Concrete Column Fire Resistance Period (FRP)

Structural Toolkit has the ability to evaluate the Fire Resistance Period (FRP) of concrete columns and walls in accordance with AS 3600 – Concrete Structures.

Two methods are available for determining the Fire Resistance Period (FRP) of concrete columns (Cl 5.6) along with a method for walls (Cl 5.7). These methods are in tabular form and derived from Clauses 5.2 and 5.3 from Eurocode 2: Design of concrete structures – Part 1-2 General rules – Structural fire design (BS EN 1992-1-2:2004 (E)).

It should be noted that the assessment of FRP can be frustratingly difficult as the FRP values have restrictions on the geometries and inputs meaning that some columns cannot be assessed.

How it works

The module works by interpolating the tabled data from EN-1992-1-2;2004 (E) (Eurocode 2) and AS 3600. It calculates the FRP using both Method A and Method B (Eurocode). Based on the inputs on the [FRP] tab along with inputs from the [Capacity] tab within the concrete column module, minimum required dimension and axis distances are calculated. The methods within the module will only calculate the FRP for columns which are braced, in accordance with the standard (Cl 5.6.2).

The loads and effective length of a column in a fire situation and desired FRP (in minutes) are entered on the [FRP] tab.

Geometry		Fire Resistance Period to be determined using Method A		
Larger column dimension (h) =	460 mm	Size (cX) =	460 mm	
Smaller column dimension (b) =	460 mm	Size (cY) =	460 mm	
Gross column area (Ag) =	211600 mm²	Concrete strength (f'c) =	50 MPa	
Column concrete area (Ac) =	205317 mm²			
Effective column length in fire (lo.fi) =	3000 mm	(2000 < lo.fi < 6000mm) (lo.fi ≤ 3000mm for Method A Table)		
lo.fi / ry =	22.6			
lo.fi / rx =	22.6			
Loading				
Dead load (G) =	2000 kN	Load type =	F	(F)loor,(S)tore,(R)oof,(O)ther
Live load (Q) =	2000 kN	Long term LL factor (Ψl.f) =	0.60	Table 4.1 (Concentrated)
Fire limit state load (N*f = G + Ψl.f*Q) =	3200 kN			
Strong axis - Mbyf* =	0 kNm	Equ. Ecc.by =	23.0 mm	
Weak axis - Mhxf* =	0 kNm	Equ. Ecc.hx =	23.0 mm	
		Minimum eccentricity: Cl 11.5.2		
Strong axis - Design Mbyf* =	73.6 kNm (Minimum)	Min. Mbyf* =	73.6 kNm (0.05*h)	
Weak axis - Design Mhxf* =	73.6 kNm (Minimum)	Min. Mhxf* =	73.6 kNm (0.05*b)	

Column dimensions and reinforcement details are taken from the [Capacity] tab. From these values, the module will determine which methods are applicable and will then give the appropriate output for each method.

On the right-hand side of the page there is a list of all of the parameters which are required for each method and whether the particular requirement has been met, making each method either valid or invalid based on its individual requirements. This will allow you to determine what is causing a particular method to be invalid.

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Method A (Table & Formula):
              Effective length (Table) = OK          lo.fi ≤ 3000mm
            Effective length (Formula) = OK          2000 ≤ lo.fi ≤ 6000mm
                     Minimum size = OK               200mm ≤ b' ≤ 450mm [b' = 2*Ag/(b+h)]
                        Size ratio = OK              h/b ≤ 1.5 (Eurocode)
                      Axis distance = OK             25mm ≤ as ≤ 80mm
                      Min. 4 bars = OK
                       Steel ratio = OK              p ≤ 4%
                       Table μ.fi = OK               0.2 ≤ μ.fi ≤ 0.7
                     Weak Ecc.b = OK                 ecc.b ≤ 0.15*b = 69mm
                    Strong Ecc.h = OK                ecc.h ≤ 0.15*h = 69mm
             Method A Valid (Table) = Y              (Y)es,(N)o
           Method A Valid (Formula) = Y              (Y)es,(N)o

