ACI 318-19 Code Revisions Impact on StructurePoint Software

General Themes & Summary

ACI 318-19 continues to unify and simplify code provisions started in 2014 reorganization of chapters by members. Nearly all the changes with software impact pertain to the design of beams and slabs in floor systems. While vertical and foundation elements are not as significantly impacted.

Some of the significant changes are:

- New provisions are introduced for the use of high-strength reinforcing
- New reinforcement strain limit is introduced for nonprestressed members
- Consideration of the bi-directional interaction of one-way shear is mandated
- Hanger reinforcement provisions are introduced
- Light-weight concrete modification factor, λ, calculation is modified
- Significant updates to one-way shear and two-way shear calculations are introduced
- Shrinkage and temperature reinforcement provisions are revised

Chapter 7: One-Way Slabs

Reinforcement strain limit is revised:
ACI 318-19, 7.3.3.1 states that *"nonprestressed slabs shall be tension-controlled in accordance with Table 21.2.2."*
ACI 318-14 stated that *"for nonprestressed slabs, ε_t, shall be at least 0.004."*

This change leads to more economical designs for nonprestressed one-way slabs by eliminating the need to add more tension steel just to satisfy a lower steel strain limit without any gain in the flexural design strength due to reduced strength reduction factor, ϕ. The software already utilizes the newly introduced provision. Therefore, there is no impact in implementation.

Minimum flexural reinforcement requirements are revised:
ACI 318-19, 7.6.1.1 states that *"a minimum area of flexural reinforcement, $A_{s,min}$, of 0.0018 A_g shall be provided."*
ACI 318-14 requirements were based on reinforcement type and grade as shown below:

<u>Deformed bars with the yield strength of reinforcement, f_y < 60,000 psi:</u>
The minimum area of flexural reinforcement, $A_{s,min}$, was equal to 0.0020 A_g.

Therefore, the $A_{s,min}$ requirement is reduced by 10% in ACI 318-19.

<u>Deformed bars or welded wire reinforcement with the yield strength of reinforcement, $f_y \geq$ 60,000 psi:</u>
The minimum area of flexural reinforcement, $A_{s,min}$, was greater of:

$$\frac{0.0018 \times 60,000}{f_y} A_g$$

$$0.0014\ A_g$$

Therefore, the $A_{s,min}$ requirement stayed unchanged for Grade 60 reinforcement in ACI 318-19. However, for higher grade reinforcement, there is an increase in the $A_{s,min}$ requirement. For example, for 80 ksi reinforcement, the new $A_{s,min}$ requirement is 0.0018 A_g instead of the ACI 318-14 value of 0.0014 A_g (i.e. 28.6% increase in ACI 318-19). This change unifies the minimum flexural reinforcement requirement irrespective of reinforcement grade and therefore, simplifies the software implementation.

New Structural Integrity Provisions are introduced:
ACI 318-19, 7.7.7.1 states that *"longitudinal structural integrity reinforcement consisting of at least one-quarter of the maximum positive moment reinforcement shall be continuous."*

The change brings one-way cast-in-place slab structural integrity provisions in line with beam structural integrity provisions. The software already utilizes the newly introduced provision. Therefore, there is no impact in implementation.

Chapter 8: Two-Way Slabs

Minimum slab thickness requirements are revised:
ACI 318-19, Table 8.3.1.1 for minimum thickness of nonprestressed two-way slabs without interior beams is revised to include Grade 80 reinforcement.

This change affects the calculation of minimum slab thickness for f_y exceeding 60,000 psi. There is an impact on the input echo section of the software while the design and investigation processes remain unaffected.

Modulus of Rupture equation is modified for f_y exceeding 80,000 psi in a nonprestressed slab systems:
ACI 318-19, 8.3.1.1 states that "*for f_y exceeding 80,000 psi, the calculated deflection limits in 8.3.2 shall be satisfied assuming a reduced modulus of rupture, $f_r = 5\sqrt{f'_c}$*."

