	810	970	1150	1350	1560
65	"	"	"	"	850	970	1150	1350	1560
70	"	"	"	"	880	970	1150	1350	1560
75	"	"	"	"	900	990	1150	1350	1560
80	"	"	"	"	"	1030	1150	1350	1560
85	"	"	"	"	"	1060	1150	1350	1560
90	"	"	"	"	"	"	1160	1350	1560
95	"	"	"	"	"	"	1200	1350	1560
100	"	"	"	"	"	"	1210	1350	1560

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	380	460	680	920	-	-	-	-	-
25	380	450	650	880	1130	-	-	-	-
30	380	450	620	850	1100	1370	-	-	-
35	"	450	600	810	1060	1330	1620	-	-
40	"	450	600	780	1030	1290	1580	1890	2230
45	"	"	600	750	990	1260	1540	1850	2190
50	"	"	600	750	960	1220	1510	1810	2150
55	"	"	"	750	920	1180	1470	1770	2110
60	"	"	"	750	900	1150	1430	1730	2070
65	"	"	"	"	900	1110	1390	1690	2020
70	"	"	"	"	900	1070	1350	1650	1980
75	"	"	"	"	900	1060	1310	1610	1940
80	"	"	"	"	"	1060	1270	1570	1900
85	"	"	"	"	"	1060	1240	1530	1860
90	"	"	"	"	"	"	1210	1490	1820
95	"	"	"	"	"	"	1210	1450	1770
100	"	"	"	"	"	"	1210	1410	1730

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	380	450	600	750	-	-	-	-	-
25	380	450	600	750	900	-	-	-	-
30	380	450	600	750	900	1060	-	-	-
35	"	450	600	750	900	1060	1210	-	-
40	"	450	600	750	900	1060	1210	1360	1560
45	"	"	600	750	900	1060	1210	1360	1560
50	"	"	600	750	900	1060	1210	1360	1560
55	"	"	"	750	900	1060	1210	1360	1560
60	"	"	"	750	900	1060	1210	1360	1560
65	"	"	"	"	900	1060	1210	1360	1560
70	"	"	"	"	900	1060	1210	1360	1560
75	"	"	"	"	900	1060	1210	1360	1560
80	"	"	"	"	"	1060	1210	1360	1560
85	"	"	"	"	"	1060	1210	1360	1560
90	"	"	"	"	"	"	1210	1360	1560
95	"	"	"	"	"	"	1210	1360	1560
100	"	"	"	"	"	"	1210	1360	1560

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4 k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/50/1.3/1.00 – Tensile Development and Lap Lengths

f'_c=50 MPa, k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	380	450	610	820	-	-	-	-	-
25	380	450	600	790	1010	-	-	-	-
30	380	450	600	760	980	1220	-	-	-
35	"	450	600	750	950	1190	1450	-	-
40	"	450	600	750	920	1160	1420	1690	2000
45	"	"	600	750	900	1120	1380	1660	1960
50	"	"	600	750	900	1090	1350	1620	1920
55	"	"	"	750	900	1060	1310	1590	1890
60	"	"	"	750	900	1060	1280	1550	1850
65	"	"	"	"	900	1060	1240	1520	1810
70	"	"	"	"	900	1060	1210	1480	1770
75	"	"	"	"	900	1060	1210	1440	1740
80	"	"	"	"	"	1060	1210	1410	1700
85	"	"	"	"	"	1060	1210	1370	1660
90	"	"	"	"	"	"	1210	1360	1620
95	"	"	"	"	"	"	1210	1360	1590
100	"	"	"	"	"	"	1210	1360	1550

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	310	350	440	570	-	-	-	-	-
25	340	380	460	570	710	-	-	-	-
30	380	410	480	580	710	870	-	-	-
35	"	440	510	590	710	870	1030	-	-
40	"	450	540	620	720	870	1030	1210	1400
45	"	"	580	650	730	870	1030	1210	1400
50	"	"	600	680	750	870	1030	1210	1400
55	"	"	"	710	780	870	1030	1210	1400
60	"	"	"	750	810	900	1030	1210	1400
65	"	"	"	"	850	930	1030	1210	1400
70	"	"	"	"	880	960	1030	1210	1400
75	"	"	"	"	900	990	1060	1210	1400
80	"	"	"	"	"	1030	1090	1210	1400
85	"	"	"	"	"	1060	1130	1210	1400
90	"	"	"	"	"	"	1160	1230	1400
95	"	"	"	"	"	"	1200	1260	1400
100	"	"	"	"	"	"	1210	1300	1400

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	380	450	610	820	-	-	-	-	-
25	380	450	600	790	1010	-	-	-	-
30	380	450	600	760	980	1220	-	-	-
35	"	450	600	750	950	1190	1450	-	-
40	"	450	600	750	920	1160	1420	1690	2000
45	"	"	600	750	900	1120	1380	1660	1960
50	"	"	600	750	900	1090	1350	1620	1920
55	"	"	"	750	900	1060	1310	1590	1890
60	"	"	"	750	900	1060	1280	1550	1850
65	"	"	"	"	900	1060	1240	1520	1810
70	"	"	"	"	900	1060	1210	1480	1770
75	"	"	"	"	900	1060	1210	1440	1740
80	"	"	"	"	"	1060	1210	1410	1700
85	"	"	"	"	"	1060	1210	1370	1660
90	"	"	"	"	"	"	1210	1360	1620
95	"	"	"	"	"	"	1210	1360	1590
100	"	"	"	"	"	"	1210	1360	1550

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	380	450	600	750	-	-	-	-	-
25	380	450	600	750	900	-	-	-	-
30	380	450	600	750	900	1060	-	-	-
35	"	450	600	750	900	1060	1210	-	-
40	"	450	600	750	900	1060	1210	1360	1510
45	"	"	600	750	900	1060	1210	1360	1510
50	"	"	600	750	900	1060	1210	1360	1510
55	"	"	"	750	900	1060	1210	1360	1510
60	"	"	"	750	900	1060	1210	1360	1510
65	"	"	"	"	900	1060	1210	1360	1510
70	"	"	"	"	900	1060	1210	1360	1510
75	"	"	"	"	900	1060	1210	1360	1510
80	"	"	"	"	"	1060	1210	1360	1510
85	"	"	"	"	"	1060	1210	1360	1510
90	"	"	"	"	"	"	1210	1360	1510
95	"	"	"	"	"	"	1210	1360	1510
100	"	"	"	"	"	"	1210	1360	1510

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

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TABLE G/≥65/1.3/1.00 – Tensile Development and Lap Lengths

$f'_c \geq 65$ MPa, $k_1=1.3$, $k_7=1.00$ {Eq. 1c: $\xi_{cd}=1.0$, $\xi_{bc}=1.0$}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	380	450	600	750	-	-	-	-	-
25	380	450	600	750	900	-	-	-	-
30	380	450	600	750	900	1070	-	-	-
35	"	450	600	750	900	1060	1270	-	-
40	"	450	600	750	900	1060	1240	1490	1750
45	"	"	600	750	900	1060	1210	1450	1720
50	"	"	600	750	900	1060	1210	1420	1690
55	"	"	"	750	900	1060	1210	1390	1650
60	"	"	"	750	900	1060	1210	1360	1620
65	"	"	"	"	900	1060	1210	1360	1590
70	"	"	"	"	900	1060	1210	1360	1560
75	"	"	"	"	900	1060	1210	1360	1520
80	"	"	"	"	"	1060	1210	1360	1510
85	"	"	"	"	"	1060	1210	1360	1510
90	"	"	"	"	"	"	1210	1360	1510
95	"	"	"	"	"	"	1210	1360	1510
100	"	"	"	"	"	"	1210	1360	1510

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	310	350	440	530	-	-	-	-	-
25	340	380	460	550	630	-	-	-	-
30	380	410	480	570	650	760	-	-	-
35	"	440	510	590	680	770	900	-	-
40	"	450	540	620	700	790	900	1060	1230
45	"	"	580	650	730	820	900	1060	1230
50	"	"	600	680	750	840	930	1060	1230
55	"	"	"	710	780	870	950	1060	1230
60	"	"	"	750	810	900	970	1060	1230
65	"	"	"	"	850	930	1000	1080	1230
70	"	"	"	"	880	960	1030	1110	1230
75	"	"	"	"	900	990	1060	1140	1230
80	"	"	"	"	"	1030	1090	1170	1240
85	"	"	"	"	"	1060	1130	1200	1270
90	"	"	"	"	"	"	1160	1230	1300
95	"	"	"	"	"	"	1200	1260	1330
100	"	"	"	"	"	"	1210	1300	1360

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	380	450	600	750	-	-	-	-	-
25	380	450	600	750	900	-	-	-	-
30	380	450	600	750	900	1070	-	-	-
35	"	450	600	750	900	1060	1270	-	-
40	"	450	600	750	900	1060	1240	1490	1750
45	"	"	600	750	900	1060	1210	1450	1720
50	"	"	600	750	900	1060	1210	1420	1690
55	"	"	"	750	900	1060	1210	1390	1650
60	"	"	"	750	900	1060	1210	1360	1620
65	"	"	"	"	900	1060	1210	1360	1590
70	"	"	"	"	900	1060	1210	1360	1560
75	"	"	"	"	900	1060	1210	1360	1520
80	"	"	"	"	"	1060	1210	1360	1510
85	"	"	"	"	"	1060	1210	1360	1510
90	"	"	"	"	"	"	1210	1360	1510
95	"	"	"	"	"	"	1210	1360	1510
100	"	"	"	"	"	"	1210	1360	1510

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	380	450	600	750	-	-	-	-	-
25	380	450	600	750	900	-	-	-	-
30	380	450	600	750	900	1060	-	-	-
35	"	450	600	750	900	1060	1210	-	-
40	"	450	600	750	900	1060	1210	1360	1510
45	"	"	600	750	900	1060	1210	1360	1510
50	"	"	600	750	900	1060	1210	1360	1510
55	"	"	"	750	900	1060	1210	1360	1510
60	"	"	"	750	900	1060	1210	1360	1510
65	"	"	"	"	900	1060	1210	1360	1510
70	"	"	"	"	900	1060	1210	1360	1510
75	"	"	"	"	900	1060	1210	1360	1510
80	"	"	"	"	"	1060	1210	1360	1510
85	"	"	"	"	"	1060	1210	1360	1510
90	"	"	"	"	"	"	1210	1360	1510
95	"	"	"	"	"	"	1210	1360	1510
100	"	"	"	"	"	"	1210	1360	1510

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/20/1.0/1.25 – Tensile Development and Lap Lengths

f'_c=20 MPa, k_1=1.0, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	390	500	740	1000	-	-	-	-	-
25	360	470	710	960	1230	-	-	-	-
30	320	430	670	920	1200	1490	-	-	-
35	"	400	630	890	1160	1450	1760	-	-
40	"	390	600	850	1120	1410	1720	2060	2430
45	"	"	560	810	1080	1370	1680	2020	2380
50	"	"	540	770	1040	1330	1640	1970	2340
55	"	"	"	740	1000	1290	1600	1930	2290
60	"	"	"	700	960	1250	1550	1890	2250
65	"	"	"	"	920	1210	1510	1840	2200
70	"	"	"	"	890	1170	1470	1800	2160
75	"	"	"	"	870	1130	1430	1760	2110
80	"	"	"	"	"	1090	1390	1710	2070
85	"	"	"	"	"	1050	1340	1670	2020
90	"	"	"	"	"	"	1300	1620	1970
95	"	"	"	"	"	"	1260	1580	1930
100	"	"	"	"	"	"	1250	1540	1880

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	320	390	540	700	-	-	-	-	-
25	320	390	540	700	870	-	-	-	-
30	320	390	540	700	870	1050	-	-	-
35	"	390	540	700	870	1050	1250	-	-
40	"	390	540	700	870	1050	1250	1470	1700
45	"	"	540	700	870	1050	1250	1470	1700
50	"	"	540	700	870	1050	1250	1470	1700
55	"	"	"	700	870	1050	1250	1470	1700
60	"	"	"	700	870	1050	1250	1470	1700
65	"	"	"	"	870	1050	1250	1470	1700
70	"	"	"	"	870	1050	1250	1470	1700
75	"	"	"	"	870	1050	1250	1470	1700
80	"	"	"	"	"	1050	1250	1470	1700
85	"	"	"	"	"	1050	1250	1470	1700
90	"	"	"	"	"	"	1250	1470	1700
95	"	"	"	"	"	"	1250	1470	1700
100	"	"	"	"	"	"	1250	1470	1700

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	490	630	930	1250	-	-	-	-	-
25	440	590	880	1200	1540	-	-	-	-
30	400	540	840	1150	1490	1860	-	-	-
35	"	500	790	1110	1450	1810	2200	-	-
40	"	490	750	1060	1400	1760	2150	2580	3040
45	"	"	700	1010	1350	1710	2100	2520	2980
50	"	"	670	970	1300	1660	2050	2470	2920
55	"	"	"	920	1250	1610	1990	2410	2870
60	"	"	"	870	1200	1560	1940	2360	2810
65	"	"	"	"	1150	1510	1890	2300	2750
70	"	"	"	"	1110	1460	1840	2250	2700
75	"	"	"	"	1090	1410	1790	2190	2640
80	"	"	"	"	"	1360	1730	2140	2580
85	"	"	"	"	"	1320	1680	2090	2530
90	"	"	"	"	"	"	1630	2030	2470
95	"	"	"	"	"	"	1580	1980	2410
100	"	"	"	"	"	"	1570	1920	2350

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	400	490	670	870	-	-	-	-	-
25	400	490	670	870	1090	-	-	-	-
30	400	490	670	870	1090	1320	-	-	-
35	"	490	670	870	1090	1320	1570	-	-
40	"	490	670	870	1090	1320	1570	1830	2130
45	"	"	670	870	1090	1320	1570	1830	2130
50	"	"	670	870	1090	1320	1570	1830	2130
55	"	"	"	870	1090	1320	1570	1830	2130
60	"	"	"	870	1090	1320	1570	1830	2130
65	"	"	"	"	1090	1320	1570	1830	2130
70	"	"	"	"	1090	1320	1570	1830	2130
75	"	"	"	"	1090	1320	1570	1830	2130
80	"	"	"	"	"	1320	1570	1830	2130
85	"	"	"	"	"	1320	1570	1830	2130
90	"	"	"	"	"	"	1570	1830	2130
95	"	"	"	"	"	"	1570	1830	2130
100	"	"	"	"	"	"	1570	1830	2130

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/25/1.0/1.25 – Tensile Development and Lap Lengths

f'_c=25 MPa, k_1=1.0, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	350	450	660	890	-	-	-	-	-
25	320	420	630	860	1100	-	-	-	-
30	290	390	600	830	1070	1330	-	-	-
35	"	360	570	790	1030	1300	1580	-	-
40	"	350	530	760	1000	1260	1540	1840	2170
45	"	"	500	730	970	1220	1500	1800	2130
50	"	"	480	690	930	1190	1470	1770	2090
55	"	"	"	660	900	1150	1430	1730	2050
60	"	"	"	630	860	1120	1390	1690	2010
65	"	"	"	"	830	1080	1350	1650	1970
70	"	"	"	"	790	1040	1320	1610	1930
75	"	"	"	"	780	1010	1280	1570	1890
80	"	"	"	"	"	970	1240	1530	1850
85	"	"	"	"	"	940	1200	1490	1810
90	"	"	"	"	"	"	1170	1450	1770
95	"	"	"	"	"	"	1130	1410	1730
100	"	"	"	"	"	"	1120	1380	1680

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	290	350	480	630	-	-	-	-	-
25	290	350	480	630	780	-	-	-	-
30	290	350	480	630	780	940	-	-	-
35	"	350	480	630	780	940	1120	-	-
40	"	350	480	630	780	940	1120	1310	1520
45	"	"	480	630	780	940	1120	1310	1520
50	"	"	480	620	780	940	1120	1310	1520
55	"	"	"	630	780	940	1120	1310	1520
60	"	"	"	630	780	940	1120	1310	1520
65	"	"	"	"	780	940	1120	1310	1520
70	"	"	"	"	780	940	1120	1310	1520
75	"	"	"	"	780	940	1120	1310	1520
80	"	"	"	"	"	940	1120	1310	1520
85	"	"	"	"	"	940	1120	1310	1520
90	"	"	"	"	"	"	1120	1310	1520
95	"	"	"	"	"	"	1120	1310	1520
100	"	"	"	"	"	"	1120	1310	1520

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	440	560	830	1120	-	-	-	-	-
25	400	520	790	1070	1380	-	-	-	-
30	360	480	750	1030	1340	1660	-	-	-
35	"	450	710	990	1290	1620	1970	-	-
40	"	440	670	950	1250	1570	1930	2300	2720
45	"	"	630	910	1210	1530	1880	2260	2670
50	"	"	600	860	1160	1480	1830	2210	2620
55	"	"	"	820	1120	1440	1780	2160	2560
60	"	"	"	780	1080	1390	1740	2110	2510
65	"	"	"	"	1030	1350	1690	2060	2460
70	"	"	"	"	990	1300	1640	2010	2410
75	"	"	"	"	970	1260	1600	1960	2360
80	"	"	"	"	"	1210	1550	1910	2310
85	"	"	"	"	"	1180	1500	1870	2260
90	"	"	"	"	"	"	1460	1820	2210
95	"	"	"	"	"	"	1410	1770	2160
100	"	"	"	"	"	"	1400	1720	2110

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	360	440	600	780	-	-	-	-	-
25	360	440	600	780	970	-	-	-	-
30	360	440	600	780	970	1180	-	-	-
35	"	440	600	780	970	1180	1400	-	-
40	"	440	600	780	970	1180	1400	1640	1900
45	"	"	600	780	970	1180	1400	1640	1900
50	"	"	600	780	970	1180	1400	1640	1900
55	"	"	"	780	970	1180	1400	1640	1900
60	"	"	"	780	970	1180	1400	1640	1900
65	"	"	"	"	970	1180	1400	1640	1900
70	"	"	"	"	970	1180	1400	1640	1900
75	"	"	"	"	970	1180	1400	1640	1900
80	"	"	"	"	"	1180	1400	1640	1900
85	"	"	"	"	"	1180	1400	1640	1900
90	"	"	"	"	"	"	1400	1640	1900
95	"	"	"	"	"	"	1400	1640	1900
100	"	"	"	"	"	"	1400	1640	1900

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/32/1.0/1.25 – Tensile Development and Lap Lengths

f'_c=32 MPa, k_1=1.0, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	310	400	590	790	-	-	-	-	-
25	290	370	560	760	980	-	-	-	-
30	290	350	530	730	950	1180	-	-	-
35	"	350	500	700	910	1150	1390	-	-
40	"	350	470	670	880	1110	1360	1630	1920
45	"	"	460	640	850	1080	1330	1600	1890
50	"	"	460	610	820	1050	1290	1560	1850
55	"	"	"	580	790	1020	1260	1530	1810
60	"	"	"	580	760	990	1230	1490	1780
65	"	"	"	"	730	950	1200	1460	1740
70	"	"	"	"	700	920	1160	1420	1710
75	"	"	"	"	700	890	1130	1390	1670
80	"	"	"	"	"	860	1100	1350	1630
85	"	"	"	"	"	830	1060	1320	1600
90	"	"	"	"	"	"	1030	1280	1560
95	"	"	"	"	"	"	1000	1250	1530
100	"	"	"	"	"	"	990	1220	1490

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	260	310	430	550	-	-	-	-	-
25	260	310	430	550	690	-	-	-	-
30	290	320	430	550	690	830	-	-	-
35	"	340	430	550	690	830	990	-	-
40	"	350	430	550	690	830	990	1160	1350
45	"	"	450	550	690	830	990	1160	1350
50	"	"	460	550	690	830	990	1160	1350
55	"	"	"	550	690	830	990	1160	1350
60	"	"	"	580	690	830	990	1160	1350
65	"	"	"	"	690	830	990	1160	1350
70	"	"	"	"	690	830	990	1160	1350
75	"	"	"	"	700	830	990	1160	1350
80	"	"	"	"	"	830	990	1160	1350
85	"	"	"	"	"	830	990	1160	1350
90	"	"	"	"	"	"	990	1160	1350
95	"	"	"	"	"	"	990	1160	1350
100	"	"	"	"	"	"	990	1160	1350

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	380	500	730	990	-	-	-	-	-
25	350	460	700	950	1220	-	-	-	-
30	320	430	660	910	1180	1470	-	-	-
35	"	390	630	880	1140	1430	1740	-	-
40	"	390	590	840	1100	1390	1700	2040	2400
45	"	"	550	800	1070	1350	1660	1990	2360
50	"	"	530	760	1030	1310	1620	1950	2310
55	"	"	"	730	990	1270	1580	1910	2270
60	"	"	"	690	950	1230	1540	1860	2220
65	"	"	"	"	910	1190	1490	1820	2180
70	"	"	"	"	870	1150	1450	1780	2130
75	"	"	"	"	860	1110	1410	1730	2090
80	"	"	"	"	"	1070	1370	1690	2040
85	"	"	"	"	"	1040	1330	1650	2000
90	"	"	"	"	"	"	1290	1610	1950
95	"	"	"	"	"	"	1250	1560	1910
100	"	"	"	"	"	"	1240	1520	1860

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	320	390	530	690	-	-	-	-	-
25	320	390	530	690	860	-	-	-	-
30	320	390	530	690	860	1040	-	-	-
35	"	390	530	690	860	1040	1240	-	-
40	"	390	530	690	860	1040	1240	1450	1680
45	"	"	530	690	860	1040	1240	1450	1680
50	"	"	530	690	860	1040	1240	1450	1680
55	"	"	"	690	860	1040	1240	1450	1680
60	"	"	"	690	860	1040	1240	1450	1680
65	"	"	"	"	860	1040	1240	1450	1680
70	"	"	"	"	860	1040	1240	1450	1680
75	"	"	"	"	860	1040	1240	1450	1680
80	"	"	"	"	"	1040	1240	1450	1680
85	"	"	"	"	"	1040	1240	1450	1680
90	"	"	"	"	"	"	1240	1450	1680
95	"	"	"	"	"	"	1240	1450	1680
100	"	"	"	"	"	"	1240	1450	1680

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/40/1.0/1.25 – Tensile Development and Lap Lengths

f'_c=40 MPa, k_1=1.0, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	290	360	520	710	-	-	-	-	-
25	290	350	500	680	870	-	-	-	-
30	290	350	470	650	850	1050	-	-	-
35	"	350	460	630	820	1020	1250	-	-
40	"	350	460	600	790	1000	1220	1460	1720
45	"	"	460	580	760	970	1190	1430	1690
50	"	"	460	580	740	940	1160	1400	1650
55	"	"	"	580	710	910	1130	1360	1620
60	"	"	"	580	700	880	1100	1330	1590
65	"	"	"	"	700	850	1070	1300	1560
70	"	"	"	"	700	820	1040	1270	1530
75	"	"	"	"	700	810	1010	1240	1490
80	"	"	"	"	"	810	980	1210	1460
85	"	"	"	"	"	810	950	1180	1430
90	"	"	"	"	"	"	930	1150	1400
95	"	"	"	"	"	"	930	1120	1360
100	"	"	"	"	"	"	930	1090	1330

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	240	280	380	490	-	-	-	-	-
25	260	290	380	490	610	-	-	-	-
30	290	320	380	490	610	740	-	-	-
35	"	340	390	490	610	740	890	-	-
40	"	350	420	490	610	740	890	1040	1200
45	"	"	440	500	610	740	890	1040	1200
50	"	"	460	520	620	740	890	1040	1200
55	"	"	"	550	620	740	890	1040	1200
60	"	"	"	580	630	740	890	1040	1200
65	"	"	"	"	660	740	890	1040	1200
70	"	"	"	"	690	740	890	1040	1200
75	"	"	"	"	700	760	890	1040	1200
80	"	"	"	"	"	790	890	1040	1200
85	"	"	"	"	"	810	890	1040	1200
90	"	"	"	"	"	"	890	1040	1200
95	"	"	"	"	"	"	920	1040	1200
100	"	"	"	"	"	"	930	1040	1200

