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ProtaStructure Design Guide

Beam-Column Joint Shear Design (ACI 318-19)

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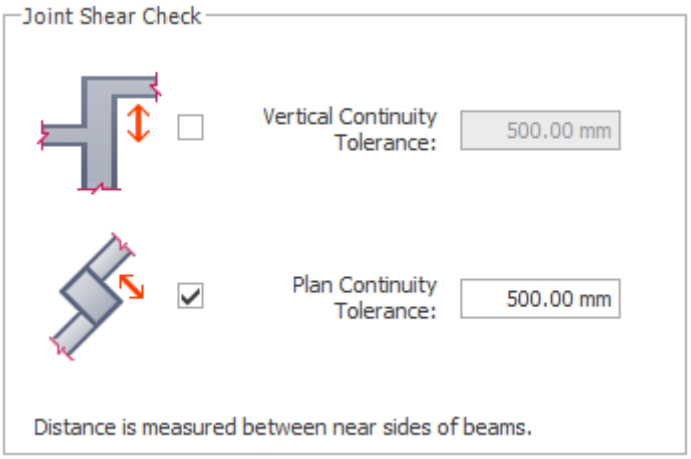
Introduction

ProtaStructure checks the beam-column joint shear limits according to **ACI 318-19 Chapter 15 and 18.8.4.** In this document, calculation details about beam-column joint shear are explained.