This change leads to higher deflections for f_y exceeding 80,000 psi in a nonprestressed slab systems.

Reinforcement strain limit is revised:
ACI 318-19, 8.3.3.1 states that *"nonprestressed slabs shall be tension-controlled in accordance with Table 21.2.2."*
ACI 318-14 stated that *"for nonprestressed slabs, ε_t, shall be at least 0.004."*

This change leads to more economical designs for nonprestressed two-way slabs by eliminating the need to add more tension steel just to satisfy a lower steel strain limit without any gain in the flexural design strength due to reduced strength reduction factor, ϕ. The software already utilizes the newly introduced provision. Therefore, there is no impact in implementation.

Effective slab width, b_{slab}, calculation is revised:
ACI 318-19, 8.4.2.2.3 states that *"the effective slab width, b_{slab}, for resisting $\gamma_f M_{sc}$ shall be the width of column or capital plus a distance on each side equal to the lesser of 1.5h of slab, and the distance to the edge of the slab on either side. Where a drop panel or shear cap is present, the distance on each side shall be lesser of 1.5h of the drop or cap, and the distance to the edge of the drop or cap plus 1.5h of the slab."*
ACI 318-14, 8.4.2.3.3 stated that *"the effective slab width, b_{slab}, for resisting $\gamma_f M_{sc}$ shall be the width of column or capital plus 1.5h of slab or drop panel on either side of column or capital."*

This change in b_{slab} formula affects the flexural design, minimum area of flexural reinforcement, unbalanced moment transfer calculations in the software.

Maximum modified values of γ_f values for nonprestressed two-way slabs:
In ACI 318-19, Table 8.4.2.2.4 for the determination of the maximum modified γ_f values for nonprestressed two-way slabs is revised as follows:

- The v_{ug} notation is replaced by a newly introduced v_{uv} notation where

v_{ug} = factored shear stress on the slab critical section for two-way action due to gravity loads without moment transfer, psi.
v_{uv} = factored shear stress on the slab critical section for two-way action, from the controlling load combination, without moment transfer, psi.

- In ACI 318-14, Table 8.4.2.3.4 for the determination of the maximum modified γ_f values for nonprestressed two-way slabs, the strain limits on ε_t were constant at 0.004 or 0.010 depending on the column location and span direction. In ACI 318-19, these limits are replaced by the expressions ε_{ty} + 0.003 and ε_{ty} + 0.008 respectively in order to accommodate nonprestressed reinforcement of higher grades. The first expression is same as the limit on ε_t for classification of tension-controlled members while the second expression allows higher ε_t value for nonprestressed reinforcement grades that are higher than 60,000 psi as compared to the previous limit of 0.010.

Determination of factored shear stress due to direct shear is revised:
ACI 318-19, 8.4.4.2.1 states that *"Factored shear stress v_u corresponds to a combination of v_{uv} and the shear stress produced by $\gamma_v M_{sc}$, where γ_v is given in 8.4.4.2.2 and M_{sc} is given in 8.4.2.2.1."*
In ACI 318-14, v_{ug} notation was utilized in lieu of the newly introduced v_{uv} notation.

This change leads to the consideration of not only gravity loads but also all the other load combinations in the factored shear stress calculations. The software already utilizes the revised provision. Therefore, there is no impact in implementation.

Minimum flexural reinforcement in nonprestressed two-way slabs:
ACI 318-19, 8.6.1.1 states that *"a minimum area of flexural reinforcement, $A_{s,min}$, of 0.0018 A_g or as defined in 8.6.1.2 shall be provided near the tension face of the slab in the direction of the span under consideration."* Prior editions of ACI 318 were based on reinforcement type and grade as follows:

Deformed bars with the yield strength of reinforcement, f_y < 60,000 psi:
The minimum area of flexural reinforcement, $A_{s,min}$, was equal to 0.0020 A_g.