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	340	440	660	880	-	-	-	-	-
25	310	410	620	850	1090	-	-	-	-
30	290	380	590	820	1060	1320	-	-	-
35	"	350	560	780	1020	1280	1560	-	-
40	"	350	530	750	990	1240	1520	1820	2150
45	"	"	500	720	950	1210	1480	1780	2110
50	"	"	480	680	920	1170	1450	1740	2070
55	"	"	"	650	890	1140	1410	1710	2030
60	"	"	"	620	850	1100	1370	1670	1990
65	"	"	"	"	820	1070	1340	1630	1950
70	"	"	"	"	780	1030	1300	1590	1910
75	"	"	"	"	770	1000	1260	1550	1870
80	"	"	"	"	"	960	1230	1510	1830
85	"	"	"	"	"	930	1190	1470	1790
90	"	"	"	"	"	"	1150	1440	1750
95	"	"	"	"	"	"	1110	1400	1710
100	"	"	"	"	"	"	1110	1360	1660

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	290	350	480	620	-	-	-	-	-
25	290	350	480	620	770	-	-	-	-
30	290	350	480	620	770	930	-	-	-
35	"	350	480	620	770	930	1110	-	-
40	"	350	480	620	770	930	1110	1300	1500
45	"	"	480	620	770	930	1110	1300	1500
50	"	"	480	620	770	930	1110	1300	1500
55	"	"	"	620	770	930	1110	1300	1500
60	"	"	"	620	770	930	1110	1300	1500
65	"	"	"	"	770	930	1110	1300	1500
70	"	"	"	"	770	930	1110	1300	1500
75	"	"	"	"	770	930	1110	1300	1500
80	"	"	"	"	"	930	1110	1300	1500
85	"	"	"	"	"	930	1110	1300	1500
90	"	"	"	"	"	"	1110	1300	1500
95	"	"	"	"	"	"	1110	1300	1500
100	"	"	"	"	"	"	1110	1300	1500

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/50/1.0/1.25 – Tensile Development and Lap Lengths

f'_c=50 MPa, k_1=1.0, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	290	350	470	630	-	-	-	-	-
25	290	350	460	610	780	-	-	-	-
30	290	350	460	580	760	940	-	-	-
35	"	350	460	580	730	920	1120	-	-
40	"	350	460	580	710	890	1090	1300	1540
45	"	"	460	580	700	870	1060	1280	1510
50	"	"	460	580	700	840	1040	1250	1480
55	"	"	"	580	700	810	1010	1220	1450
60	"	"	"	580	700	810	980	1190	1420
65	"	"	"	"	700	810	960	1170	1390
70	"	"	"	"	700	810	930	1140	1360
75	"	"	"	"	700	810	930	1110	1340
80	"	"	"	"	"	810	930	1080	1310
85	"	"	"	"	"	810	930	1060	1280
90	"	"	"	"	"	"	930	1040	1250
95	"	"	"	"	"	"	930	1040	1220
100	"	"	"	"	"	"	930	1040	1190

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	240	270	340	440	-	-	-	-	-
25	260	290	350	440	550	-	-	-	-
30	290	320	370	440	550	670	-	-	-
35	"	340	390	460	550	670	790	-	-
40	"	350	420	480	550	670	790	930	1080
45	"	"	440	500	560	670	790	930	1080
50	"	"	460	520	590	670	790	930	1080
55	"	"	"	550	610	670	790	930	1080
60	"	"	"	580	630	680	790	930	1080
65	"	"	"	"	660	710	790	930	1080
70	"	"	"	"	690	730	790	930	1080
75	"	"	"	"	700	760	820	930	1080
80	"	"	"	"	"	790	840	930	1080
85	"	"	"	"	"	810	870	930	1080
90	"	"	"	"	"	"	890	940	1080
95	"	"	"	"	"	"	920	970	1080
100	"	"	"	"	"	"	930	990	1080

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	310	400	590	790	-	-	-	-	-
25	290	370	560	760	980	-	-	-	-
30	290	350	530	730	950	1180	-	-	-
35	"	350	500	700	910	1150	1390	-	-
40	"	350	470	670	880	1110	1360	1630	1920
45	"	"	460	640	850	1080	1330	1600	1890
50	"	"	460	610	820	1050	1290	1560	1850
55	"	"	"	580	790	1020	1260	1530	1810
60	"	"	"	580	760	990	1230	1490	1780
65	"	"	"	"	730	950	1200	1460	1740
70	"	"	"	"	700	920	1160	1420	1710
75	"	"	"	"	700	890	1130	1390	1670
80	"	"	"	"	"	860	1100	1350	1630
85	"	"	"	"	"	830	1060	1320	1600
90	"	"	"	"	"	"	1030	1280	1560
95	"	"	"	"	"	"	1000	1250	1530
100	"	"	"	"	"	"	990	1220	1490

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	290	350	460	580	-	-	-	-	-
25	290	350	460	580	700	-	-	-	-
30	290	350	460	580	700	830	-	-	-
35	"	350	460	580	700	830	990	-	-
40	"	350	460	580	700	830	990	1160	1350
45	"	"	460	580	700	830	990	1160	1350
50	"	"	460	580	700	830	990	1160	1350
55	"	"	"	580	700	830	990	1160	1350
60	"	"	"	580	700	830	990	1160	1350
65	"	"	"	"	700	830	990	1160	1350
70	"	"	"	"	700	830	990	1160	1350
75	"	"	"	"	700	830	990	1160	1350
80	"	"	"	"	"	830	990	1160	1350
85	"	"	"	"	"	830	990	1160	1350
90	"	"	"	"	"	"	990	1160	1350
95	"	"	"	"	"	"	990	1160	1350
100	"	"	"	"	"	"	990	1160	1350

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/≥65/1.0/1.25 – Tensile Development and Lap Lengths

$f'_c \geq 65$ MPa, $k_1=1.0$, $k_7=1.25$ {Eq. 1c: $\xi_{cd}=1.0$, $\xi_{bc}=1.0$}

BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	290	350	460	580	-	-	-	-	-
25	290	350	460	580	700	-	-	-	-
30	290	350	460	580	700	830	-	-	-
35	"	350	460	580	700	810	980	-	-
40	"	350	460	580	700	810	960	1140	1350
45	"	"	460	580	700	810	930	1120	1320
50	"	"	460	580	700	810	930	1090	1300
55	"	"	"	580	700	810	930	1070	1270
60	"	"	"	580	700	810	930	1050	1250
65	"	"	"	"	700	810	930	1040	1220
70	"	"	"	"	700	810	930	1040	1200
75	"	"	"	"	700	810	930	1040	1170
80	"	"	"	"	"	810	930	1040	1160
85	"	"	"	"	"	810	930	1040	1160
90	"	"	"	"	"	"	930	1040	1160
95	"	"	"	"	"	"	930	1040	1160
100	"	"	"	"	"	"	930	1040	1160

MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	240	270	330	410	-	-	-	-	-
25	260	290	350	420	490	-	-	-	-
30	290	320	370	440	510	590	-	-	-
35	"	340	390	460	530	590	690	-	-
40	"	350	420	480	540	610	690	810	940
45	"	"	440	500	560	620	690	810	940
50	"	"	460	520	590	640	710	810	940
55	"	"	"	550	610	660	730	810	940
60	"	"	"	580	630	680	750	820	940
65	"	"	"	"	660	710	770	830	940
70	"	"	"	"	690	730	790	850	940
75	"	"	"	"	700	760	820	870	940
80	"	"	"	"	"	790	840	890	960
85	"	"	"	"	"	810	870	910	980
90	"	"	"	"	"	"	890	940	1000
95	"	"	"	"	"	"	920	970	1020
100	"	"	"	"	"	"	930	990	1050

BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	290	350	510	690	-	-	-	-	-
25	290	350	490	670	860	-	-	-	-
30	290	350	460	640	830	1030	-	-	-
35	"	350	460	610	800	1000	1220	-	-
40	"	350	460	590	780	980	1190	1430	1690
45	"	"	460	580	750	950	1160	1400	1650
50	"	"	460	580	720	920	1140	1370	1620
55	"	"	"	580	700	890	1110	1340	1590
60	"	"	"	580	700	860	1080	1310	1560
65	"	"	"	"	700	840	1050	1280	1530
70	"	"	"	"	700	810	1020	1250	1500
75	"	"	"	"	700	810	990	1220	1460
80	"	"	"	"	"	810	960	1190	1430
85	"	"	"	"	"	810	930	1160	1400
90	"	"	"	"	"	"	930	1130	1370
95	"	"	"	"	"	"	930	1100	1340
100	"	"	"	"	"	"	930	1070	1310

MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	290	350	460	580	-	-	-	-	-
25	290	350	460	580	700	-	-	-	-
30	290	350	460	580	700	810	-	-	-
35	"	350	460	580	700	810	930	-	-
40	"	350	460	580	700	810	930	1040	1180
45	"	"	460	580	700	810	930	1040	1180
50	"	"	460	580	700	810	930	1040	1180
55	"	"	"	580	700	810	930	1040	1180
60	"	"	"	580	700	810	930	1040	1180
65	"	"	"	"	700	810	930	1040	1180
70	"	"	"	"	700	810	930	1040	1180
75	"	"	"	"	700	810	930	1040	1180
80	"	"	"	"	"	810	930	1040	1180
85	"	"	"	"	"	810	930	1040	1180
90	"	"	"	"	"	"	930	1040	1180
95	"	"	"	"	"	"	930	1040	1180
100	"	"	"	"	"	"	930	1040	1180

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/20/1.3/1.25 – Tensile Development and Lap Lengths

f'_c=20 MPa, k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	510	650	960	1300	-	-	-	-	-
25	460	610	920	1250	1600	-	-	-	-
30	420	560	870	1200	1550	1940	-	-	-
35	"	520	820	1150	1500	1880	2290	-	-
40	"	510	780	1100	1450	1830	2240	2680	3160
45	"	"	730	1050	1400	1780	2180	2620	3100
50	"	"	700	1010	1350	1730	2130	2570	3040
55	"	"	"	960	1300	1670	2070	2510	2980
60	"	"	"	910	1250	1620	2020	2450	2920
65	"	"	"	"	1200	1570	1970	2400	2860
70	"	"	"	"	1150	1520	1910	2340	2800
75	"	"	"	"	1130	1460	1860	2280	2740
80	"	"	"	"	"	1410	1800	2230	2690
85	"	"	"	"	"	1370	1750	2170	2630
90	"	"	"	"	"	"	1690	2110	2570
95	"	"	"	"	"	"	1640	2060	2510
100	"	"	"	"	"	"	1630	2000	2450

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	420	510	700	910	-	-	-	-	-
25	420	510	700	910	1130	-	-	-	-
30	420	510	700	910	1130	1370	-	-	-
35	"	510	700	910	1130	1370	1630	-	-
40	"	510	700	910	1130	1370	1630	1910	2210
45	"	"	700	910	1130	1370	1630	1910	2210
50	"	"	700	910	1130	1370	1630	1910	2210
55	"	"	"	910	1130	1370	1630	1910	2210
60	"	"	"	910	1130	1370	1630	1910	2210
65	"	"	"	"	1130	1370	1630	1910	2210
70	"	"	"	"	1130	1370	1630	1910	2210
75	"	"	"	"	1130	1370	1630	1910	2210
80	"	"	"	"	"	1370	1630	1910	2210
85	"	"	"	"	"	1370	1630	1910	2210
90	"	"	"	"	"	"	1630	1910	2210
95	"	"	"	"	"	"	1630	1910	2210
100	"	"	"	"	"	"	1630	1910	2210

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	630	820	1210	1620	-	-	-	-	-
25	580	760	1150	1560	2010	-	-	-	-
30	520	700	1090	1500	1940	2420	-	-	-
35	"	650	1030	1440	1880	2350	2870	-	-
40	"	640	970	1380	1820	2290	2800	3350	3950
45	"	"	910	1320	1750	2220	2730	3280	3880
50	"	"	880	1260	1690	2160	2660	3210	3800
55	"	"	"	1200	1630	2090	2590	3140	3730
60	"	"	"	1140	1560	2030	2530	3070	3650
65	"	"	"	"	1500	1960	2460	2990	3580
70	"	"	"	"	1440	1900	2390	2920	3510
75	"	"	"	"	1410	1830	2320	2850	3430
80	"	"	"	"	"	1760	2250	2780	3360
85	"	"	"	"	"	1710	2180	2710	3280
90	"	"	"	"	"	"	2120	2640	3210
95	"	"	"	"	"	"	2050	2570	3130
100	"	"	"	"	"	"	2030	2500	3060

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	520	640	880	1140	-	-	-	-	-
25	520	640	880	1140	1410	-	-	-	-
30	520	640	880	1140	1410	1710	-	-	-
35	"	640	880	1140	1410	1710	2030	-	-
40	"	640	880	1140	1410	1710	2030	2380	2760
45	"	"	880	1140	1410	1710	2030	2380	2760
50	"	"	880	1140	1410	1710	2030	2380	2760
55	"	"	"	1140	1410	1710	2030	2380	2760
60	"	"	"	1140	1410	1710	2030	2380	2760
65	"	"	"	"	1410	1710	2030	2380	2760
70	"	"	"	"	1410	1710	2030	2380	2760
75	"	"	"	"	1410	1710	2030	2380	2760
80	"	"	"	"	"	1710	2030	2380	2760
85	"	"	"	"	"	1710	2030	2380	2760
90	"	"	"	"	"	"	2030	2380	2760
95	"	"	"	"	"	"	2030	2380	2760
100	"	"	"	"	"	"	2030	2380	2760

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/25/1.3/1.25 – Tensile Development and Lap Lengths

f'_c=25 MPa, k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	450	590	860	1160	-	-	-	-	-
25	410	540	820	1120	1440	-	-	-	-
30	380	500	780	1070	1390	1730	-	-	-
35	"	460	740	1030	1350	1680	2050	-	-
40	"	460	690	990	1300	1640	2000	2400	2830
45	"	"	650	940	1250	1590	1950	2350	2770
50	"	"	630	900	1210	1540	1900	2300	2720
55	"	"	"	860	1160	1500	1860	2240	2670
60	"	"	"	810	1120	1450	1810	2190	2610
65	"	"	"	"	1070	1400	1760	2140	2560
70	"	"	"	"	1030	1360	1710	2090	2510
75	"	"	"	"	1010	1310	1660	2040	2460
80	"	"	"	"	"	1260	1610	1990	2400
85	"	"	"	"	"	1230	1560	1940	2350
90	"	"	"	"	"	"	1510	1890	2300
95	"	"	"	"	"	"	1470	1840	2240
100	"	"	"	"	"	"	1460	1790	2190

MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	370	460	630	810	-	-	-	-	-
25	370	460	630	810	1010	-	-	-	-
30	380	460	630	810	1010	1230	-	-	-
35	"	460	630	810	1010	1230	1460	-	-
40	"	460	630	810	1010	1230	1460	1710	1980
45	"	"	630	810	1010	1230	1460	1710	1980
50	"	"	630	810	1010	1230	1460	1710	1980
55	"	"	"	810	1010	1230	1460	1710	1980
60	"	"	"	810	1010	1230	1460	1710	1980
65	"	"	"	"	1010	1230	1460	1710	1980
70	"	"	"	"	1010	1230	1460	1710	1980
75	"	"	"	"	1010	1230	1460	1710	1980
80	"	"	"	"	"	1230	1460	1710	1980
85	"	"	"	"	"	1230	1460	1710	1980
90	"	"	"	"	"	"	1460	1710	1980
95	"	"	"	"	"	"	1460	1710	1980
100	"	"	"	"	"	"	1460	1710	1980

BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	570	730	1080	1450	-	-	-	-	-
25	520	680	1030	1400	1790	-	-	-	-
30	470	630	970	1340	1740	2160	-	-	-
35	"	580	920	1290	1680	2110	2560	-	-
40	"	570	870	1230	1630	2050	2500	3000	3530
45	"	"	820	1180	1570	1990	2440	2930	3470
50	"	"	780	1120	1510	1930	2380	2870	3400
55	"	"	"	1070	1460	1870	2320	2810	3330
60	"	"	"	1020	1400	1810	2260	2740	3270
65	"	"	"	"	1340	1750	2200	2680	3200
70	"	"	"	"	1290	1700	2140	2620	3140
75	"	"	"	"	1260	1640	2080	2550	3070
80	"	"	"	"	"	1580	2020	2490	3000
85	"	"	"	"	"	1530	1950	2420	2940
90	"	"	"	"	"	"	1890	2360	2870
95	"	"	"	"	"	"	1830	2300	2800
100	"	"	"	"	"	"	1820	2230	2740

MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	470	570	780	1020	-	-	-	-	-
25	470	570	780	1020	1260	-	-	-	-
30	470	570	780	1020	1260	1530	-	-	-
35	"	570	780	1020	1260	1530	1820	-	-
40	"	570	780	1020	1260	1530	1820	2130	2470
45	"	"	780	1020	1260	1530	1820	2130	2470
50	"	"	780	1020	1260	1530	1820	2130	2470
55	"	"	"	1020	1260	1530	1820	2130	2470
60	"	"	"	1020	1260	1530	1820	2130	2470
65	"	"	"	"	1260	1530	1820	2130	2470
70	"	"	"	"	1260	1530	1820	2130	2470
75	"	"	"	"	1260	1530	1820	2130	2470
80	"	"	"	"	"	1530	1820	2130	2470
85	"	"	"	"	"	1530	1820	2130	2470
90	"	"	"	"	"	"	1820	2130	2470
95	"	"	"	"	"	"	1820	2130	2470
100	"	"	"	"	"	"	1820	2130	2470

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/32/1.3/1.25 – Tensile Development and Lap Lengths

f'_c=32 MPa, k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	400	520	760	1030	-	-	-	-	-
25	380	480	730	990	1270	-	-	-	-
30	380	450	690	950	1230	1530	-	-	-
35	"	450	650	910	1190	1490	1810	-	-
40	"	450	610	870	1150	1450	1770	2120	2500
45	"	"	600	830	1110	1410	1730	2070	2450
50	"	"	600	800	1070	1360	1680	2030	2400
55	"	"	"	760	1030	1320	1640	1980	2360
60	"	"	"	750	990	1280	1600	1940	2310
65	"	"	"	"	950	1240	1550	1890	2260
70	"	"	"	"	910	1200	1510	1850	2220
75	"	"	"	"	900	1160	1470	1800	2170
80	"	"	"	"	"	1120	1420	1760	2120
85	"	"	"	"	"	1080	1380	1710	2080
90	"	"	"	"	"	"	1340	1670	2030
95	"	"	"	"	"	"	1300	1620	1980
100	"	"	"	"	"	"	1290	1580	1940

MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	330	400	550	720	-	-	-	-	-
25	340	400	550	720	890	-	-	-	-
30	380	410	550	720	890	1080	-	-	-
35	"	440	550	720	890	1080	1290	-	-
40	"	450	550	720	890	1080	1290	1510	1750
45	"	"	580	720	890	1080	1290	1510	1750
50	"	"	600	720	890	1080	1290	1510	1750
55	"	"	"	720	890	1080	1290	1510	1750
60	"	"	"	750	890	1080	1290	1510	1750
65	"	"	"	"	890	1080	1290	1510	1750
70	"	"	"	"	890	1080	1290	1510	1750
75	"	"	"	"	900	1080	1290	1510	1750
80	"	"	"	"	"	1080	1290	1510	1750
85	"	"	"	"	"	1080	1290	1510	1750
90	"	"	"	"	"	"	1290	1510	1750
95	"	"	"	"	"	"	1290	1510	1750
100	"	"	"	"	"	"	1290	1510	1750

BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	500	650	950	1280	-	-	-	-	-
25	460	600	910	1230	1590	-	-	-	-
30	410	560	860	1190	1540	1910	-	-	-
35	"	510	810	1140	1490	1860	2270	-	-
40	"	500	770	1090	1440	1810	2210	2650	3120
45	"	"	720	1040	1390	1760	2160	2590	3060
50	"	"	690	990	1340	1710	2100	2540	3010
55	"	"	"	950	1290	1650	2050	2480	2950
60	"	"	"	900	1240	1600	2000	2420	2890
65	"	"	"	"	1190	1550	1940	2370	2830
70	"	"	"	"	1140	1500	1890	2310	2770
75	"	"	"	"	1120	1450	1830	2260	2710
80	"	"	"	"	"	1390	1780	2200	2650
85	"	"	"	"	"	1350	1730	2140	2600
90	"	"	"	"	"	"	1670	2090	2540
95	"	"	"	"	"	"	1620	2030	2480
100	"	"	"	"	"	"	1610	1970	2420

MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	410	500	690	900	-	-	-	-	-
25	410	500	690	900	1120	-	-	-	-
30	410	500	690	900	1120	1350	-	-	-
35	"	500	690	900	1120	1350	1610	-	-
40	"	500	690	900	1120	1350	1610	1890	2190
45	"	"	690	900	1120	1350	1610	1890	2190
50	"	"	690	900	1120	1350	1610	1890	2190
55	"	"	"	900	1120	1350	1610	1890	2190
60	"	"	"	900	1120	1350	1610	1890	2190
65	"	"	"	"	1120	1350	1610	1890	2190
70	"	"	"	"	1120	1350	1610	1890	2190
75	"	"	"	"	1120	1350	1610	1890	2190
80	"	"	"	"	"	1350	1610	1890	2190
85	"	"	"	"	"	1350	1610	1890	2190
90	"	"	"	"	"	"	1610	1890	2190
95	"	"	"	"	"	"	1610	1890	2190
100	"	"	"	"	"	"	1610	1890	2190

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/40/1.3/1.25 – Tensile Development and Lap Lengths

f'_c=40 MPa, k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	380	460	680	920	-	-	-	-	-
25	380	450	650	880	1130	-	-	-	-
30	380	450	620	850	1100	1370	-	-	-
35	"	450	600	810	1060	1330	1620	-	-
40	"	450	600	780	1030	1290	1580	1890	2230
45	"	"	600	750	990	1260	1540	1850	2190
50	"	"	600	750	960	1220	1510	1810	2150
55	"	"	"	750	920	1180	1470	1770	2110
60	"	"	"	750	900	1150	1430	1730	2070
65	"	"	"	"	900	1110	1390	1690	2020
70	"	"	"	"	900	1070	1350	1650	1980
75	"	"	"	"	900	1060	1310	1610	1940
80	"	"	"	"	"	1060	1270	1570	1900
85	"	"	"	"	"	1060	1240	1530	1860
90	"	"	"	"	"	"	1210	1490	1820
95	"	"	"	"	"	"	1210	1450	1770
100	"	"	"	"	"	"	1210	1410	1730

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	310	360	500	640	-	-	-	-	-
25	340	380	500	640	800	-	-	-	-
30	380	410	500	640	800	970	-	-	-
35	"	440	510	640	800	970	1150	-	-
40	"	450	540	640	800	970	1150	1350	1560
45	"	"	580	650	800	970	1150	1350	1560
50	"	"	600	680	800	970	1150	1350	1560
55	"	"	"	710	800	970	1150	1350	1560
60	"	"	"	750	810	970	1150	1350	1560
65	"	"	"	"	850	970	1150	1350	1560
70	"	"	"	"	880	970	1150	1350	1560
75	"	"	"	"	900	990	1150	1350	1560
80	"	"	"	"	"	1030	1150	1350	1560
85	"	"	"	"	"	1060	1150	1350	1560
90	"	"	"	"	"	"	1160	1350	1560
95	"	"	"	"	"	"	1200	1350	1560
100	"	"	"	"	"	"	1210	1350	1560