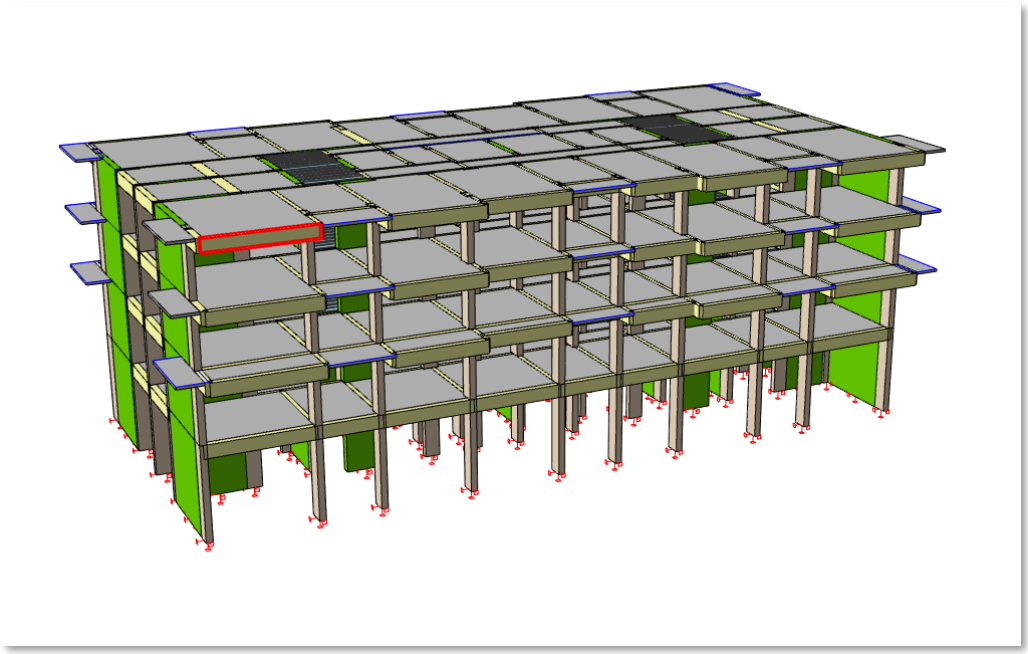
Joint Shear Check Tolerance Settings

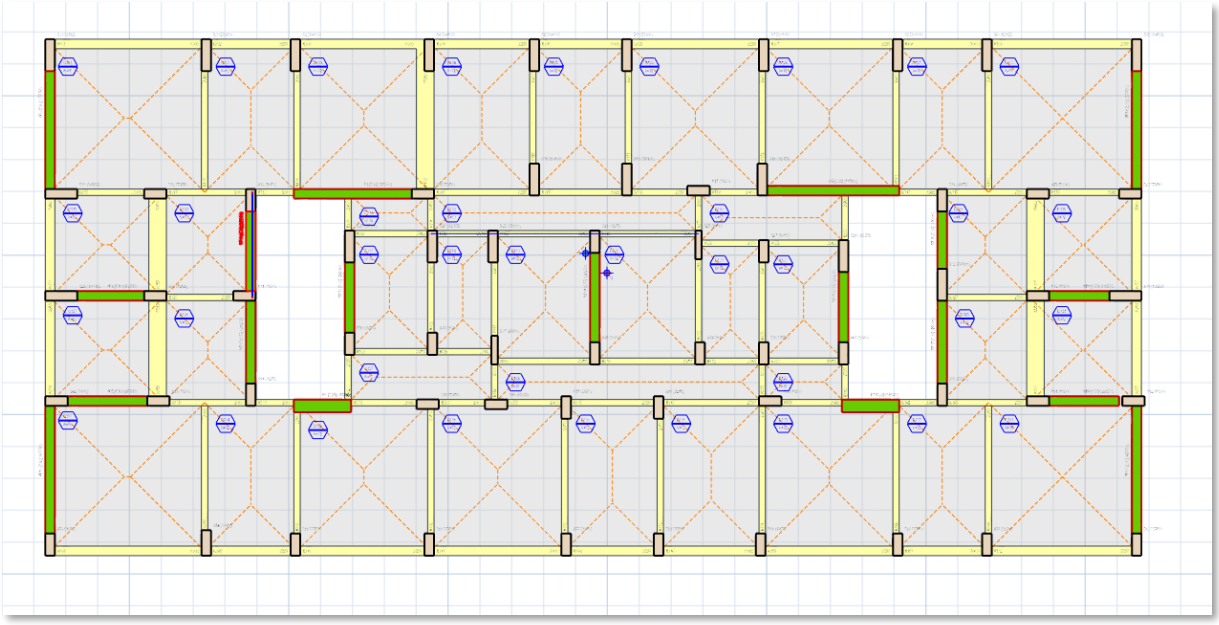
The opposite beams may not be on the same line or level at beam-column joints. In this case, the user should determine both vertical and plan tolerances. Beams that are not within the tolerance limits will be considered separate joints.



Building Model

Joint shear check is exhibited for a column of a 4-story residential building. 3D and story plan views are shown below.