Deformed bars or welded wire reinforcement with the yield strength of reinforcement, $f_y \geq$ 60,000 psi:
The minimum area of flexural reinforcement, $A_{s,min}$, was greater of:

$$\frac{0.0018 \times 60{,}000}{f_y} A_g$$

$$0.0014\ A_g$$

ACI 318-19, 8.6.1.2 states that if $v_{uv} > \phi 2 \lambda_s \lambda \sqrt{f'_c}$ on the critical section for two-way shear surrounding a column, concentrated load, or reaction area, $A_{s,min}$, provided over the width b_{slab} shall satisfy Eq. 8.6.1.2. Eq. 8.6.1.2 is given below:

$$A_{s,min} = \frac{5 v_{ug} b_{slab} b_0}{\phi \alpha_s f_y}$$

The $A_{s,min}$, equation needs to be satisfied to decrease the possibility of a flexure-driven punching failure at shear stresses exceeding $\phi 2 \lambda_s \lambda \sqrt{f'_c}$.

$A_{s,min}$, also needs to be provided at the periphery of drop panels and shear caps.

This revision unifies the minimum flexural reinforcement requirement irrespective of reinforcement grade. However, the new criteria introduced in 8.6.1.2 needs to be implemented in the software in models where $V_{uv} > \phi 2\lambda_s \lambda \sqrt{f'_c}$.

The direct design method and the equivalent frame method are recognized as "text book" material by ACI 318:
ACI 318-19 removes the provisions 8.10 for direct design method and provision 8.11 for equivalent frame method entirely. While, ACI 318-19, 6.2.4.1 states that *"two-way slabs shall be permitted to be analyzed for gravity loads in accordance with (a) or (b):*

(a) Direct design method for nonprestressed slabs
(b) Equivalent frame method for nonprestressed and prestressed slabs"

ACI 318-19, R6.2.4.1 state that *"Code editions from 1971 to 2014 contained provisions for the use of the direct design method and the equivalent frame method. These methods are well-established and covered in available texts. These provisions for gravity load analysis of two-way slabs have been removed from the Code because they are considered to be only two of several analysis methods currently used for the design of two-way slabs. The direct design method and the equivalent frame method of the 2014 Code, however, may still be used for the analysis of two-way slabs for gravity loads."*

The reason for this change is stated as *"the inclusion of the direct design method and the equivalent frame method in the code is no longer necessary because these methods can now be considered "text book" material and have been typically replaced by computer analysis methods."* The software already utilizes the equivalent frame method provisions of ACI 318-14, 8.11. Therefore, there is no impact in implementation.

Minimum extensions for deformed reinforcement are revised:
ACI 318-19, Figure 8.7.4.1.3 for the minimum extensions for deformed reinforcement in two-way slabs without beams is revised such that the 50% of column strip top reinforcement shall be as defined in ACI 318-14, but not less than 5d where d is the distance from the extreme compression fiber to centroid of longitudinal tension reinforcement.

This revision enforces an additional reinforcement length criterion in order to prevent potential punching shear deficiency due to the fact that the standard reinforcement extensions that was in ACI 318-14 may not be long enough to intercept critical shear cracks in thick two-way slabs. This will increase the reinforcement lengths at column strips of thick two-way slabs. Therefore, the change needs to be implemented in the software.

Chapter 9: Beams

Reinforcement strain limit is revised:
ACI 318-19, 9.3.3.1 states that *"Nonprestressed beams with $P_u < 0.10 f'_c A_g$ shall be tension-controlled in accordance with Table 21.2.2."*
ACI 318-14 stated that *"for nonprestressed beams with $P_u < 0.10 f'_c A_g$, ε_t, shall be at least 0.004."*

This change results in more economical flexural designs for beams by eliminating the need to add more tension steel just to satisfy a lower steel strain limit without any gain in the flexural design strength due to reduced strength reduction factor, ϕ. The software already utilizes the newly introduced provision. Therefore, there is no impact in implementation.