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	450	580	850	1150	-	-	-	-	-
25	410	540	810	1100	1420	-	-	-	-
30	380	500	770	1060	1370	1710	-	-	-
35	"	460	730	1020	1330	1660	2030	-	-
40	"	450	690	970	1280	1620	1980	2370	2790
45	"	"	650	930	1240	1570	1930	2320	2740
50	"	"	620	890	1200	1530	1880	2270	2690
55	"	"	"	850	1150	1480	1830	2220	2640
60	"	"	"	800	1110	1430	1790	2170	2580
65	"	"	"	"	1060	1390	1740	2120	2530
70	"	"	"	"	1020	1340	1690	2070	2480
75	"	"	"	"	1000	1290	1640	2020	2430
80	"	"	"	"	"	1250	1590	1970	2370
85	"	"	"	"	"	1210	1540	1920	2320
90	"	"	"	"	"	"	1500	1870	2270
95	"	"	"	"	"	"	1450	1820	2220
100	"	"	"	"	"	"	1440	1770	2160

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	380	450	620	800	-	-	-	-	-
25	380	450	620	800	1000	-	-	-	-
30	380	450	620	800	1000	1210	-	-	-
35	"	450	620	800	1000	1210	1440	-	-
40	"	450	620	800	1000	1210	1440	1690	1950
45	"	"	620	800	1000	1210	1440	1690	1950
50	"	"	620	800	1000	1210	1440	1690	1950
55	"	"	"	800	1000	1210	1440	1690	1950
60	"	"	"	800	1000	1210	1440	1690	1950
65	"	"	"	"	1000	1210	1440	1690	1950
70	"	"	"	"	1000	1210	1440	1690	1950
75	"	"	"	"	1000	1210	1440	1690	1950
80	"	"	"	"	"	1210	1440	1690	1950
85	"	"	"	"	"	1210	1440	1690	1950
90	"	"	"	"	"	"	1440	1690	1950
95	"	"	"	"	"	"	1440	1690	1950
100	"	"	"	"	"	"	1440	1690	1950

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/50/1.3/1.25 – Tensile Development and Lap Lengths

f'_c=50 MPa, k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	380	450	610	820	-	-	-	-	-
25	380	450	600	790	1010	-	-	-	-
30	380	450	600	760	980	1220	-	-	-
35	"	450	600	750	950	1190	1450	-	-
40	"	450	600	750	920	1160	1420	1690	2000
45	"	"	600	750	900	1120	1380	1660	1960
50	"	"	600	750	900	1090	1350	1620	1920
55	"	"	"	750	900	1060	1310	1590	1890
60	"	"	"	750	900	1060	1280	1550	1850
65	"	"	"	"	900	1060	1240	1520	1810
70	"	"	"	"	900	1060	1210	1480	1770
75	"	"	"	"	900	1060	1210	1440	1740
80	"	"	"	"	"	1060	1210	1410	1700
85	"	"	"	"	"	1060	1210	1370	1660
90	"	"	"	"	"	"	1210	1360	1620
95	"	"	"	"	"	"	1210	1360	1590
100	"	"	"	"	"	"	1210	1360	1550

MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	310	350	440	570	-	-	-	-	-
25	340	380	460	570	710	-	-	-	-
30	380	410	480	580	710	870	-	-	-
35	"	440	510	590	710	870	1030	-	-
40	"	450	540	620	720	870	1030	1210	1400
45	"	"	580	650	730	870	1030	1210	1400
50	"	"	600	680	750	870	1030	1210	1400
55	"	"	"	710	780	870	1030	1210	1400
60	"	"	"	750	810	900	1030	1210	1400
65	"	"	"	"	850	930	1030	1210	1400
70	"	"	"	"	880	960	1030	1210	1400
75	"	"	"	"	900	990	1060	1210	1400
80	"	"	"	"	"	1030	1090	1210	1400
85	"	"	"	"	"	1060	1130	1210	1400
90	"	"	"	"	"	"	1160	1230	1400
95	"	"	"	"	"	"	1200	1260	1400
100	"	"	"	"	"	"	1210	1300	1400

BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	400	520	760	1030	-	-	-	-	-
25	380	480	730	990	1270	-	-	-	-
30	380	450	690	950	1230	1530	-	-	-
35	"	450	650	910	1190	1490	1810	-	-
40	"	450	610	870	1150	1450	1770	2120	2500
45	"	"	600	830	1110	1410	1730	2070	2450
50	"	"	600	800	1070	1360	1680	2030	2400
55	"	"	"	760	1030	1320	1640	1980	2360
60	"	"	"	750	990	1280	1600	1940	2310
65	"	"	"	"	950	1240	1550	1890	2260
70	"	"	"	"	910	1200	1510	1850	2220
75	"	"	"	"	900	1160	1470	1800	2170
80	"	"	"	"	"	1120	1420	1760	2120
85	"	"	"	"	"	1080	1380	1710	2080
90	"	"	"	"	"	"	1340	1670	2030
95	"	"	"	"	"	"	1300	1620	1980
100	"	"	"	"	"	"	1290	1580	1940

MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
20	380	450	600	750	-	-	-	-	-
25	380	450	600	750	900	-	-	-	-
30	380	450	600	750	900	1080	-	-	-
35	"	450	600	750	900	1080	1290	-	-
40	"	450	600	750	900	1080	1290	1510	1750
45	"	"	600	750	900	1080	1290	1510	1750
50	"	"	600	750	900	1080	1290	1510	1750
55	"	"	"	750	900	1080	1290	1510	1750
60	"	"	"	750	900	1080	1290	1510	1750
65	"	"	"	"	900	1080	1290	1510	1750
70	"	"	"	"	900	1080	1290	1510	1750
75	"	"	"	"	900	1080	1290	1510	1750
80	"	"	"	"	"	1080	1290	1510	1750
85	"	"	"	"	"	1080	1290	1510	1750
90	"	"	"	"	"	"	1290	1510	1750
95	"	"	"	"	"	"	1290	1510	1750
100	"	"	"	"	"	"	1290	1510	1750

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE G/≥65/1.3/1.25 – Tensile Development and Lap Lengths

f'_c≥65 MPa, k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	380	450	600	750	-	-	-	-	-
25	380	450	600	750	900	-	-	-	-
30	380	450	600	750	900	1070	-	-	-
35	"	450	600	750	900	1060	1270	-	-
40	"	450	600	750	900	1060	1240	1490	1750
45	"	"	600	750	900	1060	1210	1450	1720
50	"	"	600	750	900	1060	1210	1420	1690
55	"	"	"	750	900	1060	1210	1390	1650
60	"	"	"	750	900	1060	1210	1360	1620
65	"	"	"	"	900	1060	1210	1360	1590
70	"	"	"	"	900	1060	1210	1360	1560
75	"	"	"	"	900	1060	1210	1360	1520
80	"	"	"	"	"	1060	1210	1360	1510
85	"	"	"	"	"	1060	1210	1360	1510
90	"	"	"	"	"	"	1210	1360	1510
95	"	"	"	"	"	"	1210	1360	1510
100	"	"	"	"	"	"	1210	1360	1510

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	310	350	440	530	-	-	-	-	-
25	340	380	460	550	630	-	-	-	-
30	380	410	480	570	650	760	-	-	-
35	"	440	510	590	680	770	900	-	-
40	"	450	540	620	700	790	900	1060	1230
45	"	"	580	650	730	820	900	1060	1230
50	"	"	600	680	750	840	930	1060	1230
55	"	"	"	710	780	870	950	1060	1230
60	"	"	"	750	810	900	970	1060	1230
65	"	"	"	"	850	930	1000	1080	1230
70	"	"	"	"	880	960	1030	1110	1230
75	"	"	"	"	900	990	1060	1140	1230
80	"	"	"	"	"	1030	1090	1170	1240
85	"	"	"	"	"	1060	1130	1200	1270
90	"	"	"	"	"	"	1160	1230	1300
95	"	"	"	"	"	"	1200	1260	1330
100	"	"	"	"	"	"	1210	1300	1360

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	380	450	670	900	-	-	-	-	-
25	380	450	640	870	1110	-	-	-	-
30	380	450	600	830	1080	1340	-	-	-
35	"	450	600	800	1040	1310	1590	-	-
40	"	450	600	760	1010	1270	1550	1860	2190
45	"	"	600	750	970	1230	1510	1820	2150
50	"	"	600	750	940	1200	1480	1780	2110
55	"	"	"	750	900	1160	1440	1740	2070
60	"	"	"	750	900	1120	1400	1700	2030
65	"	"	"	"	900	1090	1360	1660	1990
70	"	"	"	"	900	1060	1330	1620	1940
75	"	"	"	"	900	1060	1290	1580	1900
80	"	"	"	"	"	1060	1250	1540	1860
85	"	"	"	"	"	1060	1210	1500	1820
90	"	"	"	"	"	"	1210	1460	1780
95	"	"	"	"	"	"	1210	1430	1740
100	"	"	"	"	"	"	1210	1390	1700

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUM REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	380	450	600	750	-	-	-	-	-
25	380	450	600	750	900	-	-	-	-
30	380	450	600	750	900	1060	-	-	-
35	"	450	600	750	900	1060	1210	-	-
40	"	450	600	750	900	1060	1210	1360	1530
45	"	"	600	750	900	1060	1210	1360	1530
50	"	"	600	750	900	1060	1210	1360	1530
55	"	"	"	750	900	1060	1210	1360	1530
60	"	"	"	750	900	1060	1210	1360	1530
65	"	"	"	"	900	1060	1210	1360	1530
70	"	"	"	"	900	1060	1210	1360	1530
75	"	"	"	"	900	1060	1210	1360	1530
80	"	"	"	"	"	1060	1210	1360	1530
85	"	"	"	"	"	1060	1210	1360	1530
90	"	"	"	"	"	"	1210	1360	1530
95	"	"	"	"	"	"	1210	1360	1530
100	"	"	"	"	"	"	1210	1360	1530

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ (≥$L_{sy.t.min}$) and/or $L_{sy.t.lap}$ (≥$L_{sy.t.lap.min}$).

INDEX: COVER-CONTROLLED TABLES – TENSILE DEVELOPMENT LENGHTHS ($L_{sy.tb}$, $L_{sy.t.min}$) AND LAP LENGTHS ($L_{sy.tb.lap}$, $L_{sy.t.lap.min}$)

Note: To produce the Cover-Controlled Tables, it was assumed when using Eq. 1c, that basic factor ξ_{cd}=1.0 (i.e. normal-density concrete) and basic factor ξ_{bc}=1.0 (i.e. uncoated or bare steel bars).

TABLE CC/A1/1.0/1.00(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	390	500	740	1000	1230	1490	1760	2060	2430
$L_{sy.t.min}$	320	390	540	700	870	1050	1250	1470	1700
$L_{sy.tb.lap}$	390	500	740	1000	1230	1490	1760	2060	2430
$L_{sy.t.lap.min}$	320	390	540	700	870	1050	1250	1470	1700

(ii) f'_c=25 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	350	450	660	890	1100	1330	1580	1840	2170
$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
$L_{sy.tb.lap}$	350	450	660	890	1100	1330	1580	1840	2170
$L_{sy.t.lap.min}$	290	350	480	630	780	940	1120	1310	1520

(iii) f'_c=32 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	310	400	590	790	980	1180	1390	1630	1920
$L_{sy.t.min}$	260	310	430	550	690	830	990	1160	1350
$L_{sy.tb.lap}$	310	400	590	790	980	1180	1390	1630	1920
$L_{sy.t.lap.min}$	290	350	460	580	700	830	990	1160	1350

(iv) f'_c=40 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	360	520	710	870	1050	1250	1460	1720
$L_{sy.t.min}$	240	280	380	490	610	740	890	1040	1200
$L_{sy.tb.lap}$	290	360	520	710	870	1050	1250	1460	1720
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1200

(v) f'_c=50 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	350	470	630	780	940	1120	1300	1540
$L_{sy.t.min}$	240	270	340	440	550	670	790	930	1080
$L_{sy.tb.lap}$	290	350	470	630	780	940	1120	1300	1540
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1160

(vi) f'_c≥65 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	350	460	580	700	830	980	1140	1350
$L_{sy.t.min}$	240	270	330	410	490	590	690	810	940
$L_{sy.tb.lap}$	290	350	460	580	700	830	980	1140	1350
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1160

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4 k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A1/1.0/1.00(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=20 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**390**	**500**	**740**	**1000**	**1230**	**1490**	**1760**	**2060**	**2430**
	$L_{sy.t.min}$	320	390	540	700	870	1050	1250	1470	1700
	$L_{sy.tb.lap}$	**390**	**500**	**740**	**1000**	**1230**	**1490**	**1760**	**2060**	**2430**
	$L_{sy.t.lap.min}$	320	390	540	700	870	1050	1250	1470	1700
(d_b)	$L_{sy.tb}$	**39.0**	**41.7**	**46.3**	**50.0**	**51.3**	**53.2**	**55.0**	**57.2**	**60.8**
	$L_{sy.t.min}$	32.0	32.5	33.8	35.0	36.3	37.5	39.1	40.8	42.5
	$L_{sy.tb.lap}$	**39.0**	**41.7**	**46.3**	**50.0**	**51.3**	**53.2**	**55.0**	**57.2**	**60.8**
	$L_{sy.t.lap.min}$	32.0	32.5	33.8	35.0	36.3	37.5	39.1	40.8	42.5

(ii) (f'_c=25 MPa, c_{req}=20 mm) OR (f'_c=32 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**350**	**450**	**660**	**890**	**1100**	**1330**	**1580**	**1840**	**2170**
	$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
	$L_{sy.tb.lap}$	**350**	**450**	**660**	**890**	**1100**	**1330**	**1580**	**1840**	**2170**
	$L_{sy.t.lap.min}$	290	350	480	630	780	940	1120	1310	1520
(d_b)	$L_{sy.tb}$	**35.0**	**37.5**	**41.3**	**44.5**	**45.8**	**47.5**	**49.4**	**51.1**	**54.3**
	$L_{sy.t.min}$	29.0	29.2	30.0	31.5	32.5	33.6	35.0	36.4	38.0
	$L_{sy.tb.lap}$	**35.0**	**37.5**	**41.3**	**44.5**	**45.8**	**47.5**	**49.4**	**51.1**	**54.3**
	$L_{sy.t.lap.min}$	29.0	29.2	30.0	31.5	32.5	33.6	35.0	36.4	38.0

(iii) (f'_c=40 MPa, c_{req}=20 mm) OR ($f'_c \geq$50 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**360**	**520**	**710**	**870**	**1050**	**1250**	**1460**	**1720**
	$L_{sy.t.min}$	240	280	380	490	610	740	890	1040	1200
	$L_{sy.tb.lap}$	**290**	**360**	**520**	**710**	**870**	**1050**	**1250**	**1460**	**1720**
	$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1200
(d_b)	$L_{sy.tb}$	**29.0**	**30.0**	**32.5**	**35.5**	**36.3**	**37.5**	**39.1**	**40.6**	**43.0**
	$L_{sy.t.min}$	24.0	23.3	23.8	24.5	25.4	26.4	27.8	28.9	30.0
	$L_{sy.tb.lap}$	**29.0**	**30.0**	**32.5**	**35.5**	**36.3**	**37.5**	**39.1**	**40.6**	**43.0**
	$L_{sy.t.lap.min}$	29.0	29.2	28.8	29.0	29.2	28.9	29.1	28.9	30.0

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A2/1.0/1.00(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A2 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa, c_{req} = 50 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	50	50	50	50	50	50	50	50	50
$L_{sy.tb}$	320	390	540	770	1040	1330	1640	1970	2340
$L_{sy.t.min}$	320	390	540	700	870	1050	1250	1470	1700
$L_{sy.tb.lap}$	320	390	540	770	1040	1330	1640	1970	2340
$L_{sy.t.lap.min}$	320	390	540	700	870	1050	1250	1470	1700

(ii) f'_c=25 MPa, c_{req} = 30 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	30	30	30	30	30	30	35	40	40
$L_{sy.tb}$	290	390	600	830	1070	1330	1580	1840	2170
$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
$L_{sy.tb.lap}$	290	390	600	830	1070	1330	1580	1840	2170
$L_{sy.t.lap.min}$	290	350	480	630	780	940	1120	1310	1520

(iii) f'_c=32 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	290	370	560	760	980	1180	1390	1630	1920
$L_{sy.t.min}$	260	310	430	550	690	830	990	1160	1350
$L_{sy.tb.lap}$	290	370	560	760	980	1180	1390	1630	1920
$L_{sy.t.lap.min}$	290	350	460	580	700	830	990	1160	1350

(iv) f'_c=40 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	360	520	710	870	1050	1250	1460	1720
$L_{sy.t.min}$	240	280	380	490	610	740	890	1040	1200
$L_{sy.tb.lap}$	290	360	520	710	870	1050	1250	1460	1720
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1200

(v) f'_c=50 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	350	470	630	780	940	1120	1300	1540
$L_{sy.t.min}$	240	270	340	440	550	670	790	930	1080
$L_{sy.tb.lap}$	290	350	470	630	780	940	1120	1300	1540
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1160

(vi) f'_c≥65 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	350	460	580	700	830	980	1140	1350
$L_{sy.t.min}$	240	270	330	410	490	590	690	810	940
$L_{sy.tb.lap}$	290	350	460	580	700	830	980	1140	1350
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1160

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A2/1.0/1.00(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A2 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=20 MPa, c_{req}=50 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**320**	**390**	**540**	**770**	**1040**	**1330**	**1640**	**1970**	**2340**
	$L_{sy.t.min}$	320	390	540	700	870	1050	1250	1470	1700
	$L_{sy.tb.lap}$	**320**	**390**	**540**	**770**	**1040**	**1330**	**1640**	**1970**	**2340**
	$L_{sy.t.lap.min}$	320	390	540	700	870	1050	1250	1470	1700
(d_b)	$L_{sy.tb}$	**32.0**	**32.5**	**33.8**	**38.5**	**43.3**	**47.5**	**51.3**	**54.7**	**58.5**
	$L_{sy.t.min}$	32.0	32.5	33.8	35.0	36.3	37.5	39.1	40.8	42.5
	$L_{sy.tb.lap}$	**32.0**	**32.5**	**33.8**	**38.5**	**43.3**	**47.5**	**51.3**	**54.7**	**58.5**
	$L_{sy.t.lap.min}$	32.0	32.5	33.8	35.0	36.3	37.5	39.1	40.8	42.5

(ii) (f'_c=25 MPa, c_{req}=30 mm) OR (f'_c=32 MPa, c_{req}=25 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**390**	**600**	**830**	**1070**	**1330**	**1580**	**1840**	**2170**
	$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
	$L_{sy.tb.lap}$	**290**	**390**	**600**	**830**	**1070**	**1330**	**1580**	**1840**	**2170**
	$L_{sy.t.lap.min}$	290	350	480	630	780	940	1120	1310	1520
(d_b)	$L_{sy.tb}$	**29.0**	**32.5**	**37.5**	**41.5**	**44.6**	**47.5**	**49.4**	**51.1**	**54.3**
	$L_{sy.t.min}$	29.0	29.2	30.0	31.5	32.5	33.6	35.0	36.4	38.0
	$L_{sy.tb.lap}$	**29.0**	**32.5**	**37.5**	**41.5**	**44.6**	**47.5**	**49.4**	**51.1**	**54.3**
	$L_{sy.t.lap.min}$	29.0	29.2	30.0	31.5	32.5	33.6	35.0	36.4	38.0

(iii) (f'_c=40 MPa, c_{req}=20 mm) OR ($f'_c \geq$50 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**360**	**520**	**710**	**870**	**1050**	**1250**	**1460**	**1720**
	$L_{sy.t.min}$	240	280	380	490	610	740	890	1040	1200
	$L_{sy.tb.lap}$	**290**	**360**	**520**	**710**	**870**	**1050**	**1250**	**1460**	**1720**
	$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1200
(d_b)	$L_{sy.tb}$	**29.0**	**30.0**	**32.5**	**35.5**	**36.3**	**37.5**	**39.1**	**40.6**	**43.0**
	$L_{sy.t.min}$	24.0	23.3	23.8	24.5	25.4	26.4	27.8	28.9	30.0
	$L_{sy.tb.lap}$	**29.0**	**30.0**	**32.5**	**35.5**	**36.3**	**37.5**	**39.1**	**40.6**	**43.0**
	$L_{sy.t.lap.min}$	29.0	29.2	28.8	29.0	29.2	28.9	29.1	28.9	30.0

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/B1/1.0/1.00(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: B1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=25 MPa, c_{req} = 60 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	60	60	60	60	60	60	60	60	60
$L_{sy.tb}$	290	350	480	630	860	1120	1390	1690	2010
$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
$L_{sy.tb.lap}$	290	350	480	630	860	1120	1390	1690	2010
$L_{sy.t.lap.min}$	290	350	480	630	780	940	1120	1310	1520

(ii) f'_c=32 MPa, c_{req} = 40 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	40	40	40	40	40	40	40	40	40
$L_{sy.tb}$	290	350	470	670	880	1110	1360	1630	1920
$L_{sy.t.min}$	290	350	430	550	690	830	990	1160	1350
$L_{sy.tb.lap}$	290	350	470	670	880	1110	1360	1630	1920
$L_{sy.t.lap.min}$	290	350	460	580	700	830	990	1160	1350

(iii) f'_c=40 MPa, c_{req} = 30 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	30	30	30	30	30	30	35	40	40
$L_{sy.tb}$	290	350	470	650	850	1050	1250	1460	1720
$L_{sy.t.min}$	290	320	380	490	610	740	890	1040	1200
$L_{sy.tb.lap}$	290	350	470	650	850	1050	1250	1460	1720
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1200

(iv) f'_c=50 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	290	350	460	610	780	940	1120	1300	1540
$L_{sy.t.min}$	260	290	350	440	550	670	790	930	1080
$L_{sy.tb.lap}$	290	350	460	610	780	940	1120	1300	1540
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1160

(v) $f'_c \geq$65 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	290	350	460	580	700	830	980	1140	1350
$L_{sy.t.min}$	260	290	350	420	490	590	690	810	940
$L_{sy.tb.lap}$	290	350	460	580	700	830	980	1140	1350
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1160

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/B1/1.0/1.00(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: B1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=25 MPa, c_{req}=60 mm) OR (f'_c=32 MPa, c_{req}=40 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**350**	**480**	**670**	**880**	**1120**	**1390**	**1690**	**2010**
	$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
	$L_{sy.tb.lap}$	**290**	**350**	**480**	**670**	**880**	**1120**	**1390**	**1690**	**2010**
	$L_{sy.t.lap.min}$	290	350	480	630	780	940	1120	1310	1520
(d_b)	$L_{sy.tb}$	**29.0**	**29.2**	**30.0**	**33.5**	**36.7**	**40.0**	**43.4**	**46.9**	**50.3**
	$L_{sy.t.min}$	29.0	29.2	30.0	31.5	32.5	33.6	35.0	36.4	38.0
	$L_{sy.tb.lap}$	**29.0**	**29.2**	**30.0**	**33.5**	**36.7**	**40.0**	**43.4**	**46.9**	**50.3**
	$L_{sy.t.lap.min}$	29.0	29.2	30.0	31.5	32.5	33.6	35.0	36.4	38.0

(ii) (f'_c=40 MPa, c_{req}=30 mm) OR ($f'_c \geq$50 MPa, c_{req}=25 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**350**	**470**	**650**	**850**	**1050**	**1250**	**1460**	**1720**
	$L_{sy.t.min}$	290	320	380	490	610	740	890	1040	1200
	$L_{sy.tb.lap}$	**290**	**350**	**470**	**650**	**850**	**1050**	**1250**	**1460**	**1720**
	$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1200
(d_b)	$L_{sy.tb}$	**29.0**	**29.2**	**29.4**	**32.5**	**35.4**	**37.5**	**39.1**	**40.6**	**43.0**
	$L_{sy.t.min}$	29.0	26.7	23.8	24.5	25.4	26.4	27.8	28.9	30.0
	$L_{sy.tb.lap}$	**29.0**	**29.2**	**29.4**	**32.5**	**35.4**	**37.5**	**39.1**	**40.6**	**43.0**
	$L_{sy.t.lap.min}$	29.0	29.2	28.8	29.0	29.2	28.9	29.1	28.9	30.0