AS3600 does not publish the limitations
imposed in Eurocode for Method A.
              Bypass Eurocode limitations =    N  (Y)es,(N)o

Method B (Simple) :
                    Slenderness (λ) = OK             lo.fi/rmin ≤ 30
                            Size = OK                b ≤ 600 (Annex C)
                    Load level (n) = OK              0.15 ≤ n ≤ 0.7
         Mechanical reinf't ratio (ω) = OK           0.1 ≤ ω ≤ 1
                            e/b = OK                 0.025 ≤ e/b ≤ 0.5
                     Weak Ecc.b = OK                 ecc ≤ 100mm
              Method B (Simple) Valid = Y            (Y)es,(N)o

Method B (Eurocode Tables):
                    Slenderness (λ) = OK             lo.fi/rmin ≤ 80
                            Size = OK                b ≤ 600 (Annex C)
                    Load level (n) = OK              0.15 ≤ n ≤ 0.7
         Mechanical reinf't ratio (ω) = OK           0.1 ≤ ω ≤ 1
                            e/b = OK                 0.025 ≤ e/b ≤ 0.5
                     Weak Ecc.b = OK                 9mm ≤ ecc ≤ 56mm (interpolated limit)
              Method B (Tables) Valid = Y            (Y)es,(N)o

Method C: (Wall)
                     Aspect ratio = No Good          h/b ≥ 4
                   Method C Valid = N                (Y)es,(N)o
```

If the user wishes to use predetermined values for any of the table variables (to say try and match the Eurocode or AS 3600 tabled values as a reference starting point), they are able to enter these in the 'Manual values' section within the [FRP] tab, otherwise if these are left blank the module will use calculated values.

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Manual values

                   Manual axis distance (as) =            mm
                     Manual e/b (and e/h) =              (0.025 ≤ e/b ≤ 0.5) Blank for calculated

Method A & Method C (Wall) manual utilisation factor:
Use utilisation factor of μ.fi = N*f/ØNu = 0.7 =    N  (Y)es,(N)o
              Manual utilisation factor (μ.fi) =        Blank for calculated (0.2 ≤ μ.fi ≤ 0.7)

Method B manual load level:
                     Manual load level (n) =            (0.15 ≤ n ≤ 0.7) Blank for calculated
                    Manual reinf't ratio (ω) =          (0.1 ≤ ω ≤ 1) Blank for calculated
                     Manual slenderness (λ) =           (30 ≤ λ ≤ 80) Blank for calculated
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Method A - Cl 5.6.3 (Restricted tabular method)

For Method A, the module gives a minimum dimension and axis distance from the tabulated values based on the desired FRP and other input variables. It also performs a calculation from Eurocode 2 (Cl 5.3.2(4)) which gives the FRP in minutes.

For the tabulated method, values are interpolated from Table 5.2a Eurocode/Table 5.6.3 AS3600 based on the desired FRP and load level reduction. The value obtained is a minimum dimension (b, or Dc) which is the minimum value allowed for the smaller dimension of the column based on the inputs and the design axis distance. If the axis distance is within the output range, the minimum dimension will be interpolated to suit the design axis distance.

The tabular method does have some limitations. The column must have an effective length under fire conditions of less than 3m while also having restrictions on steel ratio and eccentricity. This method also accounts for the fire exposure on either one, or more than one side.

The Eurocode also has a formula-based method of calculating the FRP. This method has limitations on load level reduction, mechanical reinforcement ratio, effective length, b' (is formula based on gross area and dimensions), axis distance and number of steel bars.

There is a button to the right of this section which says "Calculate Method A as". This button determines the required axis distance to achieve the desired FRP using the formula method based on the other specifications of the column.
There is an option to bypass Eurocode limitations. This option will allow the user to see the results if the inputs are falling outside the limitations which are imposed in the Eurocode but not mentioned in AS 3600 – 2009 (now reproduced in 2018 edition).