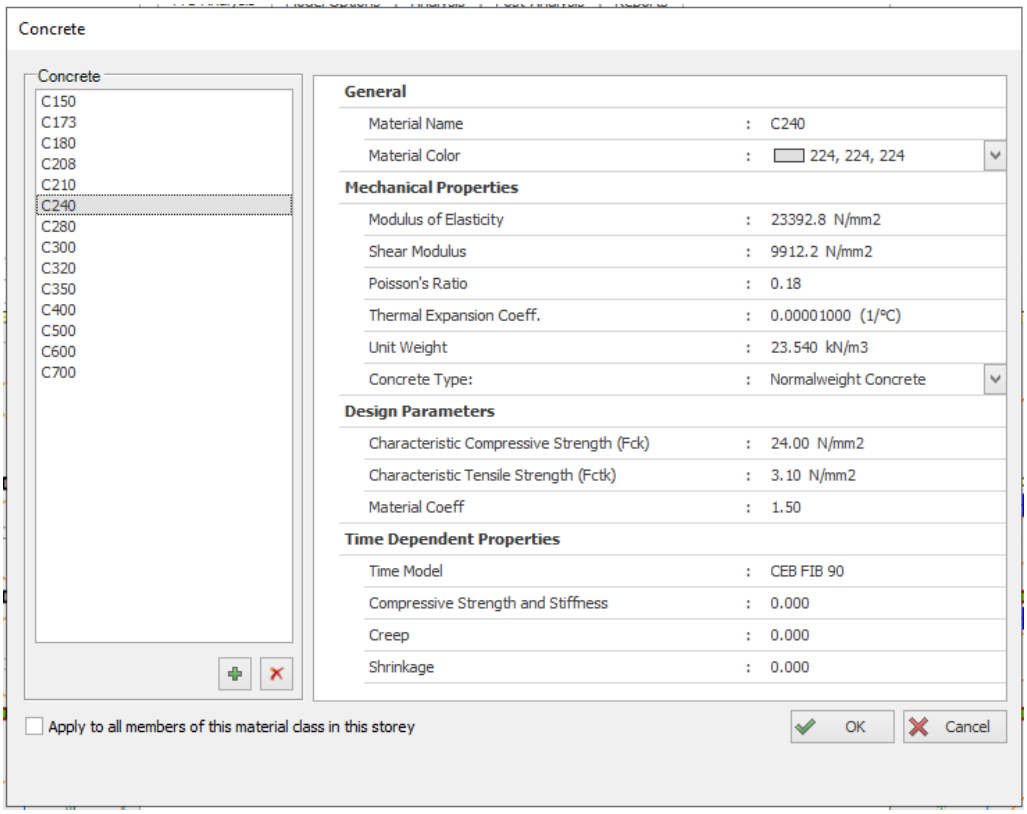




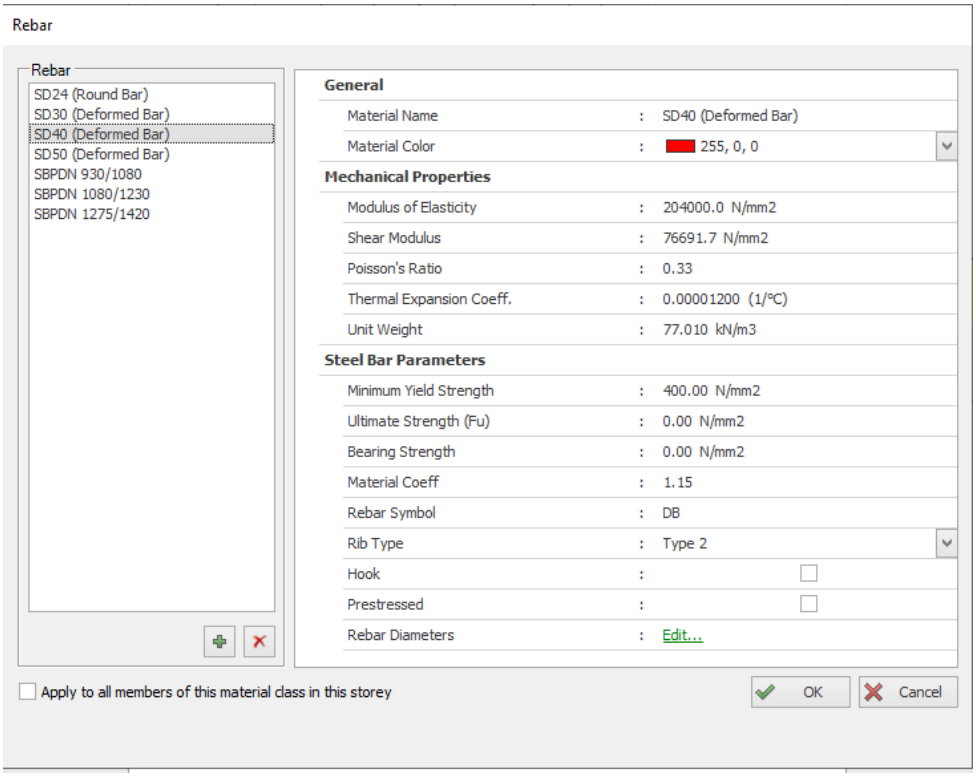
3D and Typical Plan View of Building Models (A and B Block Accordingly)