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A1/1.3/1.00(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	510	650	960	1300	1600	1940	2290	2680	3160
$L_{sy.t.min}$	420	510	700	910	1130	1370	1630	1910	2210
$L_{sy.tb.lap}$	510	650	960	1300	1600	1940	2290	2680	3160
$L_{sy.t.lap.min}$	420	510	700	910	1130	1370	1630	1910	2210

(ii) f'_c=25 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	450	590	860	1160	1440	1730	2050	2400	2830
$L_{sy.t.min}$	370	460	630	810	1010	1230	1460	1710	1980
$L_{sy.tb.lap}$	450	590	860	1160	1440	1730	2050	2400	2830
$L_{sy.t.lap.min}$	380	460	630	810	1010	1230	1460	1710	1980

(iii) f'_c=32 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	400	520	760	1030	1270	1530	1810	2120	2500
$L_{sy.t.min}$	330	400	550	720	890	1080	1290	1510	1750
$L_{sy.tb.lap}$	400	520	760	1030	1270	1530	1810	2120	2500
$L_{sy.t.lap.min}$	380	450	600	750	900	1080	1290	1510	1750

(iv) f'_c=40 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	460	680	920	1130	1370	1620	1890	2230
$L_{sy.t.min}$	310	360	500	640	800	970	1150	1350	1560
$L_{sy.tb.lap}$	380	460	680	920	1130	1370	1620	1890	2230
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1560

(v) f'_c=50 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	450	610	820	1010	1220	1450	1690	2000
$L_{sy.t.min}$	310	350	440	570	710	870	1030	1210	1400
$L_{sy.tb.lap}$	380	450	610	820	1010	1220	1450	1690	2000
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1510

(vi) $f'_c \geq$65 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	450	600	750	900	1070	1270	1490	1750
$L_{sy.t.min}$	310	350	440	530	630	760	900	1060	1230
$L_{sy.tb.lap}$	380	450	600	750	900	1070	1270	1490	1750
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1510

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A1/1.3/1.00(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=20 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**510**	**650**	**960**	**1300**	**1600**	**1940**	**2290**	**2680**	**3160**
	$L_{sy.t.min}$	420	510	700	910	1130	1370	1630	1910	2210
	$L_{sy.tb.lap}$	**510**	**650**	**960**	**1300**	**1600**	**1940**	**2290**	**2680**	**3160**
	$L_{sy.t.lap.min}$	420	510	700	910	1130	1370	1630	1910	2210
(d_b)	$L_{sy.tb}$	**51.0**	**54.2**	**60.0**	**65.0**	**66.7**	**69.3**	**71.6**	**74.4**	**79.0**
	$L_{sy.t.min}$	42.0	42.5	43.8	45.5	47.1	48.9	50.9	53.1	55.3
	$L_{sy.tb.lap}$	**51.0**	**54.2**	**60.0**	**65.0**	**66.7**	**69.3**	**71.6**	**74.4**	**79.0**
	$L_{sy.t.lap.min}$	42.0	42.5	43.8	45.5	47.1	48.9	50.9	53.1	55.3

(ii) (f'_c=25 MPa, c_{req}=20 mm) OR (f'_c=32 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**450**	**590**	**860**	**1160**	**1440**	**1730**	**2050**	**2400**	**2830**
	$L_{sy.t.min}$	370	460	630	810	1010	1230	1460	1710	1980
	$L_{sy.tb.lap}$	**450**	**590**	**860**	**1160**	**1440**	**1730**	**2050**	**2400**	**2830**
	$L_{sy.t.lap.min}$	380	460	630	810	1010	1230	1460	1710	1980
(d_b)	$L_{sy.tb}$	**45.0**	**49.2**	**53.8**	**58.0**	**60.0**	**61.8**	**64.1**	**66.7**	**70.8**
	$L_{sy.t.min}$	37.0	38.3	39.4	40.5	42.1	43.9	45.6	47.5	49.5
	$L_{sy.tb.lap}$	**45.0**	**49.2**	**53.8**	**58.0**	**60.0**	**61.8**	**64.1**	**66.7**	**70.8**
	$L_{sy.t.lap.min}$	38.0	38.3	39.4	40.5	42.1	43.9	45.6	47.5	49.5

(iii) (f'_c=40 MPa, c_{req}=20 mm) OR ($f'_c \geq$50 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**460**	**680**	**920**	**1130**	**1370**	**1620**	**1890**	**2230**
	$L_{sy.t.min}$	310	360	500	640	800	970	1150	1350	1560
	$L_{sy.tb.lap}$	**380**	**460**	**680**	**920**	**1130**	**1370**	**1620**	**1890**	**2230**
	$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1560
(d_b)	$L_{sy.tb}$	**38.0**	**38.3**	**42.5**	**46.0**	**47.1**	**48.9**	**50.6**	**52.5**	**55.8**
	$L_{sy.t.min}$	31.0	30.0	31.3	32.0	33.3	34.6	35.9	37.5	39.0
	$L_{sy.tb.lap}$	**38.0**	**38.3**	**42.5**	**46.0**	**47.1**	**48.9**	**50.6**	**52.5**	**55.8**
	$L_{sy.t.lap.min}$	38.0	37.5	37.5	37.5	37.5	37.9	37.8	37.8	39.0

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4 k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A2/1.3/1.00(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A2 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa, c_{req} = 50 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	50	50	50	50	50	50	50	50	50
$L_{sy.tb}$	420	510	700	1010	1350	1730	2130	2570	3040
$L_{sy.t.min}$	420	510	700	910	1130	1370	1630	1910	2210
$L_{sy.tb.lap}$	420	510	700	1010	1350	1730	2130	2570	3040
$L_{sy.t.lap.min}$	420	510	700	910	1130	1370	1630	1910	2210

(ii) f'_c=25 MPa, c_{req} = 30 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	30	30	30	30	30	30	35	40	40
$L_{sy.tb}$	380	500	780	1070	1390	1730	2050	2400	2830
$L_{sy.t.min}$	380	460	630	810	1010	1230	1460	1710	1980
$L_{sy.tb.lap}$	380	500	780	1070	1390	1730	2050	2400	2830
$L_{sy.t.lap.min}$	380	460	630	810	1010	1230	1460	1710	1980

(iii) f'_c=32 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	380	480	730	990	1270	1530	1810	2120	2500
$L_{sy.t.min}$	340	400	550	720	890	1080	1290	1510	1750
$L_{sy.tb.lap}$	380	480	730	990	1270	1530	1810	2120	2500
$L_{sy.t.lap.min}$	380	450	600	750	900	1080	1290	1510	1750

(iv) f'_c=40 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	460	680	920	1130	1370	1620	1890	2230
$L_{sy.t.min}$	310	360	490	640	800	970	1150	1350	1560
$L_{sy.tb.lap}$	380	460	680	920	1130	1370	1620	1890	2230
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1560

(v) f'_c=50 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	450	610	820	1010	1220	1450	1690	2000
$L_{sy.t.min}$	310	350	440	570	710	870	1030	1210	1400
$L_{sy.tb.lap}$	380	450	610	820	1010	1220	1450	1690	2000
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1510

(vi) f'_c≥65 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	450	600	750	900	1070	1270	1490	1750
$L_{sy.t.min}$	310	350	440	530	630	760	900	1060	1230
$L_{sy.tb.lap}$	380	450	600	750	900	1070	1270	1490	1750
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1510

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A2/1.3/1.00(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A2 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=20 MPa, c_{req}=50 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**420**	**510**	**700**	**1010**	**1350**	**1730**	**2130**	**2570**	**3040**
	$L_{sy.t.min}$	420	510	700	910	1130	1370	1630	1910	2210
	$L_{sy.tb.lap}$	**420**	**510**	**700**	**1010**	**1350**	**1730**	**2130**	**2570**	**3040**
	$L_{sy.t.lap.min}$	420	510	700	910	1130	1370	1630	1910	2210
(d_b)	$L_{sy.tb}$	**42.0**	**42.5**	**43.8**	**50.5**	**56.3**	**61.8**	**66.6**	**71.4**	**76.0**
	$L_{sy.t.min}$	42.0	42.5	43.8	45.5	47.1	48.9	50.9	53.1	55.3
	$L_{sy.tb.lap}$	**42.0**	**42.5**	**43.8**	**50.5**	**56.3**	**61.8**	**66.6**	**71.4**	**76.0**
	$L_{sy.t.lap.min}$	42.0	42.5	43.8	45.5	47.1	48.9	50.9	53.1	55.3

(ii) (f'_c=25 MPa, c_{req}=30 mm) OR (f'_c=32 MPa, c_{req}=25 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**500**	**780**	**1070**	**1390**	**1730**	**2050**	**2400**	**2830**
	$L_{sy.t.min}$	380	460	630	810	1010	1230	1460	1710	1980
	$L_{sy.tb.lap}$	**380**	**500**	**780**	**1070**	**1390**	**1730**	**2050**	**2400**	**2830**
	$L_{sy.t.lap.min}$	380	460	630	810	1010	1230	1460	1710	1980
(d_b)	$L_{sy.tb}$	**38.0**	**41.7**	**48.8**	**53.5**	**57.9**	**61.8**	**64.1**	**66.7**	**70.8**
	$L_{sy.t.min}$	38.0	38.3	39.4	40.5	42.1	43.9	45.6	47.5	49.5
	$L_{sy.tb.lap}$	**38.0**	**41.7**	**48.8**	**53.5**	**57.9**	**61.8**	**64.1**	**66.7**	**70.8**
	$L_{sy.t.lap.min}$	38.0	38.3	39.4	40.5	42.1	43.9	45.6	47.5	49.5

(iii) (f'_c=40 MPa, c_{req}=20 mm) OR ($f'_c \geq$50 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**460**	**680**	**920**	**1130**	**1370**	**1620**	**1890**	**2230**
	$L_{sy.t.min}$	310	360	490	640	800	970	1150	1350	1560
	$L_{sy.tb.lap}$	**380**	**460**	**680**	**920**	**1130**	**1370**	**1620**	**1890**	**2230**
	$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1560
(d_b)	$L_{sy.tb}$	**38.0**	**38.3**	**42.5**	**46.0**	**47.1**	**48.9**	**50.6**	**52.5**	**55.8**
	$L_{sy.t.min}$	31.0	30.0	30.6	32.0	33.3	34.6	35.9	37.5	39.0
	$L_{sy.tb.lap}$	**38.0**	**38.3**	**42.5**	**46.0**	**47.1**	**48.9**	**50.6**	**52.5**	**55.8**
	$L_{sy.t.lap.min}$	38.0	37.5	37.5	37.5	37.5	37.9	37.8	37.8	39.0

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/B1/1.3/1.00(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: B1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=25 MPa, c_{req} = 60 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	60	60	60	60	60	60	60	60	60
$L_{sy.tb}$	380	460	630	810	1120	1450	1810	2190	2610
$L_{sy.t.min}$	380	460	630	810	1010	1230	1460	1710	1980
$L_{sy.tb.lap}$	380	460	630	810	1120	1450	1810	2190	2610
$L_{sy.t.lap.min}$	380	460	630	810	1010	1230	1460	1710	1980

(ii) f'_c=32 MPa, c_{req} = 40 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	40	40	40	40	40	40	40	40	40
$L_{sy.tb}$	380	450	610	870	1150	1450	1770	2120	2500
$L_{sy.t.min}$	380	450	550	720	890	1080	1290	1510	1750
$L_{sy.tb.lap}$	380	450	610	870	1150	1450	1770	2120	2500
$L_{sy.t.lap.min}$	380	450	600	750	900	1080	1290	1510	1750

(iii) f'_c=40 MPa, c_{req} = 30 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	30	30	30	30	30	30	35	40	40
$L_{sy.tb}$	380	450	620	850	1100	1370	1620	1890	2230
$L_{sy.t.min}$	380	410	500	640	800	970	1150	1350	1560
$L_{sy.tb.lap}$	380	450	620	850	1100	1370	1620	1890	2230
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1560

(iv) f'_c=50 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	380	450	600	790	1010	1220	1450	1690	2000
$L_{sy.t.min}$	340	380	460	570	710	870	1030	1210	1400
$L_{sy.tb.lap}$	380	450	600	790	1010	1220	1450	1690	2000
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1510

(v) $f'_c \geq$65 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	380	450	600	750	900	1070	1270	1490	1750
$L_{sy.t.min}$	340	380	460	550	630	760	900	1060	1230
$L_{sy.tb.lap}$	380	450	600	750	900	1070	1270	1490	1750
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1510

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/B1/1.3/1.00(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: B1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.3, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=25 MPa, c_{req}=60 mm) OR (f'_c=32 MPa, c_{req}=40 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**460**	**630**	**870**	**1150**	**1450**	**1810**	**2190**	**2610**
	$L_{sy.t.min}$	380	460	630	810	1010	1230	1460	1710	1980
	$L_{sy.tb.lap}$	**380**	**460**	**630**	**870**	**1150**	**1450**	**1810**	**2190**	**2610**
	$L_{sy.t.lap.min}$	380	460	630	810	1010	1230	1460	1710	1980
(d_b)	$L_{sy.tb}$	**38.0**	**38.3**	**39.4**	**43.5**	**47.9**	**51.8**	**56.6**	**60.8**	**65.3**
	$L_{sy.t.min}$	38.0	38.3	39.4	40.5	42.1	43.9	45.6	47.5	49.5
	$L_{sy.tb.lap}$	**38.0**	**38.3**	**39.4**	**43.5**	**47.9**	**51.8**	**56.6**	**60.8**	**65.3**
	$L_{sy.t.lap.min}$	38.0	38.3	39.4	40.5	42.1	43.9	45.6	47.5	49.5

(ii) (f'_c=40 MPa, c_{req}=30 mm) OR ($f'_c \geq$50 MPa, c_{req}=25 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**450**	**620**	**850**	**1100**	**1370**	**1620**	**1890**	**2230**
	$L_{sy.t.min}$	380	410	500	640	800	970	1150	1350	1560
	$L_{sy.tb.lap}$	**380**	**450**	**620**	**850**	**1100**	**1370**	**1620**	**1890**	**2230**
	$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1560
(d_b)	$L_{sy.tb}$	**38.0**	**37.5**	**38.8**	**42.5**	**45.8**	**48.9**	**50.6**	**52.5**	**55.8**
	$L_{sy.t.min}$	38.0	34.2	31.3	32.0	33.3	34.6	35.9	37.5	39.0
	$L_{sy.tb.lap}$	**38.0**	**37.5**	**38.8**	**42.5**	**45.8**	**48.9**	**50.6**	**52.5**	**55.8**
	$L_{sy.t.lap.min}$	38.0	37.5	37.5	37.5	37.5	37.9	37.8	37.8	39.0

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A1/1.0/1.25(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.0, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	390	500	740	1000	1230	1490	1760	2060	2430
$L_{sy.t.min}$	320	390	540	700	870	1050	1250	1470	1700
$L_{sy.tb.lap}$	490	630	930	1250	1540	1860	2200	2580	3040
$L_{sy.t.lap.min}$	400	490	670	870	1090	1320	1570	1830	2130

(ii) f'_c=25 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	350	450	660	890	1100	1330	1580	1840	2170
$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
$L_{sy.tb.lap}$	440	560	830	1120	1380	1660	1970	2300	2720
$L_{sy.t.lap.min}$	360	440	600	780	970	1180	1400	1640	1900

(iii) f'_c=32 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	310	400	590	790	980	1180	1390	1630	1920
$L_{sy.t.min}$	260	310	430	550	690	830	990	1160	1350
$L_{sy.tb.lap}$	380	500	730	990	1220	1470	1740	2040	2400
$L_{sy.t.lap.min}$	320	390	530	690	860	1040	1240	1450	1680

(iv) f'_c=40 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	360	520	710	870	1050	1250	1460	1720
$L_{sy.t.min}$	240	280	380	490	610	740	890	1040	1200
$L_{sy.tb.lap}$	340	440	660	880	1090	1320	1560	1820	2150
$L_{sy.t.lap.min}$	290	350	480	620	770	930	1110	1300	1500

(v) f'_c=50 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	350	470	630	780	940	1120	1300	1540
$L_{sy.t.min}$	240	270	340	440	550	670	790	930	1080
$L_{sy.tb.lap}$	310	400	590	790	980	1180	1390	1630	1920
$L_{sy.t.lap.min}$	290	350	460	580	700	830	990	1160	1350

(vi) $f'_c \geq$65 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	350	460	580	700	830	980	1140	1350
$L_{sy.t.min}$	240	270	330	410	490	590	690	810	940
$L_{sy.tb.lap}$	290	350	510	690	860	1030	1220	1430	1690
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1180

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A1/1.0/1.25(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | **k_1=1.0, k_7=1.25** {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=20 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**390**	**500**	**740**	**1000**	**1230**	**1490**	**1760**	**2060**	**2430**
	$L_{sy.t.min}$	320	390	540	700	870	1050	1250	1470	1700
	$L_{sy.tb.lap}$	**490**	**630**	**930**	**1250**	**1540**	**1860**	**2200**	**2580**	**3040**
	$L_{sy.t.lap.min}$	400	490	670	870	1090	1320	1570	1830	2130
(d_b)	$L_{sy.tb}$	**39.0**	**41.7**	**46.3**	**50.0**	**51.3**	**53.2**	**55.0**	**57.2**	**60.8**
	$L_{sy.t.min}$	32.0	32.5	33.8	35.0	36.3	37.5	39.1	40.8	42.5
	$L_{sy.tb.lap}$	**49.0**	**52.5**	**58.1**	**62.5**	**64.2**	**66.4**	**68.8**	**71.7**	**76.0**
	$L_{sy.t.lap.min}$	40.0	40.8	41.9	43.5	45.4	47.1	49.1	50.8	53.3

(ii) (f'_c=25 MPa, c_{req}=20 mm) OR (f'_c=32 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**350**	**450**	**660**	**890**	**1100**	**1330**	**1580**	**1840**	**2170**
	$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
	$L_{sy.tb.lap}$	**440**	**560**	**830**	**1120**	**1380**	**1660**	**1970**	**2300**	**2720**
	$L_{sy.t.lap.min}$	360	440	600	780	970	1180	1400	1640	1900
(d_b)	$L_{sy.tb}$	**35.0**	**37.5**	**41.3**	**44.5**	**45.8**	**47.5**	**49.4**	**51.1**	**54.3**
	$L_{sy.t.min}$	29.0	29.2	30.0	31.5	32.5	33.6	35.0	36.4	38.0
	$L_{sy.tb.lap}$	**44.0**	**46.7**	**51.9**	**56.0**	**57.5**	**59.3**	**61.6**	**63.9**	**68.0**
	$L_{sy.t.lap.min}$	36.0	36.7	37.5	39.0	40.4	42.1	43.8	45.6	47.5

(iii) (f'_c=40 MPa, c_{req}=20 mm) OR ($f'_c \geq$50 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**360**	**520**	**710**	**870**	**1050**	**1250**	**1460**	**1720**
	$L_{sy.t.min}$	240	280	380	490	610	740	890	1040	1200
	$L_{sy.tb.lap}$	**340**	**440**	**660**	**880**	**1090**	**1320**	**1560**	**1820**	**2150**
	$L_{sy.t.lap.min}$	290	350	480	620	770	930	1110	1300	1500
(d_b)	$L_{sy.tb}$	**29.0**	**30.0**	**32.5**	**35.5**	**36.3**	**37.5**	**39.1**	**40.6**	**43.0**
	$L_{sy.t.min}$	24.0	23.3	23.8	24.5	25.4	26.4	27.8	28.9	30.0
	$L_{sy.tb.lap}$	**34.0**	**36.7**	**41.3**	**44.0**	**45.4**	**47.1**	**48.8**	**50.6**	**53.8**
	$L_{sy.t.lap.min}$	29.0	29.2	30.0	31.0	32.1	33.2	34.7	36.1	37.5

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A2/1.0/1.25(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A2 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | **k_1=1.0, k_7=1.25** {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa, c_{req} = 50 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	50	50	50	50	50	50	50	50	50
$L_{sy.tb}$	320	390	540	770	1040	1330	1640	1970	2340
$L_{sy.t.min}$	320	390	540	700	870	1050	1250	1470	1700
$L_{sy.tb.lap}$	400	490	670	970	1300	1660	2050	2470	2920
$L_{sy.t.lap.min}$	400	490	670	870	1090	1320	1570	1830	2130

(ii) f'_c=25 MPa, c_{req} = 30 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	30	30	30	30	30	30	35	40	40
$L_{sy.tb}$	290	390	600	830	1070	1330	1580	1840	2170
$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
$L_{sy.tb.lap}$	360	480	750	1030	1340	1660	1970	2300	2720
$L_{sy.t.lap.min}$	360	440	600	780	970	1180	1400	1640	1900

(iii) f'_c=32 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	290	370	560	760	980	1180	1390	1630	1920
$L_{sy.t.min}$	260	310	430	550	690	830	990	1160	1350
$L_{sy.tb.lap}$	350	460	700	950	1220	1470	1740	2040	2400
$L_{sy.t.lap.min}$	320	390	530	690	860	1040	1240	1450	1680

(iv) f'_c=40 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	360	520	710	870	1050	1250	1460	1720
$L_{sy.t.min}$	240	280	380	490	610	740	890	1040	1200
$L_{sy.tb.lap}$	340	440	660	880	1090	1320	1560	1820	2150
$L_{sy.t.lap.min}$	290	350	480	620	770	930	1110	1300	1500

(v) f'_c=50 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	350	470	630	780	940	1120	1300	1540
$L_{sy.t.min}$	240	270	350	440	550	670	790	930	1080
$L_{sy.tb.lap}$	310	400	590	790	980	1180	1390	1630	1920
$L_{sy.t.lap.min}$	290	350	460	580	700	830	990	1160	1350

(vi) $f'_c \geq$65 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	350	460	580	700	830	980	1140	1350
$L_{sy.t.min}$	240	270	330	410	490	590	690	810	940
$L_{sy.tb.lap}$	290	350	510	690	860	1030	1220	1430	1690
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1180

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A2/1.0/1.25(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A2 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.0, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=20 MPa, c_{req}=50 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**320**	**390**	**540**	**770**	**1040**	**1330**	**1640**	**1970**	**2340**
	$L_{sy.t.min}$	320	390	540	700	870	1050	1250	1470	1700
	$L_{sy.tb.lap}$	**400**	**490**	**670**	**970**	**1300**	**1660**	**2050**	**2470**	**2920**
	$L_{sy.t.lap.min}$	400	490	670	870	1090	1320	1570	1830	2130
(d_b)	$L_{sy.tb}$	**32.0**	**32.5**	**33.8**	**38.5**	**43.3**	**47.5**	**51.3**	**54.7**	**58.5**
	$L_{sy.t.min}$	32.0	32.5	33.8	35.0	36.3	37.5	39.1	40.8	42.5
	$L_{sy.tb.lap}$	**40.0**	**40.8**	**41.9**	**48.5**	**54.2**	**59.3**	**64.1**	**68.6**	**73.0**
	$L_{sy.t.lap.min}$	40.0	40.8	41.9	43.5	45.4	47.1	49.1	50.8	53.3

(ii) (f'_c=25 MPa, c_{req}=30 mm) OR (f'_c=32 MPa, c_{req}=25 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**390**	**600**	**830**	**1070**	**1330**	**1580**	**1840**	**2170**
	$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
	$L_{sy.tb.lap}$	**360**	**480**	**750**	**1030**	**1340**	**1660**	**1970**	**2300**	**2720**
	$L_{sy.t.lap.min}$	360	440	600	780	970	1180	1400	1640	1900
(d_b)	$L_{sy.tb}$	**29.0**	**32.5**	**37.5**	**41.5**	**44.6**	**47.5**	**49.4**	**51.1**	**54.3**
	$L_{sy.t.min}$	29.0	29.2	30.0	31.5	32.5	33.6	35.0	36.4	38.0
	$L_{sy.tb.lap}$	**36.0**	**40.0**	**46.9**	**51.5**	**55.8**	**59.3**	**61.6**	**63.9**	**68.0**
	$L_{sy.t.lap.min}$	36.0	36.7	37.5	39.0	40.4	42.1	43.8	45.6	47.5