Upper limit for f_y is introduced for minimum flexural reinforcement, $A_{s,min}$, calculations:
For the calculation of the minimum flexural reinforcement amount for beams with f_y exceeding 80,000 psi, ACI 318-19, 9.6.1.2 states that *"the value of f_y shall be limited to a maximum of 80,000 psi."*
ACI 318-14 did not permit the use of flexural reinforcement exceeding 80,000 psi for beams.

This change affects the flexural designs of beams with f_y exceeding 80,000 psi. The $A_{s,min}$ values calculated by equations 9.6.1.2 (a) and (b) will be same as for Grade 80 reinforcement even if the higher strength reinforcement is utilized in the design.

Lower limit of $0.5d_b$ is introduced for transverse reinforcement index, K_{tr}, when f_y > 80,000 psi:
ACI 318-19, 9.7.1.4 states that *"along development and lap splice lengths of longitudinal bars with f_y > 80,000 psi, K_{tr}, shall not be smaller than $0.5d_b$."*
ACI 318-14 did not permit the use of flexural reinforcement exceeding 80,000 psi for beams.

The requirement for a minimum value of K_{tr} along development and splice lengths improves ductility. This change affects the software implementation as K_{tr} can no longer be conservatively assumed as zero for the flexural designs of beams with f_y exceeding 80,000 psi.

Modifications to the maximum spacing of legs of shear reinforcement:
ACI 318-19, Table 9.7.6.2.2 introduces new maximum spacing of legs of shear reinforcement criteria across the width of beams. Also, a new figure is added to the commentary titled Fig. R9.7.6.2.1 - Hanger reinforcement for shear transfer.

This change improves shear behavior of wide beams that require stirrups by providing multiple stirrup legs. This new criterion affects the determination of the number of legs across the width of a wide beams in design. Therefore, the change needs to be implemented in the software.

Chapter 10: Columns

Lower limit of $0.5d_b$ is introduced for transverse reinforcement index, K_{tr}, when f_y > 80,000 psi:
ACI 318-19, 10.7.1.3 states that *"along development and lap splice lengths of longitudinal bars with f_y > 80,000 psi, K_{tr}, shall not be smaller than $0.5d_b$."*
ACI 318-14 did not permit the use of reinforcement exceeding 80,000 psi for columns.

The requirement for a minimum value of K_{tr} along development and splice lengths improves ductility. This change does not affect the spColumn implementation as transverse reinforcement index, K_{tr}, is not utilized by the program.

Chapter 11: Walls

Upper limit for the nominal shear strength, V_n:
ACI 318-19, 11.5.4.2 states that *"V_n at any horizontal section shall not exceed $8\sqrt{f'_c}A_{cv}$."*
In ACI 318-14, the limit for in-plane shear, the nominal shear strength, V_n, was $10\sqrt{f'_c}hd$.

This limit is intended to guard against diagonal compression failure in structural walls. The change creates consistency in the calculation of the in-plane shear strength of structural walls between Code chapters 18 (18.10.4) and 11 (11.5.4). However, it has no numerical impact in the software implementation as the d is already taken as $0.8l_w$ and A_{cv} equals to hl_w.

The nominal shear strength, V_n, calculations:
ACI 318-19, R11.5.4.3 states that to improve consistency in the Code, the nominal in-plane shear strength equation in section 11.5.4.3 now has the same form as the shear strength equation used in section 18.10.4.1. Accordingly, the sections 11.5.4.6 and 11.5.4.7 of ACI 318-14 for V_c calculations, and section 11.5.4.8 of ACI 318-14 for V_s calculation are completely removed from ACI 318-19. The detailed calculation option allowed within spWall is also removed by the removal of the ACI 318-14, Table 11.5.4.6.

The impact of this change can only be determined after implementation for various conditions.

