Wall and column design and detailing comparison according to new Australian Standard AS3600:2018

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Abstract

In majority of small to medium size concrete buildings in Australia, the most commonly used vertical element shape is long rectangular shape blades, the most popular one being 200mm by 1000mm. In terms of strength and serviceability limit state design, Australian standard, AS3600:2018, does not have a clear definition to distinguish between wall and column for these long shape elements. Therefore, it has been left up to the designer to follow wall or column section of the standard to design these elements that can result in different capacity and detailing requirements for the same size of vertical load-bearing element.

The aim of this paper is to go through more details of column and wall definition and their design requirements under gravity and lateral loads as per Australian standard AS3600:2018 and highlight areas that may need more clarification.

Keywords: Wall design; Column design; AS3600;2018; Detailing; Gravity load, Lateral load

1 Introduction

Australian standard for concrete structures, AS3600:2018, in section 5 where specifies the requirements for fire resisting levels, defines a criterion when a member no longer is considered a column and requirements of walls apply instead. Clause 5.6.2 of the standard says if the ratio of the longer Cross-section dimension of the column is equal to or greater than four times the shorter cross-section dimension, wall requirements may be used.

This is the only criterion that can be used to clearly distinguish wall and column in the code. Since this is applicable to fire resisting period requirements, it has been left up to designer to consider a long narrow vertical element a column or wall. Then based on this decision, different sections of the code must be used to calculate the capacity and serviceability requirements of the element.

In this paper we will go through some differences that this choice makes in ultimate limit state strength and detailing requirements of these elements with long narrow sections if assumed wall or column.

Looking at other international standards, the Canadian concrete standard A23.3, at definition section clause 2.2 defines wall as a vertical element in which the horizontal length, is at least six times the thickness, and at least one-third the clear height of the element.

American concrete code ACI 318-14, at notation section, clause 2.3 defines wall as a vertical element designed to resist axial load, lateral load, or both, with a horizontal length-to-thickness ratio greater than 3, used to enclose or separate spaces.

Eurocode 2, BS EN 1662 in clause 5.3.1 specifies columns as a member for which the section depth does not exceed 4 times its width and the height is at least 3 times the section depth, otherwise it should be considered as a wall.

These standards are drawing a line to show when a certain vertical element can be called a wall so the relevant sections of the code can be used for design.

2 Comparison between wall and column capacity

One of the popular reinforced concrete load-bearing vertical elements used in reinforced concrete buildings in Australia is a 200mm wide, 1000mm long element, sometimes called blade column. One of the reasons for their popularity seems to be their ability to fit within party walls and fit easily within architectural layout. As discussed in introduction, according to AS3600:2018, other than fire rating level requirements, there is no specific criterion that forces the designer to design this element as wall or column. We will go through requirements of both options to find out differences.

2.1 Column

In section 10 of the standard that belongs to column design, Clause 10.2.4 requires the shear reinforcement of the column to be in the shape of fitments. As outlined in clause 10.7.2, these fitments must satisfy shear and torsion requirements as well as confinement of concrete and lateral restraint of longitudinal bars. In other words straight bars are not allowed in columns and closed ties need to be used as shear reinforcement.

As per clause 10.4.1, longitudinal reinforcement in a column shall be not less than %1 of the cross-sectional area. AS3600 allows lower than %1 of area for reinforcement if area of steel is greater than $0.15N^*/f_{sy}$ but no absolute minimum has been set.

2.2 Wall

Clause 11.5 of the standard allows a simplified method to calculate the vertical load capacity of walls. Assuming a non-ductile wall with double layer of vertical and horizontal reinforcement, not being constructed in soil classification of De or Ee, subject to compression over the entire section and have a ratio of effective height to thickness of less than 30, the ultimate axial strength per unit length of a braced wall (N_u) can be taken as:

$$N_u = 0.65(t_w - 1.2e - 2e_a)0.6f'_c \tag{1}$$

Where $\boldsymbol{t_w}$ is thickness of the wall, $\boldsymbol{e}$ is eccentricity of the load perpendicular to the plane of the wall and $\boldsymbol{e_a}$ an additional eccentricity defined by standard.

Therefore, a braced 200mm thick, 1000mm long wall which is 3m tall with the minimum load eccentricity around minor axis of the wall and concrete strength of 40MPa, can be loaded up to N*=2370kN with no moment around major axis or N*=1185kN with moment around major axis of 197 kN.m. These numbers have been calculated assuming maximum allowable pressure on one side of the section and zero for the other side and also assuming plane sections remain plane.

Required vertical reinforcement for this wall is the minimum reinforcement set by clause 11.7.1 of the standard, which is 0.0025 of the wall area. In this case, two layers of N12, 350mm spacing satisfy the minimum vertical reinforcement required. Reinforcement ratio needs to be checked against serviceability and crack control requirements as well but in this paper, our focus will be on ultimate limit state and we assume no extra serviceability reinforcement is required.

According to clause 14.4.4 of section 14, design for earthquake actions, for non-ductile walls, there is no need for boundary elements or any kind of closed fitments. Straight bars are sufficient as long as they meet ultimate limit state of strength requirements.