(iii) (f'_c=40 MPa, c_{req}=20 mm) OR ($f'_c \geq$50 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**360**	**520**	**710**	**870**	**1050**	**1250**	**1460**	**1720**
	$L_{sy.t.min}$	240	280	380	490	610	740	890	1040	1200
	$L_{sy.tb.lap}$	**340**	**440**	**660**	**880**	**1090**	**1320**	**1560**	**1820**	**2150**
	$L_{sy.t.lap.min}$	290	350	480	620	770	930	1110	1300	1500
(d_b)	$L_{sy.tb}$	**29.0**	**30.0**	**32.5**	**35.5**	**36.3**	**37.5**	**39.1**	**40.6**	**43.0**
	$L_{sy.t.min}$	24.0	23.3	23.8	24.5	25.4	26.4	27.8	28.9	30.0
	$L_{sy.tb.lap}$	**34.0**	**36.7**	**41.3**	**44.0**	**45.4**	**47.1**	**48.8**	**50.6**	**53.8**
	$L_{sy.t.lap.min}$	29.0	29.2	30.0	31.0	32.1	33.2	34.7	36.1	37.5

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/B1/1.0/1.25(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: B1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.0, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=25 MPa, c_{req} = 60 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	60	60	60	60	60	60	60	60	60
$L_{sy.tb}$	290	350	480	630	860	1120	1390	1690	2010
$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
$L_{sy.tb.lap}$	360	440	600	780	1080	1390	1740	2110	2510
$L_{sy.t.lap.min}$	360	440	600	780	970	1180	1400	1640	1900

(ii) f'_c=32 MPa, c_{req} = 40 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	40	40	40	40	40	40	40	40	40
$L_{sy.tb}$	290	350	470	670	880	1110	1360	1630	1920
$L_{sy.t.min}$	290	350	430	550	690	830	990	1160	1350
$L_{sy.tb.lap}$	320	390	590	840	1100	1390	1700	2040	2400
$L_{sy.t.lap.min}$	320	390	530	690	860	1040	1240	1450	1680

(iii) f'_c=40 MPa, c_{req} = 30 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	30	30	30	30	30	30	35	40	40
$L_{sy.tb}$	290	350	470	650	850	1050	1250	1460	1720
$L_{sy.t.min}$	290	320	380	490	610	740	890	1040	1200
$L_{sy.tb.lap}$	290	380	590	820	1060	1320	1560	1820	2150
$L_{sy.t.lap.min}$	290	350	480	620	770	930	1110	1300	1500

(iv) f'_c=50 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	290	350	460	610	780	940	1120	1300	1540
$L_{sy.t.min}$	260	290	350	440	550	670	790	930	1080
$L_{sy.tb.lap}$	290	370	560	760	980	1180	1390	1630	1920
$L_{sy.t.lap.min}$	290	350	460	580	700	830	990	1160	1350

(v) $f'_c \geq$65 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	290	350	460	580	700	830	980	1140	1350
$L_{sy.t.min}$	260	290	350	420	490	590	690	810	940
$L_{sy.tb.lap}$	290	350	490	670	860	1030	1220	1430	1690
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1180

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/B1/1.0/1.25(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: B1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.0, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=25 MPa, c_{req}=60 mm) OR (f'_c=32 MPa, c_{req}=40 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**350**	**480**	**670**	**880**	**1120**	**1390**	**1690**	**2010**
	$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
	$L_{sy.tb.lap}$	**360**	**440**	**600**	**840**	**1100**	**1390**	**1740**	**2110**	**2510**
	$L_{sy.t.lap.min}$	360	440	600	780	970	1180	1400	1640	1900
(d_b)	$L_{sy.tb}$	**29.0**	**29.2**	**30.0**	**33.5**	**36.7**	**40.0**	**43.4**	**46.9**	**50.3**
	$L_{sy.t.min}$	29.0	29.2	30.0	31.5	32.5	33.6	35.0	36.4	38.0
	$L_{sy.tb.lap}$	**36.0**	**36.7**	**37.5**	**42.0**	**45.8**	**49.6**	**54.4**	**58.6**	**62.8**
	$L_{sy.t.lap.min}$	36.0	36.7	37.5	39.0	40.4	42.1	43.8	45.6	47.5

(ii) (f'_c=40 MPa, c_{req}=30 mm) OR ($f'_c \geq$50 MPa, c_{req}=25 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**350**	**470**	**650**	**850**	**1050**	**1250**	**1460**	**1720**
	$L_{sy.t.min}$	290	320	380	490	610	740	890	1040	1200
	$L_{sy.tb.lap}$	**290**	**380**	**590**	**820**	**1060**	**1320**	**1560**	**1820**	**2150**
	$L_{sy.t.lap.min}$	290	350	480	620	770	930	1110	1300	1500
(d_b)	$L_{sy.tb}$	**29.0**	**29.2**	**29.4**	**32.5**	**35.4**	**37.5**	**39.1**	**40.6**	**43.0**
	$L_{sy.t.min}$	29.0	26.7	23.8	24.5	25.4	26.4	27.8	28.9	30.0
	$L_{sy.tb.lap}$	**29.0**	**31.7**	**36.9**	**41.0**	**44.2**	**47.1**	**48.8**	**50.6**	**53.8**
	$L_{sy.t.lap.min}$	29.0	29.2	30.0	31.0	32.1	33.2	34.7	36.1	37.5

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4 k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A1/1.3/1.25(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	510	650	960	1300	1600	1940	2290	2680	3160
$L_{sy.t.min}$	420	510	700	910	1130	1370	1630	1910	2210
$L_{sy.tb.lap}$	630	820	1210	1620	2010	2420	2870	3350	3950
$L_{sy.t.lap.min}$	520	640	880	1140	1410	1710	2030	2380	2760

(ii) f'_c=25 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	450	590	860	1160	1440	1730	2050	2400	2830
$L_{sy.t.min}$	370	460	630	810	1010	1230	1460	1710	1980
$L_{sy.tb.lap}$	570	730	1080	1450	1790	2160	2560	3000	3530
$L_{sy.t.lap.min}$	470	570	780	1020	1260	1530	1820	2130	2470

(iii) f'_c=32 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	400	520	760	1030	1270	1530	1810	2120	2500
$L_{sy.t.min}$	330	400	550	720	890	1080	1290	1510	1750
$L_{sy.tb.lap}$	500	650	950	1280	1590	1910	2270	2650	3120
$L_{sy.t.lap.min}$	410	500	690	900	1120	1350	1610	1890	2190

(iv) f'_c=40 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	460	680	920	1130	1370	1620	1890	2230
$L_{sy.t.min}$	310	360	500	640	800	970	1150	1350	1560
$L_{sy.tb.lap}$	450	580	850	1150	1420	1710	2030	2370	2790
$L_{sy.t.lap.min}$	380	450	620	800	1000	1210	1440	1690	1950

(v) f'_c=50 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	450	610	820	1010	1220	1450	1690	2000
$L_{sy.t.min}$	310	350	440	570	710	870	1030	1210	1400
$L_{sy.tb.lap}$	400	520	760	1030	1270	1530	1810	2120	2500
$L_{sy.t.lap.min}$	380	450	600	750	900	1080	1290	1510	1750

(vi) $f'_c \geq$65 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	450	600	750	900	1070	1270	1490	1750
$L_{sy.t.min}$	310	350	440	530	630	760	900	1060	1230
$L_{sy.tb.lap}$	380	450	670	900	1110	1340	1590	1860	2190
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1530

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A1/1.3/1.25(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | **k_1=1.3, k_7=1.25** {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=20 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**510**	**650**	**960**	**1300**	**1600**	**1940**	**2290**	**2680**	**3160**
	$L_{sy.t.min}$	420	510	700	910	1130	1370	1630	1910	2210
	$L_{sy.tb.lap}$	**630**	**820**	**1210**	**1620**	**2010**	**2420**	**2870**	**3350**	**3950**
	$L_{sy.t.lap.min}$	520	640	880	1140	1410	1710	2030	2380	2760
(d_b)	$L_{sy.tb}$	**51.0**	**54.2**	**60.0**	**65.0**	**66.7**	**69.3**	**71.6**	**74.4**	**79.0**
	$L_{sy.t.min}$	42.0	42.5	43.8	45.5	47.1	48.9	50.9	53.1	55.3
	$L_{sy.tb.lap}$	**63.0**	**68.3**	**75.6**	**81.0**	**83.8**	**86.4**	**89.7**	**93.1**	**98.8**
	$L_{sy.t.lap.min}$	52.0	53.3	55.0	57.0	58.8	61.1	63.4	66.1	69.0

(ii) (f'_c=25 MPa, c_{req}=20 mm) OR (f'_c=32 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**450**	**590**	**860**	**1160**	**1440**	**1730**	**2050**	**2400**	**2830**
	$L_{sy.t.min}$	370	460	630	810	1010	1230	1460	1710	1980
	$L_{sy.tb.lap}$	**570**	**730**	**1080**	**1450**	**1790**	**2160**	**2560**	**3000**	**3530**
	$L_{sy.t.lap.min}$	470	570	780	1020	1260	1530	1820	2130	2470
(d_b)	$L_{sy.tb}$	**45.0**	**49.2**	**53.8**	**58.0**	**60.0**	**61.8**	**64.1**	**66.7**	**70.8**
	$L_{sy.t.min}$	37.0	38.3	39.4	40.5	42.1	43.9	45.6	47.5	49.5
	$L_{sy.tb.lap}$	**57.0**	**60.8**	**67.5**	**72.5**	**74.6**	**77.1**	**80.0**	**83.3**	**88.3**
	$L_{sy.t.lap.min}$	47.0	47.5	48.8	51.0	52.5	54.6	56.9	59.2	61.8

(iii) (f'_c=40 MPa, c_{req}=20 mm) OR ($f'_c \geq$50 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**460**	**680**	**920**	**1130**	**1370**	**1620**	**1890**	**2230**
	$L_{sy.t.min}$	310	360	500	640	800	970	1150	1350	1560
	$L_{sy.tb.lap}$	**450**	**580**	**850**	**1150**	**1420**	**1710**	**2030**	**2370**	**2790**
	$L_{sy.t.lap.min}$	380	450	620	800	1000	1210	1440	1690	1950
(d_b)	$L_{sy.tb}$	**38.0**	**38.3**	**42.5**	**46.0**	**47.1**	**48.9**	**50.6**	**52.5**	**55.8**
	$L_{sy.t.min}$	31.0	30.0	31.3	32.0	33.3	34.6	35.9	37.5	39.0
	$L_{sy.tb.lap}$	**45.0**	**48.3**	**53.1**	**57.5**	**59.2**	**61.1**	**63.4**	**65.8**	**69.8**
	$L_{sy.t.lap.min}$	38.0	37.5	38.8	40.0	41.7	43.2	45.0	46.9	48.8

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A2/1.3/1.25(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A2 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$ | k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa, c_{req} = 50 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	50	50	50	50	50	50	50	50	50
$L_{sy.tb}$	420	510	700	1010	1350	1730	2130	2570	3040
$L_{sy.t.min}$	420	510	700	910	1130	1370	1630	1910	2210
$L_{sy.tb.lap}$	520	640	880	1260	1690	2160	2660	3210	3800
$L_{sy.t.lap.min}$	520	640	880	1140	1410	1710	2030	2380	2760

(ii) f'_c=25 MPa, c_{req} = 30 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	30	30	30	30	30	30	35	40	40
$L_{sy.tb}$	380	500	780	1070	1390	1730	2050	2400	2830
$L_{sy.t.min}$	380	460	630	810	1010	1230	1460	1710	1980
$L_{sy.tb.lap}$	470	630	970	1340	1740	2160	2560	3000	3530
$L_{sy.t.lap.min}$	470	570	780	1020	1260	1530	1820	2130	2470

(iii) f'_c=32 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	380	480	730	990	1270	1530	1810	2120	2500
$L_{sy.t.min}$	340	400	550	720	890	1080	1290	1510	1750
$L_{sy.tb.lap}$	460	600	910	1230	1590	1910	2270	2650	3120
$L_{sy.t.lap.min}$	410	500	690	900	1120	1350	1610	1890	2190

(iv) f'_c=40 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	460	680	920	1130	1370	1620	1890	2230
$L_{sy.t.min}$	310	360	500	640	800	970	1150	1350	1560
$L_{sy.tb.lap}$	450	580	850	1150	1420	1710	2030	2370	2790
$L_{sy.t.lap.min}$	380	450	620	800	1000	1210	1440	1690	1950

(v) f'_c=50 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	450	610	820	1010	1220	1450	1690	2000
$L_{sy.t.min}$	310	350	440	570	710	870	1030	1210	1400
$L_{sy.tb.lap}$	400	520	760	1030	1270	1530	1810	2120	2500
$L_{sy.t.lap.min}$	380	450	600	750	900	1080	1290	1510	1750

(vi) f'_c≥65 MPa, c_{req} = 20 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	450	600	750	900	1070	1270	1490	1750
$L_{sy.t.min}$	310	350	440	530	630	760	900	1060	1230
$L_{sy.tb.lap}$	380	450	670	900	1110	1340	1590	1860	2190
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1530

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/A2/1.3/1.25(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: A2 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=20 MPa, c_{req}=50 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**420**	**510**	**700**	**1010**	**1350**	**1730**	**2130**	**2570**	**3040**
	$L_{sy.t.min}$	420	510	700	910	1130	1370	1630	1910	2210
	$L_{sy.tb.lap}$	**520**	**640**	**880**	**1260**	**1690**	**2160**	**2660**	**3210**	**3800**
	$L_{sy.t.lap.min}$	520	640	880	1140	1410	1710	2030	2380	2760
(d_b)	$L_{sy.tb}$	**42.0**	**42.5**	**43.8**	**50.5**	**56.3**	**61.8**	**66.6**	**71.4**	**76.0**
	$L_{sy.t.min}$	42.0	42.5	43.8	45.5	47.1	48.9	50.9	53.1	55.3
	$L_{sy.tb.lap}$	**52.0**	**53.3**	**55.0**	**63.0**	**70.4**	**77.1**	**83.1**	**89.2**	**95.0**
	$L_{sy.t.lap.min}$	52.0	53.3	55.0	57.0	58.8	61.1	63.4	66.1	69.0

(ii) (f'_c=25 MPa, c_{req}=30 mm) OR (f'_c=32 MPa, c_{req}=25 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**500**	**780**	**1070**	**1390**	**1730**	**2050**	**2400**	**2830**
	$L_{sy.t.min}$	380	460	630	810	1010	1230	1460	1710	1980
	$L_{sy.tb.lap}$	**470**	**630**	**970**	**1340**	**1740**	**2160**	**2560**	**3000**	**3530**
	$L_{sy.t.lap.min}$	470	570	780	1020	1260	1530	1820	2130	2470
(d_b)	$L_{sy.tb}$	**38.0**	**41.7**	**48.8**	**53.5**	**57.9**	**61.8**	**64.1**	**66.7**	**70.8**
	$L_{sy.t.min}$	38.0	38.3	39.4	40.5	42.1	43.9	45.6	47.5	49.5
	$L_{sy.tb.lap}$	**47.0**	**52.5**	**60.6**	**67.0**	**72.5**	**77.1**	**80.0**	**83.3**	**88.3**
	$L_{sy.t.lap.min}$	47.0	47.5	48.8	51.0	52.5	54.6	56.9	59.2	61.8

(iii) (f'_c=40 MPa, c_{req}=20 mm) OR (f'_c≥50 MPa, c_{req}=20 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**460**	**680**	**920**	**1130**	**1370**	**1620**	**1890**	**2230**
	$L_{sy.t.min}$	310	360	500	640	800	970	1150	1350	1560
	$L_{sy.tb.lap}$	**450**	**580**	**850**	**1150**	**1420**	**1710**	**2030**	**2370**	**2790**
	$L_{sy.t.lap.min}$	380	450	620	800	1000	1210	1440	1690	1950
(d_b)	$L_{sy.tb}$	**38.0**	**38.3**	**42.5**	**46.0**	**47.1**	**48.9**	**50.6**	**52.5**	**55.8**
	$L_{sy.t.min}$	31.0	30.0	31.3	32.0	33.3	34.6	35.9	37.5	39.0
	$L_{sy.tb.lap}$	**45.0**	**48.3**	**53.1**	**57.5**	**59.2**	**61.1**	**63.4**	**65.8**	**69.8**
	$L_{sy.t.lap.min}$	38.0	37.5	38.8	40.0	41.7	43.2	45.0	46.9	48.8

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/B1/1.3/1.25(a) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: B1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=25 MPa, c_{req} = 60 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	60	60	60	60	60	60	60	60	60
$L_{sy.tb}$	380	460	630	810	1120	1450	1810	2190	2610
$L_{sy.t.min}$	380	460	630	810	1010	1230	1460	1710	1980
$L_{sy.tb.lap}$	470	570	780	1020	1400	1810	2260	2740	3270
$L_{sy.t.lap.min}$	470	570	780	1020	1260	1530	1820	2130	2470

(ii) f'_c=32 MPa, c_{req} = 40 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	40	40	40	40	40	40	40	40	40
$L_{sy.tb}$	380	450	610	870	1150	1450	1770	2120	2500
$L_{sy.t.min}$	380	450	550	720	890	1080	1290	1510	1750
$L_{sy.tb.lap}$	410	500	770	1090	1440	1810	2210	2650	3120
$L_{sy.t.lap.min}$	410	500	690	900	1120	1350	1610	1890	2190

(iii) f'_c=40 MPa, c_{req} = 30 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	30	30	30	30	30	30	35	40	40
$L_{sy.tb}$	380	450	620	850	1100	1370	1620	1890	2230
$L_{sy.t.min}$	380	410	500	640	800	970	1150	1350	1560
$L_{sy.tb.lap}$	380	500	770	1060	1370	1710	2030	2370	2790
$L_{sy.t.lap.min}$	380	450	620	800	1000	1210	1440	1690	1950

(iv) f'_c=50 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	380	450	600	790	1010	1220	1450	1690	2000
$L_{sy.t.min}$	340	380	460	570	710	870	1030	1210	1400
$L_{sy.tb.lap}$	380	480	730	990	1270	1530	1810	2120	2500
$L_{sy.t.lap.min}$	380	450	600	750	900	1080	1290	1510	1750

(v) $f'_c \geq$65 MPa, c_{req} = 25 mm

d_b=	10	12	16	20	24	28	32	36	40
c_d=c_{min}=	25	25	25	25	25	30	35	40	40
$L_{sy.tb}$	380	450	600	750	900	1070	1270	1490	1750
$L_{sy.t.min}$	340	380	460	550	630	760	900	1060	1230
$L_{sy.tb.lap}$	380	450	640	870	1110	1340	1590	1860	2190
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1530

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

TABLE CC/B1/1.3/1.25(b) – Tensile Development and Lap Lengths

Standard Formwork & Compaction: B1 Exposure Classification

COVER-CONTROLLED: $a \geq 2c_{min}$

k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) (f'_c=25 MPa, c_{req}=60 mm) OR (f'_c=32 MPa, c_{req}=40 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**460**	**630**	**870**	**1150**	**1450**	**1810**	**2190**	**2610**
	$L_{sy.t.min}$	380	460	630	810	1010	1230	1460	1710	1980
	$L_{sy.tb.lap}$	**470**	**570**	**780**	**1090**	**1440**	**1810**	**2260**	**2740**	**3270**
	$L_{sy.t.lap.min}$	470	570	780	1020	1260	1530	1820	2130	2470
(d_b)	$L_{sy.tb}$	**38.0**	**38.3**	**39.4**	**43.5**	**47.9**	**51.8**	**56.6**	**60.8**	**65.3**
	$L_{sy.t.min}$	38.0	38.3	39.4	40.5	42.1	43.9	45.6	47.5	49.5
	$L_{sy.tb.lap}$	**47.0**	**47.5**	**48.8**	**54.5**	**60.0**	**64.6**	**70.6**	**76.1**	**81.8**
	$L_{sy.t.lap.min}$	47.0	47.5	48.8	51.0	52.5	54.6	56.9	59.2	61.8

(ii) (f'_c=40 MPa, c_{req}=30 mm) OR ($f'_c \geq$50 MPa, c_{req}=25 mm)

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**450**	**620**	**850**	**1100**	**1370**	**1620**	**1890**	**2230**
	$L_{sy.t.min}$	380	410	500	640	800	970	1150	1350	1560
	$L_{sy.tb.lap}$	**380**	**500**	**770**	**1060**	**1370**	**1710**	**2030**	**2370**	**2790**
	$L_{sy.t.lap.min}$	380	450	620	800	1000	1210	1440	1690	1950
(d_b)	$L_{sy.tb}$	**38.0**	**37.5**	**38.8**	**42.5**	**45.8**	**48.9**	**50.6**	**52.5**	**55.8**
	$L_{sy.t.min}$	38.0	34.2	31.3	32.0	33.3	34.6	35.9	37.5	39.0
	$L_{sy.tb.lap}$	**38.0**	**41.7**	**48.1**	**53.0**	**57.1**	**61.1**	**63.4**	**65.8**	**69.8**
	$L_{sy.t.lap.min}$	38.0	37.5	38.8	40.0	41.7	43.2	45.0	46.9	48.8

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$).

INDEX: SPACING-CONTROLLED TABLES – TENSILE DEVELOPMENT LENGHTHS ($L_{sy.tb}$, $L_{sy.t.min}$) AND LAP LENGTHS ($L_{sy.tb.lap}$, $L_{sy.t.lap.min}$)

Note: To produce the Spacing-Controlled Tables, it was assumed when using Eq. 1c, that basic factor ξ_{cd}=1.0 (i.e. normal-density concrete) and basic factor ξ_{bc}=1.0 (i.e. uncoated or bare steel bars).

TABLE SC/A1,A2,B1/1.0/1.25(a) – Tensile Development and Lap Lengths for Bars with no Staggering

Standard Formwork & Compaction: A1, A2 or B1 Exposure Classification

SPACING-CONTROLLED: $a \le 2c_{min}$ | **k_1=1.0, k_7=1.25** {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	390	500	740	1000	1230	1490	1760	2060	2430
$L_{sy.t.min}$	320	390	540	700	870	1050	1250	1470	1700
$L_{sy.tb.lap}$	490	630	930	1250	1540	1860	2200	2580	3040
$L_{sy.t.lap.min}$	400	490	670	870	1090	1320	1570	1830	2130

(ii) f'_c=25 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	350	450	660	890	1100	1330	1580	1840	2170
$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
$L_{sy.tb.lap}$	440	560	830	1120	1380	1660	1970	2300	2720
$L_{sy.t.lap.min}$	360	440	600	780	970	1180	1400	1640	1900

(iii) f'_c=32 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	310	400	590	790	980	1180	1390	1630	1920
$L_{sy.t.min}$	260	310	430	550	690	830	990	1160	1350
$L_{sy.tb.lap}$	380	500	730	990	1220	1470	1740	2040	2400
$L_{sy.t.lap.min}$	320	390	530	690	860	1040	1240	1450	1680

(iv) f'_c=40 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	360	520	710	870	1050	1250	1460	1720
$L_{sy.t.min}$	240	280	380	490	610	740	890	1040	1200
$L_{sy.tb.lap}$	340	440	660	880	1090	1320	1560	1820	2150
$L_{sy.t.lap.min}$	290	350	480	620	770	930	1110	1300	1500

(v) f'_c=50 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	350	470	630	780	940	1120	1300	1540
$L_{sy.t.min}$	240	270	340	440	550	670	790	930	1080
$L_{sy.tb.lap}$	310	400	590	790	980	1180	1390	1630	1920
$L_{sy.t.lap.min}$	290	350	460	580	700	830	990	1160	1350

(vi) f'_c≥65 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	290	350	460	580	700	830	980	1140	1350
$L_{sy.t.min}$	240	270	330	410	490	590	690	810	940
$L_{sy.tb.lap}$	290	350	510	690	860	1030	1220	1430	1690
$L_{sy.t.lap.min}$	290	350	460	580	700	810	930	1040	1180

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\ge L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\ge L_{sy.t.lap.min}$).