New V_n formula is introduced for individual vertical wall segments:
ACI 318-19, 11.5.4.5 states that "for all vertical wall segments sharing a common lateral force, V_n, shall not be taken greater than $8\sqrt{f'_c}A_{cv}$ where A_{cv} is the gross area of concrete bounded by web thickness and length of section. For any one of the individual vertical wall segments, V_n shall not be taken greater than $10\sqrt{f'_c}A_{cw}$, where A_{cw} is the area of concrete section of the individual vertical wall segment considered. The change creates consistency between Code chapters 18 (18.10.4.4) and 11 (11.5.4.5).

The impact of this change can only be determined after implementation for various conditions.

In-plane V_u criteria is modified for determining the minimum reinforcement for walls:
ACI 318-19, 11.6.1 states that *"if in-plane $V_u \leq 0.5\phi\alpha_c\lambda\sqrt{f'_c}A_{cv}$, minimum ρ_l and minimum ρ_t shall be in accordance with Table 11.6.1."* ACI 318-14, 11.6.1 stated that *"if in-plane $V_u \leq 0.5\phi V_c$, minimum ρ_l and minimum ρ_t shall be in accordance with Table 11.6.1."*

This change results in a lower threshold value for V_u criteria where minimum reinforcement shall be acceptable. Therefore, the wall sections that once would only require minimum reinforcement according to ACI 318-14 shall need to have more reinforcement per ACI 318-19, 11.6.2. Therefore, the change needs to be implemented in the software.

Chapter 13: Foundations

Design criteria is redefined:
ACI 318-19, 13.2.6.1 states that *"foundations shall be proportioned for bearing effects, stability against overturning and sliding at the soil-structure interface in accordance with the general building code."*
ACI 318-14, 13.2.6.1 stated that *"foundations shall be proportioned to resist factored loads and induced reactions."* which is covered within ACI 318-19, 13.2.6.3.

The reason for the change is to provide consistency with ASCE7-16 that include provisions for strength design for foundation geotechnical capacity, and to provide clarification of the requirements for foundation proportioning and design.

The size effect factor for one-way and two-way shear strength calculations can be neglected:
ACI 318-19, 13.2.6.2 states that *"for one-way shallow foundations, two-way isolated footings, or two-way combined footings and mat foundations, it is permissible to neglect the size effect factor specified in 22.5 for one-way shear strength and 22.6 for two-way shear strength."*

Chapter 19: Concrete Design and Durability Requirements

Lightweight concrete modification factor, λ:
ACI 318-19, 19.2.4.1 states that *"except as required in Table 25.4.2.4, the value of λ shall be determined using Table 19.2.4.1 based on the equilibrium density, w_c, of the concrete mixture used in design, or Table 19.2.4.2 based on the composition of the aggregate in the concrete mixture assumed in the design."*

ACI 318-19, R19.2.4 commentary states that the methodology for determining λ is changed in ACI 318-19 as follows:

- A new method for determining λ based on the equilibrium density of the lightweight concrete is introduced.
- ACI 318-14 method for determining λ based on the composition of aggregates is retained.
- ACI 318-14 method for determining λ based on splitting tensile strength and the corresponding value of measured compressive strength is removed.

In editions of prior to ACI 318-19, the upper limit on the equilibrium density for lightweight concrete was 115 pcf. And the lower limit for normal weight concrete was established at 135 pcf. Therefore, the range between 115 pcf and 135 pcf were to remain undefined. ACI 318-19 addresses this undefined range by defining lightweight concrete as having an equilibrium density from 90 pcf to 135 pcf.

This change impacts the determination of the lightweight concrete modification factor, λ, in software.