Material Properties

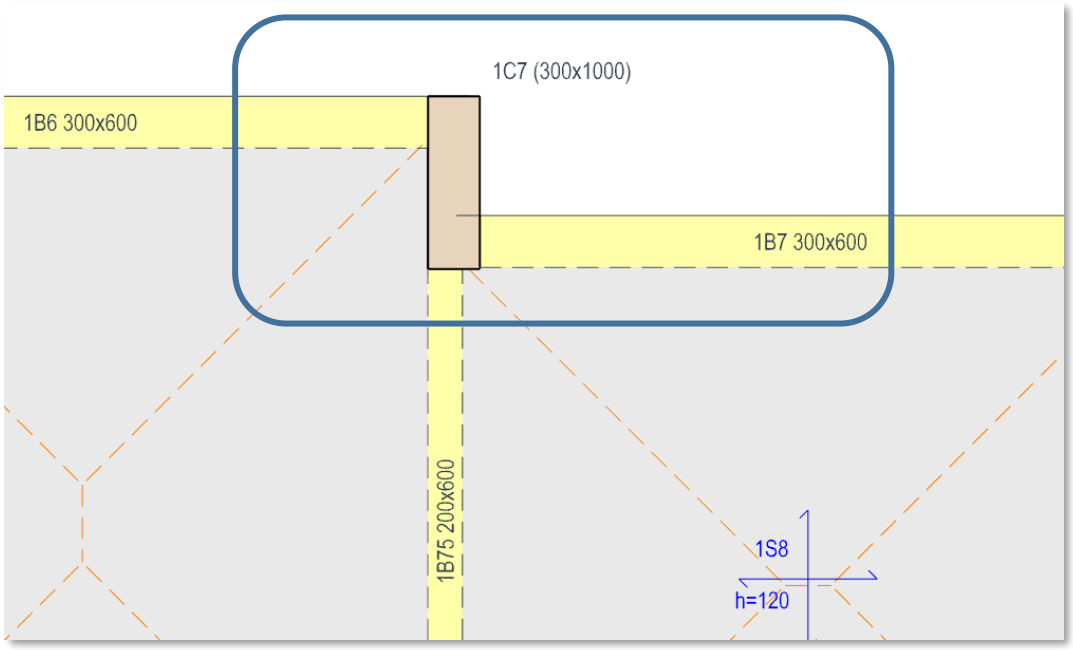
Concrete



Steel

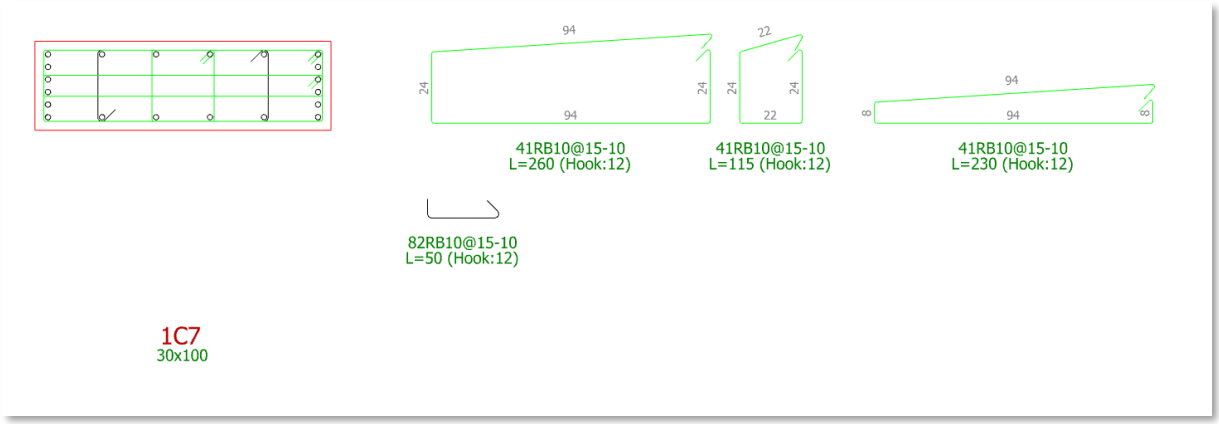


The Beam-Column Joint

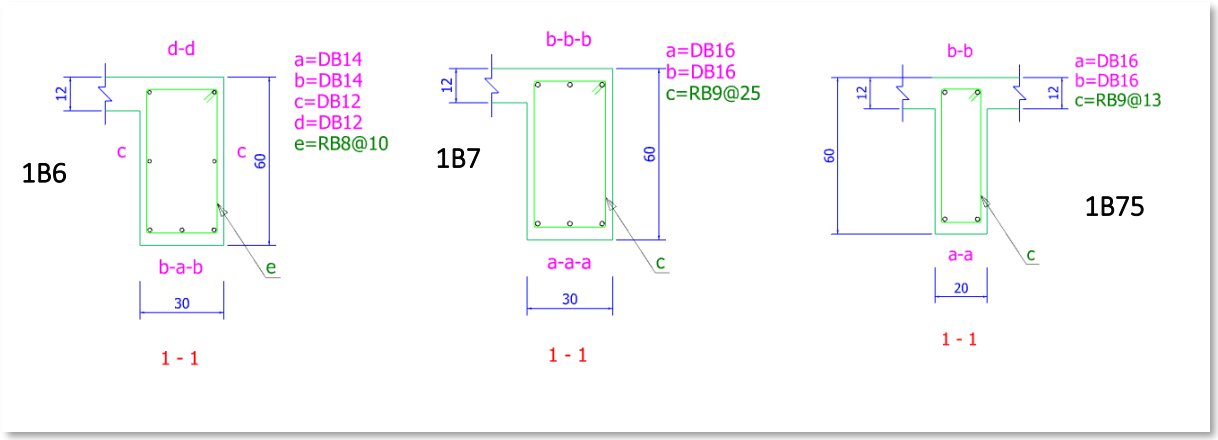


Column 1C7 in the first story will be used for calculations. There are two beams connected to 1C7 in the X direction and one in the Y direction. There is a 400 mm distance between near sides of beams in the X-direction. Since the "Plan Continuity Tolerance" is set as 500 mm, beams in the X direction (1B6-1B7) will be considered continuous.