TABLE SC/A1,A2,B1/1.0/1.25(b) – Tensile Development and Lap Lengths for Bars with no Staggering

Standard Formwork & Compaction: A1, A2 or B1 Exposure Classification

SPACING-CONTROLLED: $a \le 2c_{min}$ | **k_1=1.0, k_7=1.25** {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**390**	**500**	**740**	**1000**	**1230**	**1490**	**1760**	**2060**	**2430**
	$L_{sy.t.min}$	320	390	540	700	870	1050	1250	1470	1700
	$L_{sy.tb.lap}$	**490**	**630**	**930**	**1250**	**1540**	**1860**	**2200**	**2580**	**3040**
	$L_{sy.t.lap.min}$	400	490	670	870	1090	1320	1570	1830	2130
(d_b)	$L_{sy.tb}$	**39.0**	**41.7**	**46.3**	**50.0**	**51.3**	**53.2**	**55.0**	**57.2**	**60.8**
	$L_{sy.t.min}$	32.0	32.5	33.8	35.0	36.3	37.5	39.1	40.8	42.5
	$L_{sy.tb.lap}$	**49.0**	**52.5**	**58.1**	**62.5**	**64.2**	**66.4**	**68.8**	**71.7**	**76.0**
	$L_{sy.t.lap.min}$	40.0	40.8	41.9	43.5	45.4	47.1	49.1	50.8	53.3

(ii) f'_c=25 MPa OR 32 MPa

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**350**	**450**	**660**	**890**	**1100**	**1330**	**1580**	**1840**	**2170**
	$L_{sy.t.min}$	290	350	480	630	780	940	1120	1310	1520
	$L_{sy.tb.lap}$	**440**	**560**	**830**	**1120**	**1380**	**1660**	**1970**	**2300**	**2720**
	$L_{sy.t.lap.min}$	360	440	600	780	970	1180	1400	1640	1900
(d_b)	$L_{sy.tb}$	**35.0**	**37.5**	**41.3**	**44.5**	**45.8**	**47.5**	**49.4**	**51.1**	**54.3**
	$L_{sy.t.min}$	29.0	29.2	30.0	31.5	32.5	33.6	35.0	36.4	38.0
	$L_{sy.tb.lap}$	**44.0**	**46.7**	**51.9**	**56.0**	**57.5**	**59.3**	**61.6**	**63.9**	**68.0**
	$L_{sy.t.lap.min}$	36.0	36.7	37.5	39.0	40.4	42.1	43.8	45.6	47.5

(iii) $f'_c \ge$40 MPa

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**290**	**360**	**520**	**710**	**870**	**1050**	**1250**	**1460**	**1720**
	$L_{sy.t.min}$	240	280	380	490	610	740	890	1040	1200
	$L_{sy.tb.lap}$	**340**	**440**	**660**	**880**	**1090**	**1320**	**1560**	**1820**	**2150**
	$L_{sy.t.lap.min}$	290	350	480	620	770	930	1110	1300	1500
(d_b)	$L_{sy.tb}$	**29.0**	**30.0**	**32.5**	**35.5**	**36.3**	**37.5**	**39.1**	**40.6**	**43.0**
	$L_{sy.t.min}$	24.0	23.3	23.8	24.5	25.4	26.4	27.8	28.9	30.0
	$L_{sy.tb.lap}$	**34.0**	**36.7**	**41.3**	**44.0**	**45.4**	**47.1**	**48.8**	**50.6**	**53.8**
	$L_{sy.t.lap.min}$	29.0	29.2	30.0	31.0	32.1	33.2	34.7	36.1	37.5

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\ge L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\ge L_{sy.t.lap.min}$).

TABLE SC/A1,A2,B1/1.3/1.25(a) – Tensile Development and Lap Lengths for Bars with no Staggering

Standard Formwork & Compaction: A1, A2 or B1 Exposure Classification

SPACING-CONTROLLED: $a \le 2c_{min}$

k_1=1.3, k_7=1.25 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	510	650	960	1300	1600	1940	2290	2680	3160
$L_{sy.t.min}$	420	510	700	910	1130	1370	1630	1910	2210
$L_{sy.tb.lap}$	630	820	1210	1620	2010	2420	2870	3350	3950
$L_{sy.t.lap.min}$	520	640	880	1140	1410	1710	2030	2380	2760

(ii) f'_c=25 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	450	590	860	1160	1440	1730	2050	2400	2830
$L_{sy.t.min}$	370	460	630	810	1010	1230	1460	1710	1980
$L_{sy.tb.lap}$	570	730	1080	1450	1790	2160	2560	3000	3530
$L_{sy.t.lap.min}$	470	570	780	1020	1260	1530	1820	2130	2470

(iii) f'_c=32 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	400	520	760	1030	1270	1530	1810	2120	2500
$L_{sy.t.min}$	330	400	550	720	890	1080	1290	1510	1750
$L_{sy.tb.lap}$	500	650	950	1280	1590	1910	2270	2650	3120
$L_{sy.t.lap.min}$	410	500	690	900	1120	1350	1610	1890	2190

(iv) f'_c=40 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	460	680	920	1130	1370	1620	1890	2230
$L_{sy.t.min}$	310	360	500	640	800	970	1150	1350	1560
$L_{sy.tb.lap}$	450	580	850	1150	1420	1710	2030	2370	2790
$L_{sy.t.lap.min}$	380	450	620	800	1000	1210	1440	1690	1950

(v) f'_c=50 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	450	610	820	1010	1220	1450	1690	2000
$L_{sy.t.min}$	310	350	440	570	710	870	1030	1210	1400
$L_{sy.tb.lap}$	400	520	760	1030	1270	1530	1810	2120	2500
$L_{sy.t.lap.min}$	380	450	600	750	900	1080	1290	1510	1750

(vi) f'_c≥65 MPa

d_b=	10	12	16	20	24	28	32	36	40
c_d=	20	20	20	20	25	30	35	40	40
$L_{sy.tb}$	380	450	600	750	900	1070	1270	1490	1750
$L_{sy.t.min}$	310	350	440	530	630	760	900	1060	1230
$L_{sy.tb.lap}$	380	450	670	900	1110	1340	1590	1860	2190
$L_{sy.t.lap.min}$	380	450	600	750	900	1060	1210	1360	1530

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\ge L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\ge L_{sy.t.lap.min}$).

TABLE SC/A1,A2,B1/1.3/1.25(b) – Tensile Development and Lap Lengths for Bars with no Staggering

Standard Formwork & Compaction: A1, A2 or B1 Exposure Classification

SPACING-CONTROLLED: $a \le 2c_{min}$ | **k_1=1.3, k_7=1.25** {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_{req} from Table 4.10.3.2 of AS 3600–2009 (see Table B.4) & c_{min} = max. (c_{req}, $d_{b.5mm}$)

(i) f'_c=20 MPa

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**510**	**650**	**960**	**1300**	**1600**	**1940**	**2290**	**2680**	**3160**
	$L_{sy.t.min}$	420	510	700	910	1130	1370	1630	1910	2210
	$L_{sy.tb.lap}$	**630**	**820**	**1210**	**1620**	**2010**	**2420**	**2870**	**3350**	**3950**
	$L_{sy.t.lap.min}$	520	640	880	1140	1410	1710	2030	2380	2760
(d_b)	$L_{sy.tb}$	**51.0**	**54.2**	**60.0**	**65.0**	**66.7**	**69.3**	**71.6**	**74.4**	**79.0**
	$L_{sy.t.min}$	42.0	42.5	43.8	45.5	47.1	48.9	50.9	53.1	55.3
	$L_{sy.tb.lap}$	**63.0**	**68.3**	**75.6**	**81.0**	**83.8**	**86.4**	**89.7**	**93.1**	**98.8**
	$L_{sy.t.lap.min}$	52.0	53.3	55.0	57.0	58.8	61.1	63.4	66.1	69.0

(ii) f'_c=25 MPa OR 32 MPa

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**450**	**590**	**860**	**1160**	**1440**	**1730**	**2050**	**2400**	**2830**
	$L_{sy.t.min}$	370	460	630	810	1010	1230	1460	1710	1980
	$L_{sy.tb.lap}$	**570**	**730**	**1080**	**1450**	**1790**	**2160**	**2560**	**3000**	**3530**
	$L_{sy.t.lap.min}$	470	570	780	1020	1260	1530	1820	2130	2470
(d_b)	$L_{sy.tb}$	**45.0**	**49.2**	**53.8**	**58.0**	**60.0**	**61.8**	**64.1**	**66.7**	**70.8**
	$L_{sy.t.min}$	37.0	38.3	39.4	40.5	42.1	43.9	45.6	47.5	49.5
	$L_{sy.tb.lap}$	**57.0**	**60.8**	**67.5**	**72.5**	**74.6**	**77.1**	**80.0**	**83.3**	**88.3**
	$L_{sy.t.lap.min}$	47.0	47.5	48.8	51.0	52.5	54.6	56.9	59.2	61.8

(iii) $f'_c \ge$40 MPa

		N10	N12	N16	N20	N24	N28	N32	N36	N40
(mm)	$L_{sy.tb}$	**380**	**460**	**680**	**920**	**1130**	**1370**	**1620**	**1890**	**2230**
	$L_{sy.t.min}$	310	360	500	640	800	970	1150	1350	1560
	$L_{sy.tb.lap}$	**450**	**580**	**850**	**1150**	**1420**	**1710**	**2030**	**2370**	**2790**
	$L_{sy.t.lap.min}$	380	450	620	800	1000	1210	1440	1690	1950
(d_b)	$L_{sy.tb}$	**38.0**	**38.3**	**42.5**	**46.0**	**47.1**	**48.9**	**50.6**	**52.5**	**55.8**
	$L_{sy.t.min}$	31.0	30.0	31.3	32.0	33.3	34.6	35.9	37.5	39.0
	$L_{sy.tb.lap}$	**45.0**	**48.3**	**53.1**	**57.5**	**59.2**	**61.1**	**63.4**	**65.8**	**69.8**
	$L_{sy.t.lap.min}$	38.0	37.5	38.8	40.0	41.7	43.2	45.0	46.9	48.8

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\ge L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\ge L_{sy.t.lap.min}$).

APPENDIX C – WORKED EXAMPLES USING DESIGN TABLES TO AS 3600–2009

Five worked examples are given in this appendix to illustrate the use of the three types of design tables presented in Appendix B, *Design Tables to AS 3600–2009*, when undertaking a basic or refined design, for stress development of straight D500N tensile bars in accordance with Clause 13.1 *Stress Development in Reinforcement* and Clause 13.2 *Splicing of Reinforcement* of Section 13 of AS 3600–2009 incorporating the latest amendments [1]. In all five examples, basic factor ξ_{cd}=1.0 corresponding to normal-density concrete, and basic factor ξ_{bc}=1.0 for uncoated or bare steel bars. *Designers should always independently check the solutions they use from the three types of tables in Appendix B, or those in Appendix D, and most importantly, ensure that the assumptions behind the tables match their design situation.*

EXAMPLE C.1 – *Refined Design aided by using the General Tables in Appendix B*

A narrow portion of slab located between a concrete lift shaft and an adjacent concrete wall contains lapped top and bottom main (N24) bars in two planes (see Fig. C.1). From site measurements, average main bar centre-to-centre spacing is 116 mm (s_{cc}). The bars have to be fully anchored in tension at both adjacent faces of the lift shaft and the wall, which are only 1500 mm apart. The minimum extension of the main bars from the adjacent faces of either the lift shaft or the wall is 1350 mm, with a corresponding maximum gap of 150 mm at each main bar end. Therefore, the minimum lap length is 1200 mm. Overall slab depth will be 400 mm in this region, with normal-density, grade 32 (f'_c=32 MPa) concrete. Transverse bars (yet to be designed, and absent from Fig. C.1) will be tied to the underside of the bottom main bars and to the topside of the top main bars. Therefore, the transverse bars will confine the adjacent laps. Minimum concrete covers to the top and bottom layers of transverse bars will be 40 mm. For obvious practical reasons, the main bar laps are all non-contact.

The General Tables in Appendix B will first be used to ascertain whether basic lap length $L_{sy.tb.lap}$ will suffice, or if, due to the restricted lap length, refined design calculations are required to take into account the beneficial confining effect of the continuous transverse reinforcement, which would then have to be designed with this additional purpose in mind.

In accordance with Fig. A.5(a), which is applicable as no laps are staggered, c_d=min. (a/2, c), while a=(s_{cc}-2d_b)=116-2×24=68 mm, whereby c_d=min. (68/2, 40 + unknown transverse bar diameter, $d_{b.tr}$) = 34 mm, say 35 mm for the purpose of using the General Tables.

Lapping of the top main bars is more critical than the bottom main bars as there is at least 300 mm of concrete to be poured below the top laps, in which case, in accordance with Table B.1, k_1=1.3 (which allows for the detrimental effects of aerated concrete under the horizontal top bars, and the potentially poor bond conditions). Also, because all of the main bars will be lapped together, from the same table k_7=1.25. It follows that General Table G/32/1.3/1.25 is applicable (see INDEX on p.16): within this table, the corresponding secondary table for Basic Lap Length (mm) $L_{sy.tb.lap}$, shows that for c_d=35 mm and N24 bars, $L_{sy.tb.lap}$=1490 mm. However, this exceeds the available lap length of 1200 mm, so refined design has to be investigated. According to the corresponding secondary table Minimum Refined Lap Length (mm) $L_{sy.t.lap.min}$, minimum possible lap length, $L_{sy.t.lap.min}$=1120 mm, which is less than 1200 mm. Therefore, refined design calculations can be performed, using the top transverse bars to provide the necessary confinement to the top main bar lapped splices.

Considering the bottom main bar lapped splices, again in accordance with Table B.1, k_1=1.0 for the bottom bars, and with all the main bars lapped together, k_7=1.25, so General Table G/32/1.0/1.25 is applicable: within this table, the corresponding secondary table for basic lap lengths shows that for c_d=35 mm and N24 bars, $L_{sy.tb.lap}$=1140 mm. Because this is less than the available lap length of 1200 mm, refined design is unnecessary, and therefore the bottom transverse bars can be designed independently, and will not be considered further herein.

Now considering the top transverse bars, and for interest in the process checking the solution in the General Table, k_3=1-0.15(c_d-d_b)/d_b=1-0.15×(34-24)/24=0.9375, while without significant transverse pressure applied to the slab over the lapped region, k_5=1.0. Therefore, since according to Eq. 2 the minimum value of $k_3k_4k_5$=0.7, the minimum allowable value of k_4=0.7/(0.9375×1.0)=0.747, and Eq. 3b gives $L_{sy.t.lap.min}$=1.25×0.747×0.5×1.3×0.9375×500×24/(1.08×√32)=1120 mm rounded to the nearest 10 mm (noting that c_d=34 mm was used here rather than 35 mm), identical to the General Table G/32/1.3/1.25, where $L_{sy.t.lap.min}$ is insensitive to c_d. Since this latter value is close to the available lap length of 1200 mm, the top transverse reinforcement will be designed as follows to achieve this maximum level of confinement. By definition, k_4=[0.7≤{1.0-$K\lambda$}≤1.0], and therefore the corresponding maximum allowable value of $K\lambda$=1-0.747=0.253. From Fig. A.3 it can be seen for the case of a slab (or wall) without fitments that K=0.05, in which case the maximum allowable value of λ=0.253/K=0.253/0.05=5.06 for design.

Finally, by definition λ=(ΣA_{tr} - $\Sigma A_{tr.min}$)/A_s =(ΣA_{tr} - 0.25A_s)/A_s, where A_s is the cross-sectional area of a single top main N24 bar = 452 mm^2. It follows that the maximum effective combined cross-sectional area of the top transverse bars spread evenly over the 1200 mm long laps, ΣA_{tr}=5.06A_s+0.25A_s=5.31A_s=2400 mm^2. Providing N20@200 top transverse bars for this purpose in the slab portion located between the concrete lift shaft and adjacent wall would result in 7N20 bars spread over the lapped region, giving ΣA_{tr}≈2200mm^2, slightly less than the maximum possible. Checking the adequacy of this solution, λ=(ΣA_{tr}-0.25A_s)/A_s=(2200-0.25×452)/452=4.62, whereby k_4=1.0-$K\lambda$=1.0-0.05×4.62=0.769, and finally from Eq. 3b, $L_{sy.t.lap}$=$k_7L_{sy.t}$=$k_7k_4k_5L_{sy.tb}$=1.25×0.769×1.0×1197=1150 mm,[7] less than the 1200 mm provided, and also, as required by Eq. 3b, >29k_1d_b =29×1.3×24=905 mm. As expected, this value of $L_{sy.t.lap}$ is slightly more than the minimum possible value of 1120 mm given in General Table G/32/1.3/1.25. This completes the design of the N24 bar laps.

FIGURE C.1 – ***A constrained situation requiring refined design to determine a shorter lap length for top bars according to Example C.1***

In conclusion, this example illustrates how the General Tables can be used to investigate the feasibility of refining basic designs, and how, particularly in constrained situations, refined design can possibly be used for economy to maintain simple, conventional reinforcement detailing. Alternative means of anchoring the short main bars in Fig. C.1, such as welding lapped bars together or increasing the anchorage of the bar free ends by having added hooks, cogs or proprietary heads, could have created practical problems such as increasing congestion, and would most likely be less economical.

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7 Assuming c_d=35 mm, General Table G/32/1.3/1.25 gives $L_{sy.tb}$=1190 mm directly, and simplifies this calculation without losing accuracy, i.e. it results in $L_{sy.t.lap}$=1140 mm.

EXAMPLE C.2 – *Standard Design Solutions for a General Notes Drawing derived using the Cover-Controlled Tables in Appendix B*

As explained in the Introduction, an important reason for preparing this technical note, and the tables in Appendix B, is to assist design engineers to improve the consistency of the standard design solutions they include in their design documentation to satisfy the stress development and lap splicing requirements of Section 13 of AS 3600–2009.

The basic design solutions (basic development length, $L_{sy.tb}$, or basic lapped splice length, $L_{sy.tb.lap}$) provided in the Cover-Controlled Tables and Spacing-Controlled Tables in Appendix B are well suited to this application, as they are complete, and therefore no further (refined) calculations need be performed. Also, they address a wide range of practical design cases and provide conservative solutions in accordance with AS 3600–2009.

For improved economy, the design solutions chosen for inclusion in the typical table of basic development and lapped splice lengths on the General Notes Drawing should be project specific, as illustrated in this example. For this purpose, the key design variables should first be identified, along with their relevant values.

Consider the case of the interior of a low-rise, cast in situ, normal-density concrete building. For brevity, only the concrete floors are considered here, for which the following is known: Exposure Classification, *EC* = A1; band beams more than 300 mm deep; f'_c = 25 or 32 MPa depending on floor location; and main bars in the slabs and beams vary from N16 to N32:

TENSILE DEVELOPMENT AND LAPPED SPLICE LENGTHS – *mm*

BEAM & SLAB MAIN BARS: Exposure Classification: A1 f'_c = 25 or 32 MPa

Grade D500N	N16	N20	N24	N28	N32
Min. clear cover *(mm)*	20	20	25	30	35
Min. clear distance *(mm)*	40	40	50	60	70
Good bond conditions: No more than 300 mm of concrete cast below bars[8]					
Development length, or Lap length – staggered/low-stress	***660***	***890***	***1100***	***1330***	***1580***
Lap length – otherwise	***830***	***1120***	***1380***	***1660***	***1970***
Poor bond conditions: More than 300 mm of concrete cast below bars[9]					
Development length, or Lap length – staggered/low-stress	***860***	***1160***	***1440***	***1730***	***2050***
Lap length – otherwise	***1080***	***1450***	***1790***	***2160***	***2560***

As noted in the footnotes to the table *Tensile Development and Lapped Splice Lengths* opposite, the minimum clear cover (c_{min}) and clear distance (*a*) requirements of the Cover-Controlled Tables must apply, viz. $a \geq 2c_{min}$ where c_{min}=max. ($d_{b.5mm}$,c_{req}). Clear distance, *a*, is illustrated in Figs A.4 and A.5 for bars being anchored or lap spliced, respectively. For situations where $a \leq 2c_{min}$, then the Spacing-Controlled Tables in Appendix B could be used in a similar manner to derive the standard design solutions for a project.

EXAMPLE C.3 – *Refined Design of the Tensile Lapped Splices in Two High-Strength Concrete Columns aided by using the General Tables in Appendix B*

The refined lap lengths of the tensile splices in two large, concentric circular reinforced-concrete columns, constructed using high-strength grade 65 MPa (f'_c=65 MPa), normal-density concrete shall be calculated, taking into account the passive confinement provided by the grade 500 MPa helical fitments. A transverse section through the 900 mm diameter lower column is shown in Fig. C.3(a), which supports the 700 mm diameter upper column with the transverse section shown in Fig. C.3(b).

The combination of design action effects acting within the top and bottom regions of the columns are such that they lie within the hatched area of Fig. 10.7.3.1(A) of AS 3600–2009, and therefore the column cores require special confinement as defined in Clause 10.7.3 of AS 3600–2009. For constructability, the splices between the longitudinal bars will be assumed to fall within the special confinement region in the bottom region of each column (see below), and therefore will be designed as full tensile lapped spices.

Referring to Clause 10.7.3.1 of AS 3600–2009, it will be assumed that the following conditions apply concerning the special confinement regions:

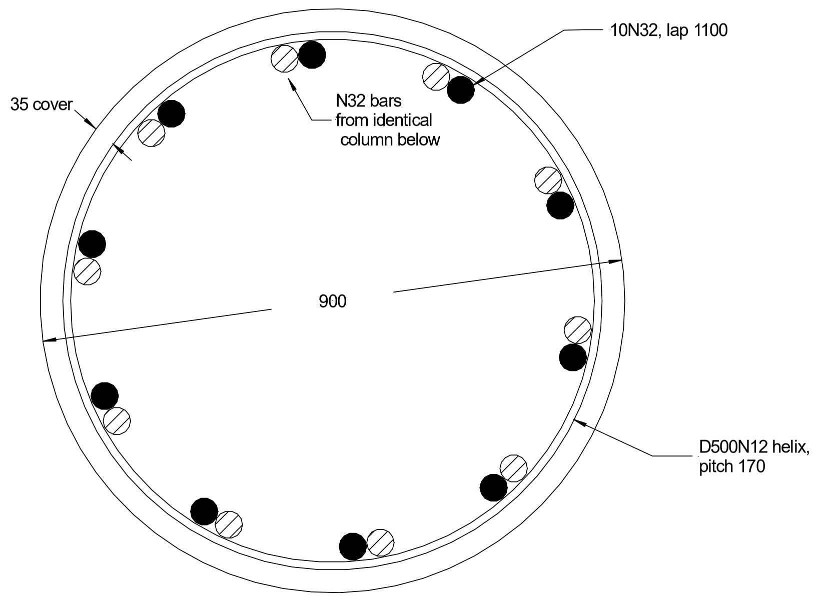
- fitments shall provide an effective confining pressure applied to the core, $f_{r.eff}$, of at least 0.01 f'_c calculated using Clause 10.7.3.3 of AS 3600–2009, and not the deemed-to-comply formula in Clause 10.7.3.4;
- fitment pitch shall not exceed the lesser of 0.6D_c and 300 mm, where D_c is the column diameter, and also according to Clause 10.7.4.3(b), the pitch shall not exceed 15d_b;
- from Table 10.7.4.3 of AS 3600–2009, the nominal bar diameter of the helix shall not be less than 10 mm or 12 mm for 24 mm or 32 mm diameter longitudinal bars, respectively; and
- the action effects are such that the special confinement regions at both column ends are all 1.2D_c long, i.e. 840 mm and 1080 mm for the 700 and 900 mm diameter columns, respectively.

Accordingly, for the N24 bars in the upper column, a D500L10 (d_b=9.5 mm, $A_{b.fit}$=A_{tr}=71 mm^2) helix will be used, and in the lower column with the N32 bars, a D500N12 (d_b=12 mm, $A_{b.fit}$=A_{tr}=113 mm^2) helix. Their pitches, *s*, can be determined directly by simplified calculation according to Clause 10.7.3.3 of AS 3600–2009 to give *s*=140 or 170 mm for the upper and lower columns with the N24 or N32 longitudinal bars, respectively, as shown in Fig. C.3(c).

