Concrete Design to AS 3600-2018 Amendment 2

Rev 1, Updated 23 March 2023

AS 3600-2018 Concrete Structures amendment 2 involves the following key changes relating to Structural Toolkit:

- Nomenclature change of the bending with axial compression capacity reduction factor (ø factor) in Table 2.2.2
- The addition of a concrete compressive strength of 120MPa (f'c) to tables (Table 3.1.1.1 & 3.1.2)
- Significant revisions to shear and torsion design (Section 8)
- Revision to wall provisions for requiring restraint for vertical reinforcement (Cl 11.7.4 (b))

This document discusses the changes affecting Structural Toolkit and has therefore omits any changes relating to pre-stress and/or detailing.

R1

This revision adds further discussion on the requirements for additional tension forces due to shear and whether this needs to be calculated when no ligs are present, and discussion on the sign of the øVuc term in the ΔFtds equation.

A section on Reinforced Footings and the requirement for transverse shear reinforcement where D ≥ 750mm has also been added.

Given the variation now to the AS5100.5-2107 Bridge Design Part 5: Concrete, the latest release cannot be used if complying with the Bridge standard.

Capacity reduction factor

For bending with axial compression, amendment 2 introduces a new factor kø for calculating the reduction factor for bending with axial compression. The resulting ø factor is no different to that of the previous amendment 1. This change in nomenclature is reflected in the new Concrete Column V5.22 release with Structural Toolkit V5.5.

(d) Bending with axial compression, where—	
(i) $N_u \geq N_{ub}$	$0.65k_\phi$
(ii) $N_u < N_{ub}$	$0.65k_\phi + [(\phi - 0.65k_\phi)(1 - N_u/N_{ub})]$ and ϕ is obtained from Item (b)
	Short columns with $Q/G \geq 0.25$, $k_\phi = 1.0$, otherwise, $k_\phi = 12/13$

Shear and torsional requirements

The shear and torsion design changes of amendment 2 result in significant changes to the Concrete Member and Column design (as well as revisions to Pads, Pier and Beam and Bondbeams).

Even though the design shear force no longer utilises a modified V*eq (now removed) with the design shear V* being increased by torsion when T* > 0.25øTcr, designs using these modules may now require minimum shear reinforcement at lower design shear values; require more additional longitudinal reinforcement; and have reduced web crushing capacities.

Shear capacity

With the removal of V*eq from Cl 8.2.1.2, a torsional component is no longer incorporated into the equivalent shear capacity assessment against øVu in Eq 8.2.3.1(1). This means that when torsion (T*) is greater than 0.25øTcr (and hence needs to be considered in accordance with Cl 8.2.1.2), the shear capacity is assessed against only the design shear force which will be lower than previous.

This however does not necessarily mean that shear/torsion design will become less critical, as the way the reinforcement requirements and web crushing capacity are calculated have also changed.

The web crushing capacities Eq 8.2.3.3(1) and 8.2.3.3(2) now include a factor of 0.9, reducing these capacities by 10%.

The kv value used in Eq 8.2.4.1 for Vuc is now limited by 0.15 instead of 0.10 for the simplified method in Eq 8.2.4.3(1). This may result in higher Vuc values in some cases, being more prevalent with shallower members. However, it will only affect members with shear reinforcement that is less than the minimum Asv requirements.

Shear reinforcement

The first release of the 2018 standard removed the requirement for minimum shear ligs when V* < 0.5 øVuc (along with a number of waivers relating to band beams and slabs), changing this to V* < øVuc, however, the way in which Vuc was calculated underwent complete revision. At the time there was some argument as to if this omission was an error and there was speculation of a return of some factor, possible 0.65.

The amendment 2 sees the inclusion of a new factor ks (V* < ks øVuc) in Cl 8.2.1.6 resulting in a ks value of 0.5 when the beam is greater than 650mm deep, reducing to 1.0 when less or equal to 300mm deep. For members of depths between 300mm and 750mm, this will result in a lower cutoff for the need of transverse shear reinforcement than the previous amendment. Of course, there was always a requirement for minimum shear for beams greater or equal to 750mm in Cl 8.2.1.6(c).