Column Section and Reinforcement



Beam Section and Reinforcement



Calculation Details

According to **ACI 318-19 Chapter 15,** beams and columns can be classified to their continuity conditions. In addition, joints can be referred to as confined or not, according to the properties of the connected beams. Nominal shear strength calculations are different for particular conditions.

A **continuous column** should satisfy the following conditions according to **15.2.6**:

(a) The column extends above the joint at least one column depth, **h**, measured in the direction of joint shear considered.

(b) Longitudinal and transverse reinforcement from the column below the joint is continued through the extension.

A **continuous beam** should satisfy the following conditions according to **15.2.7**:

(a) The beam extends at least one beam depth **h** beyond the joint face.

(b) Longitudinal and transverse reinforcement from the beam on the opposite side of the joint is continued through the extension.

Confinement conditions of a beam-column joint can be listed according to **15.2.8** as follows:

(a) The width of each transverse beam is at least three-quarters of the width of the column face into which the beam frames

(b) Transverse beams extend at least one beam depth **h** beyond the joint faces

(c) Transverse beams contain at least two continuous top and bottom bars with:

1)

$$A_{s,min} = max \begin{cases} \dfrac{0.25\sqrt{f_c'}}{f_y} b_w d \\ \dfrac{1.4}{f_y} b_w d \end{cases}$$

2) No. 10 or larger stirrups satisfying **ACI 318-19 Table 9.6.3.4**

3) According to **ACI 318-19 Table 9.7.6.2.2**, the maximum spacing of legs of shear reinforcement along the length of the member and across the member's width shall be per **Table 9.7.6.2.2**.

Where for a statically determinate beam with a flange in tension, the value of b_w shall be the smaller of b_f and $2b_w$, and the value of f_y shall be limited to a maximum of **550 MPa**.

According to **ACI 318-19 ,18.4.4.7.1,** Beam-Column joints should satisfy:

$$\phi V_n \geq V_u$$

Where;

- V_u is joint shear calculated on a plane at mid-height of the joint using tensile and compressive beam forces and column shear consistent with beam nominal moment strengths M_n.
- V_n (Nominal Shear Strength) of the joint shall be calculated per **Table 15.4.2.3 in ACI 318-19.**

Column	Beam in the Direction of V_u	Confinement of Transverse Beams	V_n
Continuous or meets	Continuous or meets	Confined	$2.0 * \lambda * \sqrt{f_c'} * A_j$
		Not Confined	$1.7 * \lambda * \sqrt{f_c'} * A_j$
	Other	Confined	$1.7 * \lambda * \sqrt{f_c'} * A_j$
		Not Confined	$1.3 * \lambda * \sqrt{f_c'} * A_j$
Other	Continuous or meets	Confined	$1.7 * \lambda * \sqrt{f_c'} * A_j$
		Not Confined	$1.3 * \lambda * \sqrt{f_c'} * A_j$
	Other	Confined	$1.3 * \lambda * \sqrt{f_c'} * A_j$
		Not Confined	$1.0 * \lambda * \sqrt{f_c'} * A_j$

Structural Parameters	Symbol	Value
Modification Factor (For normal weight concrete)	λ	1
Strength Reduction Factor	ϕ	0.75

Effective Joint Width Calculation

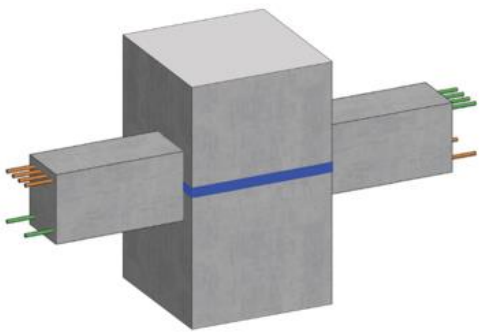
According to **ACI318-19 15.4.2.4**, effective joint width should be calculated as follows:

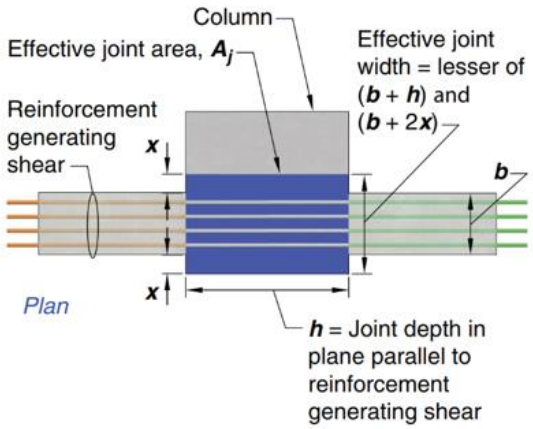
If $b_c > b_w$

$$b_j = min\{b_w + h_c; (b_w + 2 * x)\}$$

If $b_w > b_c$

$$b_j = b_c$$





Verification of Joint Shear Check Results

In this section, Joint Shear Checks are performed for column 1C7.

X-Direction Checks

Beams B1B6 and 1B7 are connected to the column in the X direction.

Calculation of Effective Joint Width, bj:

Since b_c(100 cm) > b_{w1} , b_{w2} (30cm), effective joint width will be calculated per **ACI318-19 15.4.2.4.**

h_c = 30 cm

The beam is at the corner of the column, x = 0 cm.

$$b_j = min\{30 + 30 ; (30 + 2 * 0)\}$$

$$b_j = 30\ cm$$

Calculation of Shear Force:

V_u is taken as the factored shear force in the section.

$$V_u = 2.94\ kN$$

Calculation of Shear Force Limit:

The joint is classified as, Continuous column + discontinuous beams + unconfined column. The formulation below will be used for the calculation of limiting shear force.

$$1.3 * \lambda * \sqrt{f_c'} * A_j$$

$\lambda = 1.0$ (for Normal Weight Concrete)

$f_c' = 24\ Mpa$

$b_j = 300\ mm$

$h = 300\ mm$

$\emptyset = 0.75$

$V_n = 0.75 * 573.18\ kN$

$$V_n = 429.88\ kN$$

X Direction Checks

Joint	Confined	Member	b_j (cm)	h (cm)	V_e / V_u (kN)	Continuous Beam	b (cm)	V_n (kN)	V_u (kN)
1B6 + 2C7 + 1C7 + 1B7	No	2C7 - Storey:2	30.0	30.0	4.16	-	-	2.94	429.88
		1C7 - Storey:1	30.0	30.0	2.94	-	-		
		1B6	-	-	-	No	30.0		
		1B7	-	-	-	No	30.0		

Joint Shear Force, Ve = 2.94 kN < 429.88 kN ✓

Y-Direction Checks

Only beam 1B75 is connected to the column in the X-direction.

Calculation of Effective Joint Width, bj:

Since b_c(30 cm) > b_{w1} (20cm), effective joint width will be calculated with **ACI318-19 15.4.2.4.**

h_c = 100 cm

The beam is at the corner of the column, x = 0 cm.

$$b_j = min\{20 + 100; (20 + 2 * 0)\}$$

$$b_j = 20\ cm$$

Calculation of Shear Force:

V_u is taken as the factored shear force in the section.

$$V_u = 5.98\ kN$$

Calculation of Shear Force Limit:

The joint is classified as, Continuous column + discontinuous beams + unconfined column. The formulation below will be used for the calculation of limiting shear force.

$$1.3 * \lambda * \sqrt{f_c'} * A_j$$

$\lambda = 1.0$ (for Normal Weight Concrete)

$f_c' = 24\ Mpa$

$b_j = 200\ mm$

$h = 1000\ mm$

$\emptyset = 0.75$

$V_n = 0.75 * 1273.75\ kN$

$$V_n = 955.31\ kN$$

Y Direction Checks

Joint	Confined	Member	b_j (cm)	h (cm)	V_s / V_u (kN)	Continuous Beam	b (cm)	V_n (kN)	V_u (kN)
2C7	No	2C7 - Storey:2	20.0	100.0	5.98	-	-	5.98	955.31
1B75 +		1C7 - Storey:1	20.0	100.0	11.11	-	-		
1C7		1B75	-	-	-	No	20.0		

Joint Shear Force, Ve = 5.98 kN < 955.31 kN ✓

Summary

This document explains the calculation details of beam-column joint shear design conditions according to ACI 318-19.

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