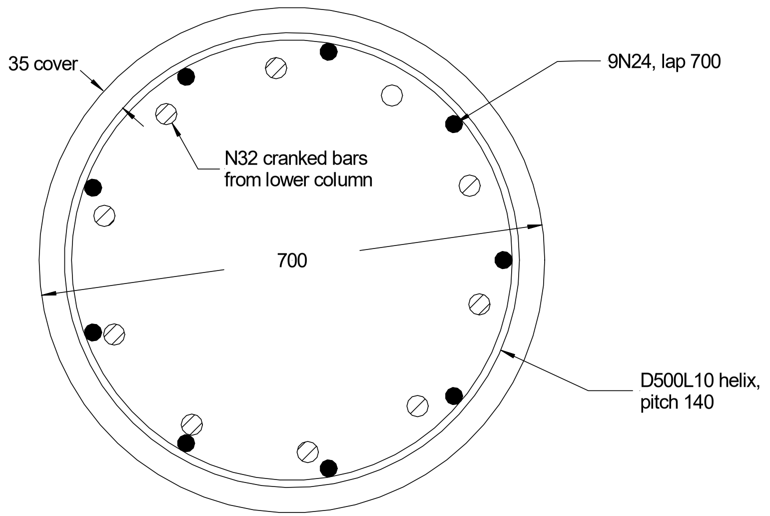
In order to calculate the refined tensile lap lengths for the upper and lower columns, the appropriate General Tables in Appendix B will first be used to determine their minimum values, assuming c_d=45 or 47 mm, for the upper and lower columns, respectively. It follows from Table G/≥65/1.0/1.25, noting that k_7=1.25 as none of the laps will be staggered, that the minimum refined lap length, $L_{sy.t.lap.min}$=700 or 930 mm, respectively; these values will be used as initial estimates to conservatively calculate k_4 for each of these design cases.

8 The values of basic tensile development length ($L_{sy.tb}$) and basic tensile lap length ($L_{sy.tb.lap}$) have been taken directly from Cover-Controlled Tables CC/A1/1.0/1.00(b)(ii) and CC/A1/1.0/1.25(b)(ii). The min. clear cover and distance requirements of the tables apply.

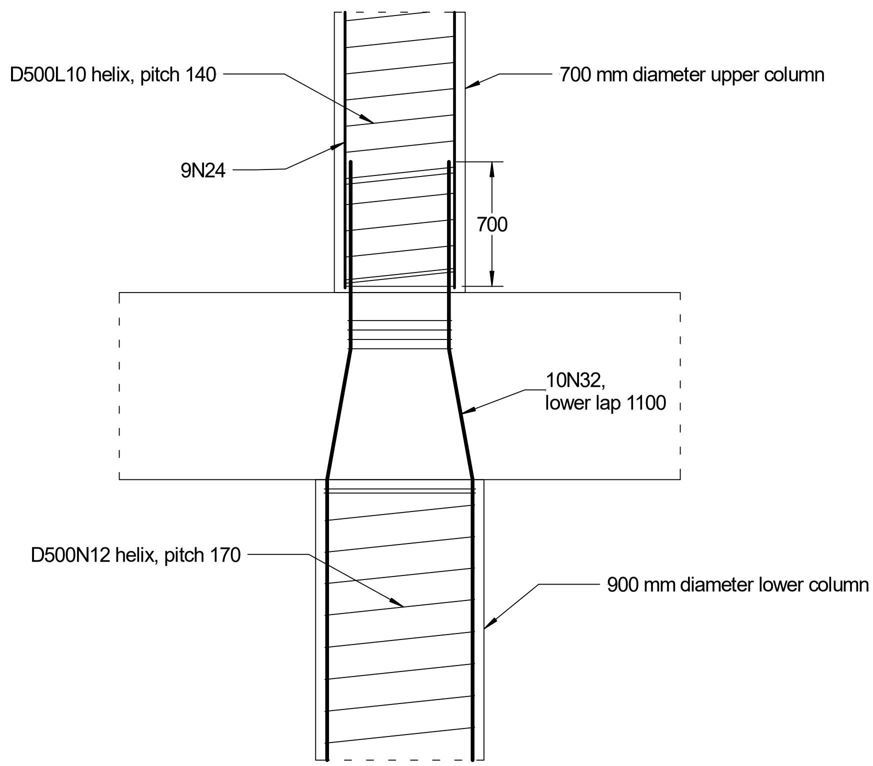
9 The values of basic tensile development length ($L_{sy.tb}$) and basic tensile lap length ($L_{sy.tb.lap}$) have been taken directly from Cover-Controlled Tables CC/A1/1.3/1.00(b)(ii) and CC/A1/1.3/1.25(b)(ii). The min. clear cover and distance requirements of the tables apply.



(a) Transverse section through lower column in lapped splice region



(b) Transverse section through upper column in lapped splice region



(c) Vertical section through junction between columns

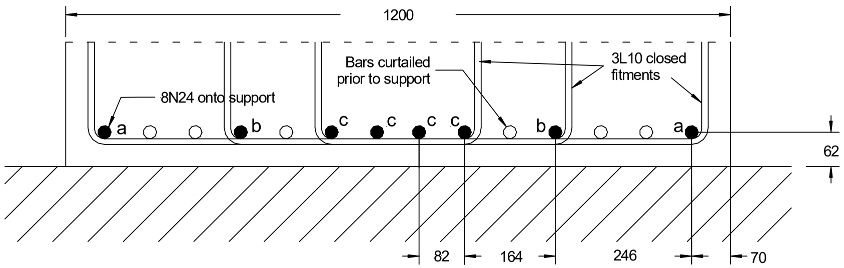
FIGURE C.3 – *High-strength concrete column of Example C.3*

For the upper column, therefore $\Sigma A_{tr} \approx A_{tr} \times L_{sy.t.lap.min}/s$=71×700/140=355 mm^2. In accordance with Fig. A.3, for all the N24 column bars, K=0.10, and $\Sigma A_{tr.min}$=0.25A_s=0.25×452=113 mm^2. Therefore, k_4=1-$K\lambda$=1-0.10×(ΣA_{tr}-$\Sigma A_{tr.min}$)/A_s=1-0.10×(355-113)/452=0.947. It follows that for the upper column, $L_{sy.t.lap}$=max. ($k_7k_4k_5L_{sy.tb}$, 29k_1d_b) = max. (1.25×0.947×1.0×0.5×1.0×(1-0.15×(45-24)/24)×500×24×100/(132-24)/65$^{0.5}$,29×1.0×24)=max. (709, 696) mm, and therefore the rounded value of 700 mm shown in Fig. C.3(c) is considered to be sufficiently accurate.

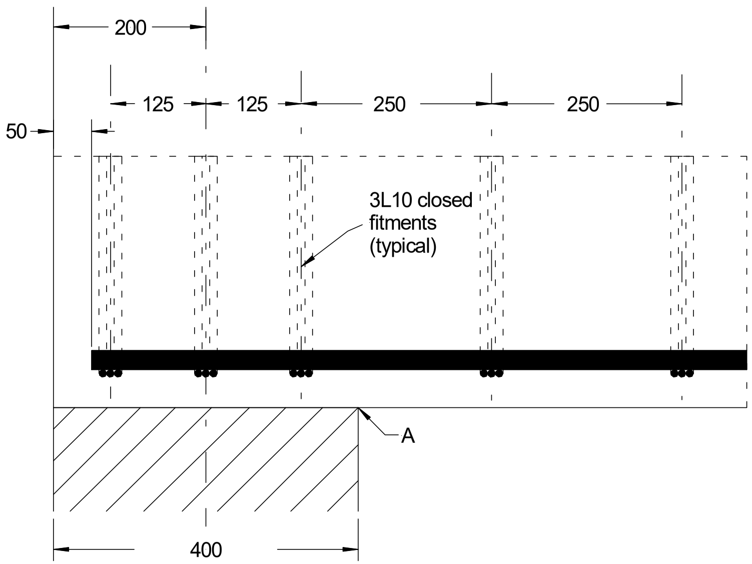
Similarly, for the lower column, therefore $\Sigma A_{tr} \approx A_{tr} \times L_{sy.t.lap.min}/s$=113×930/170=618 mm^2. In accordance with Fig. A.3, for all the N32 column bars, K=0.10, and $\Sigma A_{tr.min}$=0.25A_s=0.25×804=201 mm^2. Therefore, k_4=1-$K\lambda$=1-0.10×(ΣA_{tr}-$\Sigma A_{tr.min}$)/A_s=1-0.10×(618-201)/804=0.948. It follows that for the upper column, $L_{sy.t.lap}$=max. ($k_7k_4k_5L_{sy.tb}$, 29k_1d_b) = max.(1.25×0.948×1.0×0.5×1.0×(1-0.15×(47-32)/32)×500×32×100/(132-32)/65$^{0.5}$, 29×1.0×32) = max. (1093, 928) mm, with the lap length of 1100 mm shown in Fig. C.3(c) considered sufficiently accurate for design. However, for this column $L_{sy.t.lap}$ exceeds $L_{sy.t.lap.min}$, so ΣA_{tr} has been underestimated and therefore $L_{sy.t.lap}$ could be slightly reduced by iteration.

EXAMPLE C.4 – *Refined Design of a Tensile End Anchorage under Transverse Compression in a Continuous Concrete Beam aided by using the General Tables in Appendix B*

Anchorage of the bottom longitudinal bars at the simply-supported end of an external solid, continuous reinforced-concrete beam with a 1200 mm wide by 1000 mm deep rectangular cross-section, directly supported across its full width by a 400 mm wide, transverse concrete member, could be enhanced by transverse pressure due to a design end reaction or shear force, V^*=320 kN. Refined design calculations are necessary to investigate whether or not the ends of the bottom bars have to be hooked or cogged in order for them to be adequately anchored in accordance with the requirements of AS 3600–2009.



(a) Transverse section through simple end-support region



(b) Vertical section through a longitudinal bar 'c' in (a)

FIGURE C.4 – *Continuous concrete beam of Example C.4*

For Exposure Classification B1, minimum concrete cover to reinforcement equals 40 mm, with grade 32 MPa (f'_c=32 MPa), normal-density concrete cast in situ – see Table B.4.

As shown in Fig. C.4(a), eight of the fourteen N24 bars at mid-span continue onto the end support, with a nominal end cover of 50 mm giving a maximum end anchorage available of 350 mm measured from the interior face of the support member (point A in Fig. C.4(b)). These eight longitudinal bars are labelled in Fig. C.4(a) as 'a', 'b' or 'c', which as explained as follows, are increasingly confined by the three sets of D500L10 closed fitments @ 125 mm centres located directly over the support region.

- In the case of the two outer corner bars 'a', for each set of fitments only one L10 bar (nominal diameter, d_b=9.5 mm, with cross-sectional area, A_{tr}=71 mm^2) crosses a potential longitudinal crack extending from the bar to either the vertical exposed concrete surface or the beam soffit, whereby for each set of fitments A_{tr}=71 mm^2, and therefore in total for the three end sets of fitments ΣA_{tr}=3×71=213 mm^2. For these bars, K=0.10 (see Fig. A.3 for Beam, putting n_l=n_{bs}=1), and $\Sigma A_{tr.min}$=0.25A_s, A_s being the cross-sectional area of a single N24 bar = 452 mm^2, i.e. $\Sigma A_{tr.min}$=0.25×452=113 mm^2. It follows that for the two 'a' bars, k_4=1-$K\lambda$=1-0.10×(ΣA_{tr}-$\Sigma A_{tr.min}$)/A_s=1-0.10×(213-113)/452=0.98.
- In the case of the two inner corner bars 'b', for each set of fitments two L10 bars cross a potential longitudinal crack extending from the bar to the beam soffit, whereby for each set of fitments A_{tr}=2×71=142 mm^2, and therefore over the end support ΣA_{tr}=3×142=426 mm^2. For these corner bars too, K=0.10, and $\Sigma A_{tr.min}$=113 mm^2. It follows that for the two 'b' bars, k_4=1-$K\lambda$=1-0.10×(ΣA_{tr}-$\Sigma A_{tr.min}$)/A_s=1-0.10×(426-113)/452=0.93.
- Finally, in the case of the four inner bars 'c', for each set of fitments three L10 bars cross a potential longitudinal crack extending from the bar to the beam soffit, whereby for each set of fitments A_{tr}=3×71=213 mm^2, and therefore over the end support ΣA_{tr}=3×213=639 mm^2. For these inner bars, according to Fig. A.3, weighted-average K=0.075, and $\Sigma A_{tr.min}$=113 mm^2. It follows that for the four 'c' bars, k_4=1-$K\lambda$=1-0.075×(ΣA_{tr}-$\Sigma A_{tr.min}$)/A_s=1-0.075×(639-113)/452=0.91.

In accordance with Clause 8.1.10.4 of AS 3600–2009, at the simple support it may be assumed that the anchor point for the bottom longitudinal reinforcement is located halfway along the length of the end bearing, b_s=400 mm, i.e. 200 mm away from point A in Fig. C.4(b) towards the beam end vertical face. It will be further assumed that the transverse concrete member supporting the beam end is laterally or transversely unrestrained, so that no additional longitudinal tensile forces develop in the main reinforcement of the continuous beam at ultimate load. Therefore, at the middle of the support, the eight anchored bars have to develop a combined design tensile force, T^*/ϕ, equal to $V^*\cot\theta_v/\phi$, and the truss angle or inclination of the compressive strut will be assumed to equal 30°, while ϕ=0.8.

Assuming a critical section at point A in Fig. C.4(b), however, the design tensile force T^*, increases to $V^*\cot\theta_v/\phi + V^*b_s/(2z)/\phi$, and it will be assumed that internal lever arm, z, between the resultant tensile force in the bottom bars and the resultant compressive force in the top face of the concrete beam equals 0.9d, where from Fig. C.4(a), d=1000-62=938 mm. It follows that T^*/ϕ=320×(cot30°/0.8+400/(2×0.9×938)/0.8)=788 kN, or 788/8=98.5 kN per N24 bar. It follows that under design ultimate load conditions, at the critical section through point A in Fig. C.4(b), the resultant tensile stress, σ_{st}, in each N24 bar is 98.5×1000/452=217.9 MPa.

It follows that in accordance with Clause 13.1.2.4 of AS 3600–2009, tensile development length, $L_{st}=L_{sy.t}\times\sigma_{st}/f_{sy}=L_{sy.t}\times217.9/500=0.436L_{sy.t}$. It should be noted further that in accordance with Clause 8.1.10.4(a)(ii) of AS 3600–2009, when not less than one half of the tensile reinforcement required at mid-span extends past the inner face of the support, as is the case for the beam in Fig. C.4, then the minimum extension of the bottom longitudinal bars shall be $12d_b=12\times24=288$ mm, which is already satisfied by the detail shown in Fig. C.4(b).

In order to calculate refined tensile development length, $L_{sy.t}$, for both outer corner bars ‘a’, referring to Fig. A.2, c_d=min. (a/2,c_1,c), and if follows from Fig. C.4(a) that c_d= min. ((246-24)/2,70-24/2,62-24/2)=50 mm. Being bottom bars (k_1=1.0) and choosing from the Index on p.16 General Table G/32/1.0/1.00, for an N24 bar, $L_{sy.tb}$=820 mm (>$29k_1d_b$=696 mm).

Transverse compressive pressure, $\rho_p=V^*/(b_s\times b)=320\times1000/(400\times1200)=0.667$ MPa, whereby $k_5=1\text{-}0.04\times0.667=0.97$. Therefore, finally, for the outer corner bars ‘a’, $L_{st}=0.436L_{sy.t}=0.436k_4k_5L_{sy.tb}=0.436\times0.98\times0.97\times820=340$ mm, which is less than the anchorage of 350 mm provided by the straight N24 bars, which is therefore satisfactory.

Next the anchorage of the two inner corner bars ‘b’ and the four inner bars ‘c’ will be calculated to determine their design development lengths, viz.: for the ‘b’ bars, c_d=min. (a/2,c)=min. ((164-24)/2,62-24/2)=50 mm, whereby $L_{sy.tb}$=820 mm remains unchanged, and $L_{st}=0.436L_{sy.t}=0.436k_4k_5L_{sy.tb}=0.436\times0.93\times0.97\times820=322$ mm, which is also less than the anchorage of 350 mm provided, which again is satisfactory; and for the ‘c’ bars, c_d=min. (a/2,c)=min. ((82-24)/2,62-24/2)=29 mm, whereby again from General Table G/32/1.0/1.00 but using c_d=30 mm, $L_{sy.tb}$=950 mm, and it follows that tensile development length $L_{st}=0.436L_{sy.t}=0.436k_4k_5L_{sy.tb}=0.436\times0.91\times0.97\times950=366$ mm, which although slightly greater than 350 mm, for design may also be deemed to be satisfactory.

This completes the design check of the reinforcement details shown in Fig. C.4, which has confirmed that none of the bottom bars extending onto the end support have to be hooked or cogged. This is a result of refined design, which has taken into account the beneficial, combined confining effects of the transverse reinforcing steel (fitments) and the transverse compressive stress in the concrete, at a direct support like shown generally in Fig. 2(b).

EXAMPLE C.5 – *Simple Design Example to illustrate Use of the Spacing-Controlled Tables in Appendix B, or the AS 3600–2009 Quick-Reference Table in Appendix D*

The design of the development length of the two terminated N28 bottom bars of the simply-supported rectangular beam shown in Fig. C13.1.2.3 of the Commentary to AS 3600–2009 [6] and used in the related *Example calculation* of Paragraph C13.1.2.3 *Refined development length* therein will be studied using the appropriate Spacing-Controlled Table in Appendix B, as detailed below. The beam has four bottom N28 bars over the mid-span region, and the two inner bars are terminated before the end supports. It is assumed in the example that these terminated bars must be able to develop their design yield stress, f_{sy}=500 MPa, over the mid-span region of the beam, extending between two central loading points.

The clear cover to the terminated N28 bars is given as 40 mm, so the bottom cover to the N12 fitments (stirrups) equals 28 mm. Characteristic compressive strength, f'_c=32 MPa, so for the purposes of this example, referring to Table B.4 in Appendix B, firstly it will be assumed that EC=A2, whereby c_{req}=25 mm, which is slightly less than the design cover of 28 mm, and therefore this is a conservative assumption when designing for bond or stress development. In order to use the Spacing-Controlled Tables, the minimum allowable clear concrete cover is calculated to equal c_{min}=max. ($d_{b.5mm}$,c_{req})=max. (30, 25) = 30 mm.

Clear distance between bars developing stress, a, i.e. the clear distance between the two inner terminated bars, is specified as 60 mm. (Note that the situation being considered actually matches the ‘Support’ case shown in Fig. A.4, as alternate bars are not being terminated, which is the ‘Span’ case shown in Fig. A.4 and this is the normal case for wider beams with more bottom bars being terminated than in this worked example.)

It follows that $a=2c_{min}$, so in fact either the Spacing-Controlled tables ($a\le2c_{min}$) or Cover-Controlled tables ($a\ge2c_{min}$) in Appendix B may be used for the design. Moreover, in Appendix B it is explained that the Spacing-Controlled Tables should only be used when bars developing stress immediately adjacent to each other are terminated, which is satisfied for this design case.

Bond conditions are ‘good’ for bottom bars, so k_1=1.0, while k_7 is irrelevant since the bars are being anchored, not lapped. Referring to the Index of Spacing-Controlled Tables (see p. 66), Tables SC/A1,A2,B1/1.0/1.25(a) or (b) may be used. Since a single grade of concrete (f'_c=32 MPa) is specified, Table SC/A1,A2,B1/1.0/1.25(a)(iii) is applicable, and it follows from this table that for the N28 bars, basic development length, $L_{sy.tb}$=1180 mm. In the Commentary to AS 3600–2009, by direct calculation it is shown that $L_{sy.tb}$=1178 mm, and allowing for rounding when the Spacing-Controlled Tables were produced, there is exact agreement without having to directly use Eq. 1c.

The same Spacing-Controlled Table also gives $L_{sy.t.min}$=830 mm, indicating that refined design could potentially reduce the development length by a significant amount (up to the maximum possible amount of 29% according to Table B.2 in Appendix B), but only if the confinement offered by the N12@150 stirrups is large enough. The calculations presented in the Commentary to AS 3600–2009 indeed show that this is not the case, and that refined design only yields $L_{sy.t}$=1120 mm (a modest 5% reduction), which is therefore of limited practical benefit applied to this design case.

For interest, referring to the Index of Cover-Controlled Tables (see p. 41), Tables CC/A2/1.0/1.00(a) or (b) may be used. Again, since a single grade of concrete (f'_c=32 MPa) is specified, Table CC/A2/1.0/1.00(a)(iii) is applicable, and it follows from this table too that for N28 bars, basic development length, $L_{sy.tb}$=1180 mm, i.e. for the design case in hand with $a=2c_{min}$, these solutions are identical for both types of tables.

Similarly, referring to the Index of General Tables (see p. 16), Table G/32/1.0/1.00 could have been used, and with c_d=30 mm, once again it will be seen that $L_{sy.tb}$=1180 mm.

Exactly the same answers for $L_{sy.tb}$ and $L_{sy.t.min}$ are contained in the AS 3600–2009 Quick-Reference Table in Appendix D, but it is necessary to use the solutions for EC=A1 and $f'_c\ge32$ MPa for this to be the case. As noted in Appendix D, this table was derived assuming $a\ge2c_{min}$, and by assuming EC=A1, c_{min}=max. ($d_{b.5mm}$,c_{req})=max. (30, 20) = 30 mm, so it holds that $a\ge60$ mm, which is correct for the design example, and explains why exactly the same solutions are obtained.

In comparison, using the AS 3600–2001 Quick-Reference Table in Appendix D the same way, with EC=A1 and $f'_c\ge32$ MPa, and referring to the associated row of *Beam/Column* solutions, it directly gives a significantly larger and therefore more conservative value of development length equal to 1360 mm. This is 15% greater than that required using basic design according to Section 13 of AS 3600–2009, and 21% greater than can be achieved by opting for refined design, as illustrated in the *Example calculation* of Paragraph C13.1.2.3 of the Commentary to AS 3600–2009, and also explained above.

APPENDIX D – ALTERNATIVE QUICK-REFERENCE TABLES

Quick-Reference Tables are provided below as a possible alternative to using Appendix B, *Design Tables to AS 3600–2009* which provides more specific solutions for a broader range. The first such table (*AS 3600–2009 Quick-Reference Table*) contains tensile development lengths and tensile lap lengths to AS 3600–2009. **It was derived directly using the solutions in General Tables G/{f'_c}/1.0/1.25, with f'_c dependent on the Exposure Classification, *EC*.** A similar, second table (*AS 3600–2001 Quick-Reference Table*) satisfies AS 3600–2001, but with some additional improvements to the design rules included [3]. Using these two tables one can compare the results of the different requirements of these two editions of AS 3600.

AS 3600–2009 Quick-Reference Table – Tensile Development Lengths (*Basic* $L_{sy.tb}$ and *Min. Refined* $L_{sy.t.min}$) and Tensile Lap Lengths (*Basic* $L_{sy.tb.lap}$ and *Min. Refined* $L_{sy.t.lap.min}$)

The AS 3600–2009 Quick-Reference Table of tensile development lengths (*basic* $L_{sy.tb}$ and minimum *refined* $L_{sy.t.min}$) and tensile lap lengths (*basic* $L_{sy.tb.lap}$ and minimum *refined* $L_{sy.t.lap.min}$) that follows has been derived (with values given in millimetres rounded to the nearest 10 mm, and also in multiples of bar diameter, d_b) with the following assumptions applying.