8.2.1.6 *Requirements for transverse shear reinforcement*

Transverse reinforcement shall be provided in all regions for any of the following cases:

(a) $V^* - \gamma_p P_v > k_s \phi V_{uc}$ . . . 8.2.1.6(1)

where

(i) $D \leq 300$ mm, $k_s = 1.0$; or

(ii) 300 mm $< D <$ 650 mm, $k_s = (1000 - D)/700$; or

(iii) $D \geq 650$ mm, $k_s = 0.5$

and γ_p is given in Clause 8.2.1.3.

R1

The Commentary in C8.2.1.6 states that the CSA (Canadian Standards Association) adopts a ks of 1.0 for beams and one-way slabs irrespective of depth and that ASSHTO (The American Association of State Highway and Transportation Officials) adopts a ks of 1 for slabs, footings and culverts, and 0.5 for beams.

Torsional capacity

Torsion resistance calculated by Eq 8.2.5.6 replaces 1.7Aoh at the front, with 2.0Ao, where Ao = 0.85Aoh for solid sections. This now aligns with AS 5100.5 Cl 8.2.5.6, and so the option to the side has been removed. The resulting change has no effect on the capacity given 2*(0.85*Aoh) = 1.7*Aoh.

Torsional reinforcement

Minimum transverse torsional reinforcement in Cl 8.2.5.5 is now based on the maximum of the minimum transverse shear reinforcement (Cl 8.2.1.7) and an area of leg that provides an equivalent Tus based on a torsional capacity equal to 0.25*Tcr (Cl 8.2.5.6). For the torsional leg area, this is a 75% reduction from the previous requirements, where the minimum reinforcement was based on Tus=Tcr. For most designs, however, the minimum shear requirement of Cl 8.2.1.7 appears to be critical for minimum reinforcement.

Given the Asv from Cl 8.2.1.7 is based on the total shear reinforcement area (leg area x legs crossing shear plane), for consideration with minimum transverse torsional reinforcement, it is converted into Asw, being based on a single leg area only (Asv/legs crossing shear plane).

Additional tension forces due to shear and torsion

Cl 8.2.7 has significantly changed in amendment 2, with the additional force ΔFtd now being split up into its shear and torsion components.

R1

~~The clause also no longer requires there to be transverse shear reinforcement for additional tension forces to be present (ie. even if no transverse shear reinforcement is needed, additional tension forces are still present and need to be considered). A comparison of the changes can be seen below for reference.~~

The first edition of AS3600-2018 and amendment A1, Cl 8.2.7 both stated "additional longitudinal forces at sections where transverse reinforcement is required". Ambiguity was introduced into amendment by removing the previous statement in amendment A2 stating "The additional longitudinal force caused by shear and/or torsion shall be as follows".

The commentary Cl 8.2.7 refers to the Fig 8.2.5.2 and Fig 8.2.5.6(A) which both show ligs and discuss a truss analogy which requires tensile ties vertically suggesting the additional tensile is only necessary when ligs are necessary. We spoke to a University Professorial Fellow who is closely associated with the Concrete Institute of Australia who indicated that he believed the requirement would only be necessary when ligs are required to carry the shear force above that of the unreinforced capacity, however, this is not a Code Committee response. This is being for forward to the code committee for comment.

8.2.7 Additional longitudinal tension forces caused by shear

The additional longitudinal forces at sections where transverse reinforcement is required for shear and/or torsion on each of the tensile and compressive sides are:

(a) Shear with torsion excluding box sections—

$$\Delta F_{td} = \cot\theta_v \sqrt{\left(\left|V^*_{eq}\right| - 0.5\phi V_{us} - \gamma_p P_v\right)^2 + \left[\frac{0.45T^* u_h}{2A_o}\right]^2} \text{, but not less than zero} \quad \ldots 8.2.7.1(1)$$

AS 3600 -2018 (+A1)

8.2.7 Additional longitudinal tension forces caused by shear and torsion

The additional longitudinal force caused by shear and/or torsion shall be as follows:

$$\Delta F_{td} = \Delta F_{tds} + \Delta F_{tdt} \quad \ldots 8.2.7(1)$$

where

(a) For shear:

$$\Delta F_{tds} = 0.5\left(V^* - \gamma_p P_v + \phi V_{uc}\right)\cot\theta_v \text{, but not less than zero} \quad 8.2.7(2)$$

(b) For torsion:

$$\Delta F_{tdt} = 0.5T^* \frac{u_o}{2A_o}\cot\theta_v \text{, but not less than zero} \quad 8.2.7(3)$$

AS 3600 -2018 (+A2)

Eq 8.2.7(2) no longer uses V*eq, using just V*and as with the shear capacity, this results in a lower design shear force being used when T* > 0.25øTcr. This shear component equation has also been further modified to include +øVuc rather than -0.5øVus that was used previously resulting in an increase in additional tension forces when Vuc increases (concrete contribution to shear). This generally results in higher values of additional tension forces than previously and subsequently more longitudinal reinforcement.