Chapter 21: Strength Reduction Factors

Generalization of the strain reduction limit on ε_t:
In ACI 318-19, Table 21.2.2 for strength reduction factor, ϕ, for moment, axial force, or combined moment and axial force, the tension-controlled strain limit is defined as an expression of f_y, to explicitly cover nonprestressed reinforcement grades other than Grade 60. Therefore, beginning with the 2019 Code, the expression (ε_{ty} + 0.003) defines the lower limit on ε_t for tension-controlled behavior.

Chapter 22: Sectional Strength

Upper limit for f_y is introduced for maximum axial compressive strength, $P_{n,max}$, calculations:
For the calculation of the maximum axial compressive strength, $P_{n,max}$, for nonprestressed and prestressed members with f_y exceeding 80,000 psi, ACI 318-19, 22.4.2.1 states that *"the value of f_y shall be limited to a maximum of 80,000 psi."*
ACI 318-14 did not permit the use of reinforcement exceeding Grade 80.

This change affects the designs of structural members with f_y exceeding 80,000 psi. The P_0 values calculated by equations 22.4.2.2 and 22.4.2.3 will be same as for Grade 80 reinforcement even if the higher strength reinforcement is utilized in the design.

Bidirectional one-way shear effects are to be considered:
The interaction of one-way shear forces acting along orthogonal axes shall need to be considered per ACI 318-19 as provision 22.5.1.11 states that *"if* $\frac{v_{u,x}}{\phi v_{n,x}} > 0.5$ *and* $\frac{v_{u,y}}{\phi v_{n,y}} > 0.5$*, then Eq. (22.5.1.11) shall be satisfied.*

$$\frac{v_{u,x}}{\phi v_{n,x}} + \frac{v_{u,y}}{\phi v_{n,y}} \le 1.5 \qquad (22.5.1.11)"$$

There is a minimal impact in spSlab implementation as each orthogonal direction is run independently per the equivalent frame method. However, if the $\frac{v_u}{\phi v_n}$ ratio of a specific run exceeds 0.5, the requirement to check Eq. 22.5.1.11 manually can be indicated.

One-way shear strength provisions in relation with V_c for nonprestressed members are modified substantially:
ACI 318-19, 22.5.5.1 states that *"for nonprestressed members, V_c shall be calculated by Table 22.5.5.1 and 22.5.5.1.1 through 22.5.5.1.3."*

The new Table 22.5.5.1 is titled V_c for nonprestressed members and aims to unify the ACI 318-14 provisions of:

- 22.5.5: V_c for nonprestressed members without axial force
- 22.5.6: V_c for nonprestressed members with axial compression
- 22.5.7: V_c for nonprestressed members with significant axial tension

The new Table 22.5.5.1 introduces a criteria for A_v and $A_{v,min}$ that results in set of equations to calculate V_c.
ACI 318-19, 22.5.5.1.1 states that *"V_c shall not be taken greater than $5\lambda\sqrt{f'_c}b_w d$."*
ACI 318-19, 22.5.5.1.2 states that *"In Table 22.5.5.1, that value of $N_u / 6A_g$ shall not be taken greater than $0.05 f'_c$."*
ACI 318-19, 22.5.5.1.3 states that *"The size effect modification factor, λ_s, shall be determined by*

$$\lambda_s = \sqrt{\frac{2}{(1+d/10)}} \le 1.0 \qquad (22.5.5.1.3)"$$

The changes account for size effect and low reinforcement levels for members without shear reinforcement. It also simplifies and reduces the equations for nonprestressed concrete members with and without axial load effects. The impact of this change will vary and can only be determined after implementation for various conditions.

The size effect factor, λ_s, is introduced in v_c calculation for two-way members without shear reinforcement:
ACI 318-19, Table 22.6.5.2 now incorporates the size effect factor, λ_s, in equations (a), (b), and (c).

This change accounts for depth effect of slabs without shear reinforcement. For two-way slabs without shear reinforcement and d > 10 in., the size effect factor will result in reduced two-way shear strength values as compared to ACI 318-14. The software implementation will be affected accordingly.