As per clause 11.2.1(a), braced walls subject to compression over the entire section can be designed as a column. Column confinement requirements can be overridden by the requirements of clause 11.7.4. This clause allows walls designed as column with concrete strength not exceeding 50MPa to be designed without restraining vertical reinforcements if meet one of three requirements, one of them is having not more than %1 vertical reinforcement and a minimum horizontal reinforcement of 0.0025.

Therefore, if we use vertical reinforcement of N16 bars, 200mm spacing, placed in both faces of the wall, and horizontal reinforcement of N12, 350mm spacing, the wall can be loaded as high as N*=4720kN with no moment around major axis or N*=1185kN with moment around major axis of 197 kN.m.

It worth mentioning that requirement of placing vertical and horizontal reinforcement on both wall faces for walls designed using simplified method (Equation 1) is a new requirement set by the latest Australian standard AS3600:2018 for heavily loaded walls. One layer of reinforcement was allowed for same walls as per the previous revision of the standard AS3600:2009.

Keeping the same exact reinforcement, the capacity of the wall can be further increased by designing the wall as column allowing tension as per clause 11.2.1 (b). This clause allows walls that are subject to tension on part of the section and with H/L ratio greater than 2, which is applicable to this case study, to be designed as column. Referring to clause 11.7.4 again, being a 40MPa wall with %1 vertical reinforcement, confinement reinforcement can be omitted if we have minimum of 0.0025 horizontal reinforcement. The same exact axial load-moment diagram capacity curve as a confined column with same vertical reinforcement can be used now when designing this wall.

Figure 1 illustrates how changing vertical reinforcement and design methods used, can affect the design capacity of the wall/column in study.

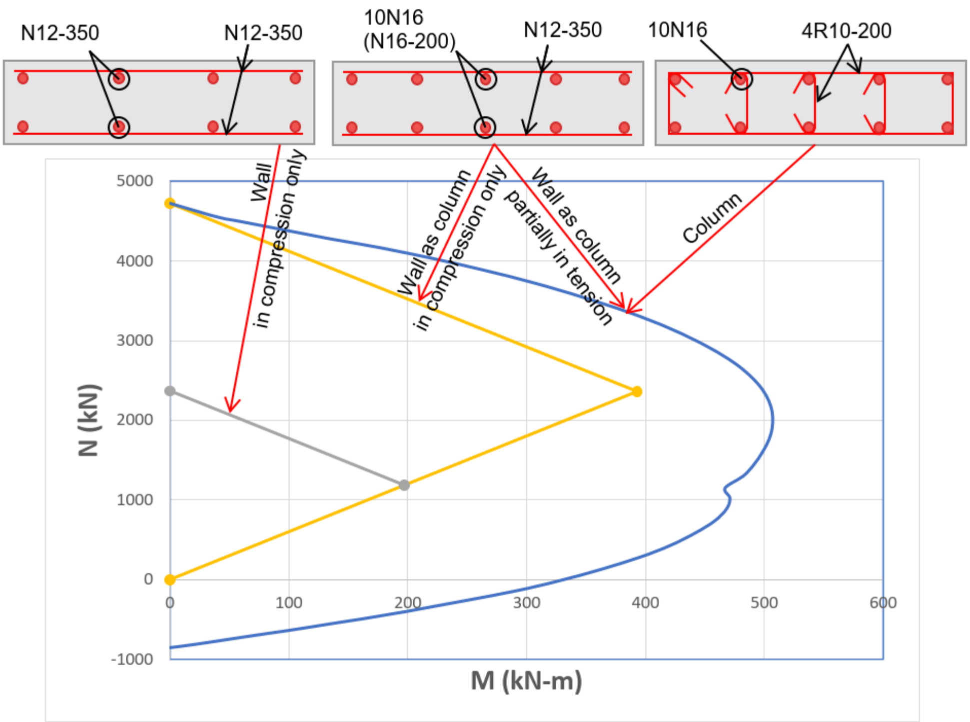

Figure 1: Axial load-moment capacity curve of studied column and wall cases

3 Conclusion

A popular size of blade column has been studied and capacities have been calculated using different scenarios allowed in AS3600:2018. The presented case study showed that only by considering the same element being wall instead of column, 4 confinement ties spaced at 200mm can be removed and be replaced by N12 bars 350mm spacing and still get the same exact capacity.

As another example, with the current code requirement, a 200x400mm vertical element with the same assumptions above, and %1 of vertical reinforcement can be designed as a wall without any closed confinement ties but with the same capacity as a confined column with the same %1 of reinforcement.

This study can be summarized as follows:

- Concrete code AS3600:2018 leaves deciding on whether a vertical element is wall or column to designer when calculating capacity unlike other international standards such as American, European and Canadian concrete codes
- Changing the assumption from column to wall for the studied case can result in less and simpler reinforcement required but without reducing the capacity
- Further studies are required to come up with a clear definition and criterion to instruct the designer to follow wall or column sections of the standard for a vertical element. This can potentially be setting a certain ratio for length to thickness and height to length of the vertical element to be considered wall.

4 References

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