R1

~~Despite this change not being intuitive, it has been raised with a member of the code committee, with a response that the term "+øVuc" is correct.~~ Note that this was not an official code committee response.

The derivation of the ΔFtd equation is not explained in the commentary. Using substitution ΔFtds = 0.5*(V*+ øVuc) Cotθv can be rewritten as 0.5*(øVuc + øVus + øVuc) cotθv then (øVuc + 0.5 øVus) cotθv (or V* cotθv when no ligs are required). The commentary C8.2.7 states the vectorial components of the longitudinal forces that occur in the stringers of the truss models as a result of the applied shear and/or torsion are calculated and summed. See commentary Figure C8.2.5.2 and Figure C8.2.5.6(A) where the stringers are labelled as the longitudinal bars and both figures show ligs.

Through truss analogy, it could be implied the additional tensile forces transferred are a result of the shear forces would be the excess of force over the ability of the concrete to carry without reinforcement. ΔFtds = (V*-øVuc) Cotθv ie the ligs force øVus being the vertical truss tie, resolved to the tensile bar orientation using the compressive stress field angle calculated in Cl 8.2.4. The application of the 0.5 term in the front is not explained.

We asked the same University Professorial Fellow if Eq 8.2.7(2) is correct stating ΔFtds = 0.5(V*+øVuc) Cotθv or should this be ΔFtds =0.5(V*-øVuc) Cotθv (reflecting the component carried by the ligs). The opinion was that subtracting rather than adding appeared to be the correct approach, however, this is not a Code Committee response. This is being for forward to the code committee for comment.

Eq 8.2.7(3), being the torsional component, now uses 0.5T* instead of 0.45T* and a uo instead of uh, where uo = 0.92uh.

R1

Reinforced Footings and the requirement for transverse shear reinforcement where D ≥ 750mm

Clause 8.2.1.6 states for one-way slabs where D≥750mm transverse shear reinforcement is required irrespective of the unreinforced shear capacity of the concrete. This implies for two-way slabs and footings this requirement is waived providing the concrete has sufficient unreinforced shear capacity (ks*øVuc, where ks=0.5 when D≥650mm) in each direction when considering a shear plane crossing the footing. If the footing acts in a one-way manner this waiver cannot be applied. (Whether the footing acts one way this can be assessed on a similar design moment analogy to a two-way slab panel 4 edges discontinuous using the non-ductile table Table 6.10.3.2(B). A two-way slab is considered one-way if the for the ratio of longer to shorter sides ≥ 2.

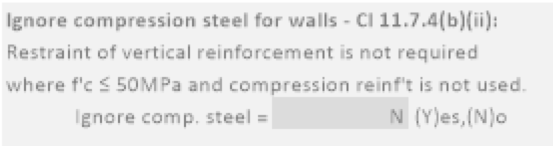
Shear stress capacity

Amendment 2 has re-added the limit of 0.2f'c and 10MPa to Eq 8.4.3. The option to apply this limit in Corbels V5.04 to the side has been removed, and fully incorporated into the relevant formula.

Concrete Walls

Restraint of vertical reinforcement in Cl 11.7.4 now contains further requirements. The previous requirements when designing as a column are still present, however the restraint waiver for when N* < 0.5 øNu can only be used if using less or equal to 50MPa concrete strength.

In the new Concrete Column V5.22 released with Structural Toolkit V5.5, the user can select to not use the compressive reinforcement as outlined in Cl 11.7.4(b)(ii). This will lower the axial capacities through the moment range. This option can be found in the [Capacity] section on the right side of the page.



Should you have any questions regarding the changes made to Structural Toolkit to implement the amendment 2, contact our support team.

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