Chapter 24: Serviceability Requirements

Effective moment of inertia, I_e equations are revised:
ACI 318-19, 24.2.3.5 states that *"for nonprestressed members, unless obtained by a more comprehensive analysis, effective moment of inertia, I_e, shall be calculated in accordance with Table 24.2.3.5 using:*

$$M_{cr} = \frac{f_r I_g}{y_t} \qquad (24.2.3.5)"$$

As stated in ACI 318-19, R24.2.3.5, the effective moment of inertia approximation developed by Bischoff and Scanlon is adopted and Branson equation (ACI 318-14, Eq. 24.2.3.5a) is removed from ACI 318-19. The commentary further states that the ACI 318-14, Eq. 24.2.3.5a has been shown to underestimate deflections for members with low reinforcement ratios, which often occur in slabs, and did not consider the effects of restraint. For members with greater than 1% reinforcement and a service moment at least twice the cracking moment, there is little difference between deflections calculated using the former and the ACI 318-19 provisions. This change affects the software implementation.

Reinforcement distribution in tension flange of T-beam is modified:
Commentary of ACI 318-19 states that for T-beams designed to resist negative moments due to gravity and wind loads, all tension reinforcement required for strength is located within the lesser of the effective flange width and $\ell_n/10$. Common practice is to place more than half of the reinforcement over the beam web.

The proposed commentary revision provides guidance on the distribution of tension reinforcement in the effective flange width. This change has little or no impact in software implementation.

Shrinkage and temperature reinforcement requirements are revised:
ACI 318-19, 24.4.3.2 states that *"the ratio of deformed shrinkage and temperature reinforcement to gross concrete area shall be greater than or equal to 0.0018."* ACI 318-14 requirements were based on reinforcement type and grade as shown below:

<u>Deformed bars with the yield strength of reinforcement, $f_y < 60{,}000$ psi:</u>
The minimum shrinkage and temperature reinforcement ratio was equal to 0.0020 A_g.

Therefore, the minimum shrinkage and temperature reinforcement ratio requirement is reduced by 10% in ACI 318-19.

<u>Deformed bars or welded wire reinforcement with the yield strength of reinforcement, $f_y \geq 60{,}000$ psi:</u>
The minimum shrinkage and temperature reinforcement ratio was greater of:

$$\frac{0.0018 \times 60{,}000}{f_y}$$

$$0.0014$$

Therefore, the minimum shrinkage and temperature reinforcement ratio requirement stayed unchanged for Grade 60 reinforcement in ACI 318-19. However, for higher grade reinforcement, there is an increase in this requirement. For example, for 80 ksi reinforcement, the new minimum shrinkage and temperature reinforcement ratio requirement is 0.0018 instead of the ACI 318-14 value of 0.0014 (i.e. 28.6% increase in ACI 318-19).

This change unifies the minimum flexural reinforcement requirement irrespective of reinforcement grade and therefore, simplifies the software implementation.

Chapter 25: Reinforcement Details

Lower limit of 0.5d_b is introduced for transverse reinforcement index, K_{tr}, for bars with $f_y > 80{,}000$ psi spaced closer than 6 in. on center:
ACI 318-19, 25.4.2.2 states that *"for bars with $f_y > 80{,}000$ psi spaced closer than 6 in. on center, K_{tr} shall not be smaller than 0.5 d_b."*
ACI 318-14 did not permit the use of flexural reinforcement exceeding 80,000 psi.

The requirement for a minimum value of K_{tr} along development and splice lengths improves ductility. This change affects the software implementation as K_{tr} can no longer be conservatively assumed as zero f_y exceeding 80,000 psi.

Development of reinforcement provisions are modified:

In ACI 318-19, 25.4, the development length equations are revised to cover high-strength reinforcement and concrete, to account for spacing between bars. New modification factors such as ψ_g to modify development length based on grade of reinforcement are introduced.

This change affects the calculation of development length in spSlab and spBeam.