- For beam webs and columns, and other types of "narrow" elements or members, the clear concrete cover (c) is the minimum distance from the representative bar to any adjacent concrete surface.
- The clear distance (a) between adjacent parallel bars developing stress equals at least twice the clear concrete cover (c). A longer lap might be required if this condition is not satisfied.
- Clear concrete cover (c) is not less than bar diameter (d_b), and in design $c \geq d_{b.5mm}$.
- In narrow elements or members, the clear distance (s_b) between each pair of bars being spliced does not exceed $3d_b$. This requirement does not apply to splices in wide elements or members.
- As a practical limit, bar diameter (d_b) does not exceed 20 mm in 20 MPa concrete.
- The maximum centre-to-centre spacing between adjacent parallel bars is 300 mm.
- Bond conditions are 'good' with k_1=1.0, e.g. horizontal bars do not have more than 300 mm of concrete cast below them (which for example, excludes horizontal bars in walls from being designed). In accordance with Clause 13.1.2.2, development and lap lengths can increase by up to 30% if bond conditions are 'poor', i.e. k_1=1.3.
- The detrimental effects of lightweight concrete or slip-forming need to be allowed for separately according to Clause 13.1.2.2 – see Eq. 1c herein in Section 2.
- Lap lengths have been calculated conservatively by ignoring any beneficial effects of possible staggering or lower bar stress levels, i.e. k_7 has been assumed to equal 1.25.

The design solutions are presented in five groups according to the different combinations of minimum concrete cover (c) and concrete compressive strength grade (f'_c) in Table 4.10.3.2 of AS 3600-2009, for common Exposure Classifications A1, A2, B1 and B2, that apply when *standard formwork & compaction* are used (see Table B.4 herein). For Exposure Classification A1 or A2, when bar diameter (d_b) exceeds the minimum allowable concrete cover according to Table 4.10.3.2, **design solutions have been determined assuming $c=d_{b.5mm}$=25, 30, 35, 40 or 40 mm for d_b= 24, 28, 32, 36 or 40 mm, respectively**, and are shown in *italics* in the AS 3600–2009 Quick-Reference Table. The possibility of transverse reinforcement increasing the concrete cover has conservatively been ignored The solutions represent the maximum development or lap length required for all possible combinations of c and f'_c applicable to each particular group.

Minimum refined development and lap lengths ($L_{sy.t.min}$ and $L_{sy.t.lap.min}$) have been calculated assuming product $k_3k_4k_5$=0.7, i.e. the maximum possible benefit is provided by confinement from transverse reinforcement and/or transverse pressure. It follows that, depending on the value of k_3, $0.7 \leq k_4k_5 \leq 1.0$. It is left up to the designer to confirm that there is sufficient transverse reinforcement (accounted for by k_4) and/or transverse pressure (accounted for by k_5) to justify using a refined development or lap length, if it is less than the corresponding basic development or lap length ($L_{sy.tb}$ or $L_{sy.tb.lap}$) – see worked examples in Appendix C.

It can be seen from the AS 3600–2009 Quick-Reference Table that:

- development and lap lengths generally reduce as the Exposure Classification becomes more severe, i.e. moving from A1 to B2, which is mainly due to the general increase in concrete cover (c) according to Table B.4; and
- minimum refined development and lap lengths ($L_{sy.t.min}$ and $L_{sy.t.lap.min}$) can be significantly shorter than their corresponding basic lengths ($L_{sy.tb}$ and $L_{sy.tb.lap}$), particularly for large diameter bars, which can justify additional calculations for beams & columns with confining fitments, etc. – see worked examples in Appendix C.

Solutions are colour-coded according to the following arbitrary ranges of length, given as a multiple of bar diameter (d_b):

(light green)	$\leq 30d_b$
(beige)	$> 30d_b$ to $\leq 40d_b$
(pink)	$> 40d_b$ to $\leq 50d_b$
(light blue)	$> 50d_b$ to $\leq 60d_b$
(blue)	$> 60d_b$

Repeating, as stated immediately above, solutions shown in *italics* are where, for Exposure Classification A1 or A2, bar diameter (d_b) exceeds the minimum allowable concrete cover, c.

Example D.1 – Fully anchor all horizontal N16@250 bars in the top face of a 250 mm deep slab, with f'_c=32 MPa (normal-density) and cover (c) of 40 mm for Exposure Classification B1.

Clear distance, a= 250-16 = 234 >2c (=80 mm), which has to be satisfied for the AS 3600–2009 Quick-Reference Table to be used; also, k_1=1.0 (good bond conditions) and k_7=1.25 (no staggering of end anchorages). This combination of f'_c and c for Exposure Classification B1 corresponds to the fourth group of solutions in the Quick-Reference Table. It follows that for d_b=16 mm, $L_{sy.tb} = L_{sy.t.min} = L_{sy.t}$ = 480 mm (30.0 d_b), i.e. the basic and refined tensile development lengths are equal in this case.

Example D.2 – Lap same bars as in Example D.1, in either contact or non-contact splices, to fully develop f_{sy} outside lapped splices which are not staggered.

Clear distance, a= 250-2×16 = 218 >2c (=80 mm), which has to be satisfied for the Quick-Reference Table to be used; also, k_1=1.0 (good bond conditions) and k_7=1.25 (no staggering). Since a slab is a wide member, there is not restriction on the value of s_b for non-contact splices. Again using the fourth group of solutions in the Quick-Reference Table, it follows that $L_{sy.tb.lap} = L_{sy.t.lap.min} = L_{sy.t.lap}$ = 600 mm (37.5 d_b), i.e. the basic and refined tensile lap lengths are also equal in this case, but 25% greater than the development lengths in Example D.1.

AS 3600–2009 QUICK-REFERENCE TABLE (Normal-density concrete: ξ_{cd}=1.0; Bare steel bars: ξ_{bc}=1.0)

Tensile Development Lengths (Basic $L_{sy.tb}$ & Min. Refined $L_{sy.t.min}$) and Tensile Lap Lengths (Basic $L_{sy.tb.lap}$ & Min. Refined $L_{sy.t.lap.min}$) of Straight D500N Bars ($a \geq 2c$)

Exposure Classification, *EC*	Development or Lap Length (k_1=1.0,k_7=1.25)		Bar Diameter, d_b (mm) 10	12	16	20	24	28	32	36	40
A1 (f'_c = 20 or 25 MPa for d_b≤20 mm) (f'_c = 25 MPa for d_b≥24 mm)	$L_{sy.tb}$	mm (× d_b)	390 (39.0)	500 (41.7)	740 (46.3)	1000 (50.0)	1100 (45.8)	1330 (47.5)	1580 (49.4)	1840 (51.1)	2170 (54.3)
	$L_{sy.t.min}$		320 (32.0)	390 (32.5)	540 (33.8)	700 (35.0)	780 (32.5)	940 (33.6)	1120 (35.0)	1310 (36.4)	1520 (38.0)
	$L_{sy.tb.lap}$		490 (49.0)	630 (52.5)	930 (58.1)	1250 (62.5)	1380 (57.5)	1660 (59.3)	1970 (61.6)	2300 (63.9)	2720 (68.0)
	$L_{sy.t.lap.min}$		400 (40.0)	490 (40.8)	670 (41.9)	870 (43.5)	970 (40.4)	1180 (42.1)	1400 (43.8)	1640 (45.6)	1900 (47.5)
A1 (f'_c ≥ 32 MPa)	$L_{sy.tb}$	mm (× d_b)	310 (31.0)	400 (33.3)	590 (36.9)	790 (39.5)	980 (40.8)	1180 (42.1)	1390 (43.4)	1630 (45.3)	1920 (48.0)
	$L_{sy.t.min}$		260 (26.0)	310 (25.8)	430 (26.9)	550 (27.5)	690 (28.8)	830 (29.7)	990 (30.9)	1160 (32.2)	1340 (33.5)
	$L_{sy.tb.lap}$		380 (38.0)	500 (41.7)	730 (45.6)	990 (49.5)	1220 (50.8)	1470 (52.5)	1740 (54.4)	2040 (56.7)	2400 (60.0)
	$L_{sy.t.lap.min}$		320 (32.0)	390 (32.5)	530 (33.1)	690 (34.5)	860 (35.8)	1040 (37.1)	1230 (38.4)	1450 (40.3)	1680 (42.0)
A2 (f'_c ≥ 20 MPa for d_b≤20 mm) (f'_c ≥ 25 MPa for d_b≥24 mm)	$L_{sy.tb}$	mm (× d_b)	320 (32.0)	390 (32.5)	600 (37.5)	830 (41.5)	1070 (44.6)	1330 (47.5)	1580 (49.4)	1840 (51.1)	2170 (54.3)
	$L_{sy.t.min}$		320 (32.0)	390 (32.5)	540 (33.8)	700 (35.0)	780 (32.5)	940 (33.6)	1120 (35.0)	1310 (36.4)	1520 (38.0)
	$L_{sy.tb.lap}$		400 (40.0)	490 (40.8)	750 (46.9)	1030 (51.5)	1340 (55.8)	1660 (59.3)	1970 (61.6)	2300 (63.9)	2720 (68.0)
	$L_{sy.t.lap.min}$		400 (40.0)	490 (40.8)	670 (41.9)	870 (43.5)	970 (40.4)	1180 (42.1)	1400 (43.8)	1640 (45.6)	1900 (47.5)
B1 (f'_c ≥ 25 MPa)	$L_{sy.tb}$	mm (× d_b)	290 (29.0)	350 (29.2)	480 (30.0)	670 (33.5)	880 (36.7)	1120 (40.0)	1390 (43.5)	1690 (46.9)	2010 (50.3)
	$L_{sy.t.min}$		290 (29.0)	350 (29.2)	480 (30.0)	630 (31.5)	780 (32.5)	940 (33.6)	1120 (35.0)	1310 (36.4)	1520 (38.0)
	$L_{sy.tb.lap}$		360 (36.0)	440 (36.7)	600 (37.5)	840 (42.0)	1100 (45.8)	1390 (49.6)	1740 (54.4)	2110 (58.6)	2510 (62.8)
	$L_{sy.t.lap.min}$		360 (36.0)	440 (36.7)	600 (37.5)	780 (39.0)	970 (40.4)	1180 (42.1)	1400 (43.8)	1640 (45.6)	1900 (47.5)
B2 (f'_c ≥ 32 MPa)	$L_{sy.tb}$	mm (× d_b)	290 (29.0)	350 (29.2)	460 (28.8)	580 (29.0)	760 (31.7)	970 (34.7)	1200 (37.5)	1460 (40.6)	1740 (43.5)
	$L_{sy.t.min}$		290 (29.0)	350 (29.2)	460 (28.8)	580 (29.0)	690 (28.8)	830 (29.6)	990 (30.9)	1160 (32.2)	1340 (33.5)
	$L_{sy.tb.lap}$		320 (32.0)	390 (32.5)	530 (33.1)	720 (36.0)	950 (39.6)	1210 (43.2)	1490 (46.6)	1820 (50.6)	2180 (54.5)
	$L_{sy.t.lap.min}$		320 (32.0)	390 (32.5)	530 (33.1)	690 (34.5)	860 (35.8)	1040 (37.1)	1240 (38.8)	1450 (40.3)	1680 (42.0)

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min}$, and minimum refined lap length, $L_{sy.t.lap.min}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min}$). Also, while using Eq. 1c to produce the AS 3600–2009 Quick-Reference Table, basic factor ξ_{cd}=1.0 (i.e. normal-density concrete) and basic factor ξ_{bc}=1.0 (i.e. uncoated or bare steel bars).

AS 3600–2001 Design Rules (incorporating recommended improvements [3])

In accordance with Clause 13.1.2.1 of AS 3600–2001, it is intended that the development length ($\bar{L}_{sy.t}$) to develop the nominal yield strength of a grade 500 MPa (f_{sy}=500 MPa) straight, deformed Ductility Class N (D500N) bar in tension shall be calculated as follows:

$$\bar{L}_{sy.t} = \frac{\bar{k}_1 \bar{k}_2 f_{sy} A_b}{(2\bar{c}_d + d_b)\sqrt{f'_c}} \geq 29\bar{k}_1 d_b$$

where:

$\bar{k}_1$ = 1.25 for horizontal bars with more than 300 mm of concrete cast below the bars (poor bond conditions); or
= 1.0 for all other bars (good bond conditions);

$\bar{k}_2$ = 1.7 for bars in slabs and walls if the clear distance between adjacent parallel bars developing stress is not less than 150 mm;
= 2.2 for longitudinal bars in beams or columns with fitments;
= 2.4 for all other longitudinal bars;

f_{sy} = nominal yield strength of the reinforcing bars (500 MPa);

A_b = cross-sectional area of a single reinforcing bar (mm^2);

$2\bar{c}_d$ = twice the cover to the bars (c), or the clear distance between adjacent parallel bars developing stress (a), whichever is the lesser, noting that in the formula its value is bounded according to $2d_b \leq 2\bar{c}_d \leq 6d_b$ (mm);

d_b = nominal bar diameter (mm); and

f'_c = characteristic compressive cylinder strength of normal-density concrete at 28 days (MPa).

In accordance with Clause 13.2.2, the same formula shall be used to calculate the tensile lap length ($\bar{L}_{sy.t.lap}$), with due account taken of the presence of the lapped bars when determining the clear distance, *a*. For bars in the same plane, the clear distance should be determined assuming contact lapped splices, i.e. lapped bars touch each other, while non-contact lapped splices are equally acceptable, and have the same value of tensile lap length ($\bar{L}_{sy.t.lap}$).

AS 3600–2001 Quick-Reference Table – Tensile Development Lengths ($\bar{L}_{sy.t}$) and Tensile Lap Lengths ($\bar{L}_{sy.t.lap}$) of Straight D500N Bars

The AS 3600–2001 Quick-Reference Table of tensile development lengths ($\bar{L}_{sy.t}$) and lap lengths ($\bar{L}_{sy.t.lap}$), with values given in millimetres rounded to the nearest 10 mm, and also in multiples of bar diameter, d_b, has been derived based on the following assumptions.

- The rules of AS 3600–2001 have been updated according to more recent recommendations: see [3], "*A Review of Australian Design and Construction Practices Concerning Anchorage and Lap Splicing of Reinforcing Bars, with Particular Emphasis on Slabs and Walls*", available at SRIA's web site www.sria.com.au.
- For beam webs and columns, and other types of "narrow" elements or members, the concrete cover (c) shall be taken as the minimum clear distance from the representative bar to any exposed concrete surface including a vertical side.
- The clear distance between adjacent parallel bars developing stress (a) equals at least twice the concrete cover (c). A larger anchorage or lap length may be required if this condition is not satisfied. Also, see *AS 3600–2001 Quick-Reference Table* note.
- Clear concrete cover, c, is not less than the bar diameter, d_b, and as for the AS 3600–2009 Quick-Reference Table, results shown in *italics* correspond to $c=d_{b.5mm}$=25, 30, 35, 40 or 40 mm for d_b= 24, 28, 32, 36 or 40 mm, respectively.
- The maximum bar diameter used in slabs or walls equals 32 mm, while in grade 20 MPa concrete, the nominal bar diameter does not exceed 20 mm. These are practical limits only, noting that the design rules are not restricted in this manner.
- The maximum centre-to-centre spacing between adjacent parallel bars is 300 mm.
- $\bar{k}_1$=1.0, i.e. horizontal bars do not have more than 300 mm of concrete cast below them (which therefore excludes horizontal bars in walls), or else the bars are vertical.
- $\bar{k}_2$=1.7 for bars in slabs and walls, with bar clear distance not less than 150 mm.
- Wherever possible, lapped splices should be staggered.

The design solutions are presented in five groups according to the different combinations of Exposure Classification, *EC*, and concrete compressive strength grade, f'_c, given in the first column of the AS 3600–2001 Quick-Reference Table. The solutions represent the maximum lengths required for all of the combinations of these variables in the group.

Where reinforcing bars of different sizes are lapped, the tensile lap length should equal the larger of the tensile lap length ($\bar{L}_{sy.t.lap}$) for the smaller diameter bar, and the tensile development length ($\bar{L}_{sy.t}$) for the larger diameter bar.

Common bar chair sizes (mm) are: 20, 25, 30, 35, 40, 45, 50, 65, 75+. These values are reflected in the values of clear cover, *c*, used in the table, where reduced concrete covers are also associated with higher concrete strength grades according to Table B.4. The possibility of transverse reinforcement increasing the concrete cover has conservatively been ignored.

It can be seen from the AS 3600–2001 Quick-Reference Table that development and lap lengths generally reduce as the Exposure Classification becomes more severe, i.e. moving from A1 to B2, which is mainly due to the general increase in concrete cover (c).

Solutions are colour-coded according to the following arbitrary ranges of length, given as a multiple of bar diameter (d_b):

(light green)	≤ $30d_b$
(tan)	> $30d_b$ to ≤ $40d_b$
(pink)	> $40d_b$ to ≤ $50d_b$
(light blue)	> $50d_b$ to ≤ $60d_b$
(blue)	> $60d_b$

Note: Variables that specifically relate to the design rules in AS 3600–2001 are identified by a top bar accent, e.g. $\bar{k}_1$. They are defined where they are first used, and as they are only used in this appendix, for brevity they are not generally included with the rest of the terminology of the technical note defined in Appendix A.

Example D.3 – Fully anchor all horizontal N16@250 bars in the top face of a 250 mm deep slab, with f'_c=32 MPa (normal-density) and cover (c) of 40 mm for Exposure Classification B1.

Clear distance, a= 250-16 = 234 >2c (=80 mm), which has to be satisfied for the AS 3600–2001 Quick-Reference Table to be used; also, $\bar{k}_1$=1.0 (good bond conditions); $\bar{k}_2$=1.7. This combination of f'_c and c for Exposure Classification B1 corresponds to the fourth group of solutions in the Quick-Reference Table. It follows that for d_b=16 mm, $\bar{L}_{sy.t}$=470 mm (29.4 d_b). This is almost exactly the same solution as for Example D.1, as given by AS 3600-2009.

Example D.4 – Lap same bars as in Example D.3, in either contact or non-contact splices, to fully develop f_{sy} outside lapped splices which are not staggered.

Clear distance, a= 250-2×16 = 218 >2c (=80 mm), which has to be satisfied for the AS 3600–2001 Quick-Reference Table to be used; also, $\bar{k}_1$=1.0 (good bond conditions); $\bar{k}_2$=1.7. It follows that $\bar{L}_{sy.t.lap}$ = 470 mm (29.4 d_b). This is ≈25% less than required by AS 3600-2009 due to k_7=1.25, without staggering. However, $L_{sy.tb.lap}$ = 470 mm is also acceptable to AS 3600–2009 if the laps are staggered 50% in a non-critical region, which is normally feasible on site.

AS 3600–2001 QUICK-REFERENCE TABLE (Normal-density concrete; Bare steel bars)

Tensile Development Length ($\bar{L}_{sy.t}$) and Tensile Lap Length ($\bar{L}_{sy.t.lap}$) of Straight D500N Bars ($a≥2c$)

Exposure Classification, *EC*	Development ($\bar{L}_{sy.t}$) or Lap ($\bar{L}_{sy.t.lap}$) Length, ($\bar{k}_1$=1.0)		Bar Diameter, d_b (mm) 10	12	16	20	24	28	32	36	40
A1 (f'_c = 20 or 25 MPa for d_b≤20 mm) (f'_c = 25 MPa for d_b≥24 mm)	*Slab/Wall*	mm (× d_b)	300 (30.0)	410 (34.2)	680 (42.5)	1000 (50.0)	*1040 (43.3)*	*1190 (42.5)*	*1340 (41.9)*	No solutions provided – see assumptions	
	Beam/Column		390 (39.0)	530 (44.2)	880 (55.0)	1290 (64.5)	*1340 (55.8)*	*1540 (55.0)*	*1730 (54.1)*	*1930 (53.6)*	*2300 (57.5)*
	Other		420 (42.0)	580 (48.3)	960 (60.0)	1400 (70.0)	*1470 (61.3)*	*1680 (60.0)*	*1890 (59.1)*	*2110 (58.6)*	*2510 (62.8)*
A1 (f'_c ≥ 32 MPa)	*Slab/Wall*	mm (× d_b)	290 (29.0)	350 (29.2)	540 (33.8)	790 (39.5)	*920 (38.3)*	*1050 (37.5)*	*1180 (36.9)*	No solutions provided – see assumptions	
	Beam/Column		310 (31.0)	420 (35.0)	700 (43.8)	1020 (50.5)	*1190 (49.6)*	*1360 (48.6)*	*1530 (47.8)*	*1710 (47.5)*	*2040 (51.0)*
	Other		330 (33.0)	460 (38.3)	760 (47.5)	1110 (55.5)	*1300 (54.2)*	*1480 (52.9)*	*1670 (52.2)*	*1860 (51.7)*	*2220 (55.5)*
A2 (f'_c ≥ 20 MPa for d_b≤20 mm) (f'_c ≥ 25 MPa for d_b≥24 mm)	*Slab/Wall*	mm (× d_b)	290 (29.0)	350 (29.2)	480 (30.0)	700 (35.0)	920 (38.3)	1190 (42.5)	*1340 (41.9)*	No solutions provided – see assumptions	
	Beam/Column		290 (29.0)	380 (31.7)	620 (38.8)	910 (45.5)	1190 (49.6)	1540 (55.0)	*1730 (54.1)*	*1930 (53.6)*	*2300 (57.5)*
	Other		300 (30.0)	410 (34.2)	680 (42.5)	990 (49.5)	1300 (54.2)	1680 (60.0)	*1890 (59.1)*	*2110 (58.6)*	*2510 (62.8)*
B1 (f'_c ≥ 25 MPa)	*Slab/Wall*	mm (× d_b)	290 (29.0)	350 (29.2)	470 (29.4)	580 (29.0)	730 (30.4)	940 (33.6)	1080 (33.8)	No solutions provided – see assumptions	
	Beam/Column		290 (29.0)	350 (29.2)	470 (29.4)	700 (35.0)	950 (39.6)	1220 (43.6)	1400 (43.8)	1710 (47.5)	2040 (51.0)
	Other		290 (29.0)	350 (29.2)	520 (32.5)	760 (38.0)	1040 (43.3)	1330 (47.5)	1520 (47.5)	1860 (51.7)	2220 (55.5)
B2 (f'_c ≥ 32 MPa)	*Slab/Wall*	mm (× d_b)	290 (29.0)	350 (29.2)	470 (29.4)	580 (29.0)	700 (29.2)	820 (29.3)	950 (29.7)	No solutions provided – see assumptions	
	Beam/Column		290 (29.0)	350 (29.2)	470 (29.4)	580 (29.0)	750 (31.3)	980 (35.0)	1230 (38.4)	1410 (39.2)	1680 (42.0)
	Other		290 (29.0)	350 (29.2)	470 (29.4)	590 (29.5)	820 (34.2)	1070 (38.2)	1340 (41.9)	1530 (42.5)	1830 (45.8)

Note: As can readily be seen from the formula given in this appendix for calculating tensile development length, $\bar{L}_{sy.t}$, in accordance with AS 3600–2001, the tensile development length, $\bar{L}_{sy.t}$, and the tensile lap length, $\bar{L}_{sy.t.lap}$, will be equal in value if, for all other variables in the formula equal, $\bar{c}_d$ has the same value. This will generally be the case when $a≥2c$, for the anchored or lap spliced bars, which is a condition that must be satisfied for all the solutions in the AS 3600–2001 Quick-Reference Table to be valid. However, the determination of clear distance, *a*, should take into account whether the bars developing stress are being anchored or lapped, e.g.: Fig. A.4 shows how to determine clear distance, *a*, for planar anchored bars; and Fig. A.5 shows how for planar lapped bars, whether lapped splices are contact or non-contact. This distinction about the calculation of *a*, and therefore $2\bar{c}_d$ in the formula in AS 3600–2001 for $\bar{L}_{sy.t}$, for either anchored or lap-spliced bars, appears to have not been widely understood or practiced in the past. Neither has the inequality $2d_b≤2\bar{c}_d≤6d_b$ been applied in the past, but importantly defines the range of feasible solutions. Also, the AS 3600–2001 Quick-Reference Table only applies for normal-density concrete and uncoated or bare steel bars.