The user must exercise caution when using this option as it may give a result which does not conform to standards.
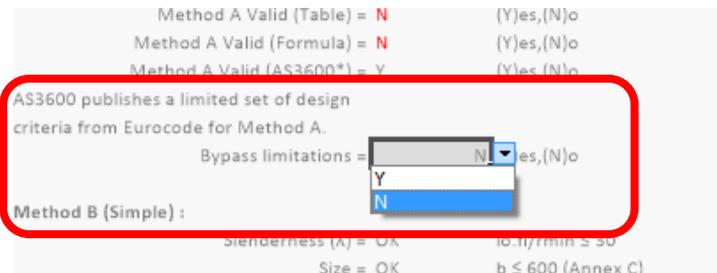
Method B - Cl 5.6.4 (General tabular method)

Similar to Method A, Method B is derived from Eurocode 2. It also gives a minimum dimension and axis distance for a given desired FRP along with other variables.

The AS 3600 version uses a load level of 0.2 compared to 0.15 in the lower load level column in Eurocode (the table values are the same, so it is assumed that this is a rounding difference in AS 3600). The values for load level and mechanical reinforcement ratio are also calculated differently in AS 3600 when compared to Eurocode. The module allows you to choose which of these standards you want to use to calculate load level and mechanical reinforcement ratio.

Method B has two options. The first is a method which contains a simple table which appears in both AS 3600 and the Eurocode. It is a simplified version (using a slenderness of 30 and e/b ratio of 0.25) presented in 9 separate tables in Annex C of the Eurocode, which make up the more extensive method used in the module. These tables take into account variables such as desired FRP, mechanical reinforcement ratio, slenderness, load level (n), eccentricity and ratio of eccentricity to the minimum dimension (e/b). Based on these variables the tables will give either one or two values of axis distance and corresponding minimum dimension. These values are interpolated to give the appropriate values, taking all tabled values into consideration.

The module will show the various steps of the interpolations including final values from each table, interpolation between 2 tables for e/b, then interpolation of these values based on mechanical reinforcement ratio which will give the final minimum dimension (b) and axis distance (as) range. The image below shows the interpolation steps of the 9 tables to arrive at the final values.

Explanation of interpolation:
Step 1 - Interpolation of primary Annex C tables for FRP, λ & n

Step 2 - Interpolation between primary Annex C tables for e/b

e/b=0.025		e/b=0.25		e/b=0.5	
C1	C1-C2	C2	C2-C3	C3	ω=0.1
C4	C4-C5	C5	C5-C6	C6	ω=0.5
C7	C7-C8	C8	C8-C9	C9	ω=1.0

Step 3 - Interpolation of subtables for mechanical reinf't ratio (ω)

C1	C1-C2	C2	C2-C3	C3
	Subtable A		Subtable B	
C4	C4-C5	C5	C5-C6	C6
	Subtable C		Subtable D	
C7	C7-C8	C8	C8-C9	C9

Step 4 - Final values of each subtable

C1	C1-C2	C2	C2-C3	C3
	Subtable A		Subtable B	
C4	C4-C5	C5	C5-C6	C6
	Subtable C		Subtable D	
C7	C7-C8	C8	C8-C9	C9

Step 5 - Final interpolation for minimum b from given as

If two values are given at the end of the interpolations, the spreadsheet will determine the minimum dimension based on the value of the design axis distance. If the axis distance is larger than the greater axis distance of the outputs, the larger of the output values will be selected. If the axis distance is less than the minimum in the outputs no value will be given.

Similar to Method A, there are a number of limitations to Method B, namely the column load level, slenderness, mechanical reinforcement ratio, first order moment, and situations where the desired FRP requires a width greater than 600mm (Note 2 in the tables within Structural Toolkit). In this case, specific assessment for buckling is required by Eurocode and no result is returned as further assessment of the column is required for its given parameters.

The "Calculate Method B FRP" button will give you the FRP in minutes based on your inputs (Dimensions and axis distance along with the other load factors). This button only gives the FRP if you have inputs parameters that fall within the tables.

Concrete Wall

The concrete wall works very similarly to Method A, however it will only be valid if the ratio of the longer cross-section dimension of the column is greater than 4 times the shorter cross-section dimension. It also only gives one output for axis distance and minimum dimension. These values are the minimums based on the input conditions.

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