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ASSESMENT OF CONFINEMENT DESIGN PROVISION OF SNI 2847 2013

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ABSTRACT

In 2013, Indonesia has been published new reinforced concrete (RC) design code, which called SNI 2847 2013. This code improved the previous reinforced concrete provision. This standard also specified detailing for RC buildings in the high-risk earthquake region. For reinforced concrete columns at special moment resisting frame, transverse reinforcement is provided to allow column to have large deformation demand without degradation in lateral load resistance. In this study, the confinement design equations of SNI 2847 2013 are evaluated with column test data with several parameters. The result of study exhibited that this confinement design provisions are needed to improve.

Keywords: design code, earthquake risk, reinforced concrete.

INTRODUCTION

Transverse reinforcement of concrete column has several functions such as (1) To resist shear when diagonal shear crack cross the transverse reinforcement; (2) To restrain slip between lap splice of longitudinal bars; (3) To restrain compression longitudinal reinforcement from buckling; (4) To confine concrete column core after concrete cover spilled [1]. All of these functions are effective after the concrete has spiled or cracked. These functions are importance to maintain vertical and lateral capacities under cyclic load in earthquake. To achieve sufficient ductility and strength in the post-yield range, confinement provision of SNI 2847-2013[2] adopt ACI 318M-11[3] confinement requirements. These provision [2,3] exhibited that amount of confinement steel related to compressive concrete strength, yield strength of transverse reinforcement, and cross-section of column including concrete core.
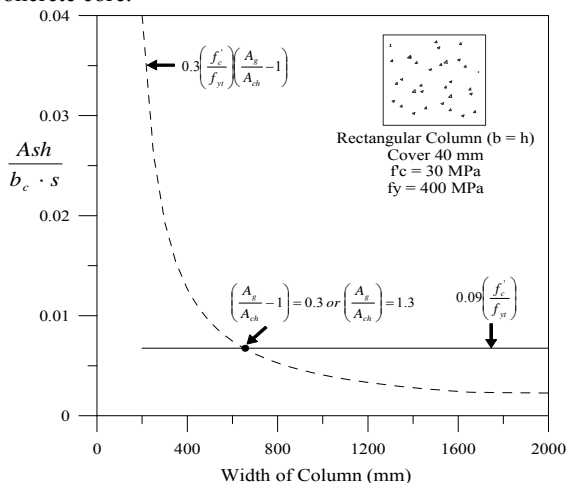

Figure-1. Confinement design equation of ACI 318/ SNI 2847 2002).

Figure-1 shows confinement reinforcement requirement ratio based on [2,3] that applied to a

rectangular column with concrete cover 40 mm, concrete compressive strength 30 MPa and yield tension strength of transverse reinforcement 400 MPa. For small column, the amount confinement reinforcement determined by the equation in dash line while for large column, the confinement demands were determined by equation in the straight line. The demand of the confinement requirement moves from equation in the dash line to equation straight line at column with a size of 650x650 mm with ratio cross-section of gross area to concrete core area about 1.3. Lower limit confinement provision [2, 3]] was intended for yielding regions to have a sufficient flexural curvature capacity [1], but it never mentioned about the relationship to column performance level and axial load level. ACI Committee 318 revise confinement provisions in ACI 318-14 [4] with add equation that considers axial load level effect.

LITERATURE REVIEW SNI 2847-2013

The requirement of confining reinforcement were derive on concept that axial load capacity of column should maintained after spilling of concrete cover. Total volumetric ratio of transverse reinforcement shall not be less than require by

$$\frac{A_{sh}}{b_c \cdot s} \geq 0.3 \left(\frac{f_c^{'}}{f_{yt}} \right) \left(\frac{A_g}{A_{ch}} - 1 \right) \qquad (1)$$

$$\frac{A_{sh}}{b_c \cdot s} \geq 0.09 \left(\frac{f_c^{'}}{f_{yt}} \right) \qquad (2)$$

Where, A_{sh} is total cross-sectional area of transverse reinforcement within spacing, s, and perpendicular to dimension, b_c (mm^2), b_c is cross-sectional dimension of member core measured to the outside edges of the transverse reinforcement (mm), s is center-to-center spacing of transverse reinforcement (mm), $f'c$ is compressive strength of concrete (MPa), f_{yt} is yield strength of transverse reinforcement (MPa), A_g is cross-sectional gross area of column (mm^2), A_{ch} is cross-

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sectional area of concrete core column measured to the outside edges of the transverse reinforcement. (mm²)

However, the philosophy of this code were maintaining the axial load strength after concrete cover sapling does not directly relate to performance of column.

ACI 318 – 14

Confining reinforcement in ACI 318-14 still included equations (1) and (2) also added new equation that developed from column test data [5].

$$0.2 k_f k_n \frac{P_u}{f_{yt} \cdot A_{ch}} \; ; P_u > 0.3 A_g f_c \qquad (3)$$

Where,

$$k_f = \frac{f_c'}{175} + 0.6 \geq 1 \qquad (4)$$

$$k_n = \frac{n_l}{n_l - 2} \qquad (5)$$

Pu is ultimate axial force of column (N), n_l is the number of longitudinal bars in the column that are laterally supported by corner hoops or ties

COMPARISON COFINEMENT DEMAND OF SNI 2847-2013 AND ACI 318-14

Figure-2 illustrates the comparison of confining requirement volumetric ratio in SNI 2847-2013[2] and ACI 318-14[4] for 650x650 mm square column. Dashed line represent the confining ratio using equation (2) and solid line reflect equation (3). For low axial load (Pu/Agfc < 0.29), both code have the same confining ratio. But, for axial load exceed about 0.29 Pu/Agfc, ACI [4] begin require more confining reinforcement than SNI [2]. Confining reinforcement increase as axial load level increases in ACI [4].
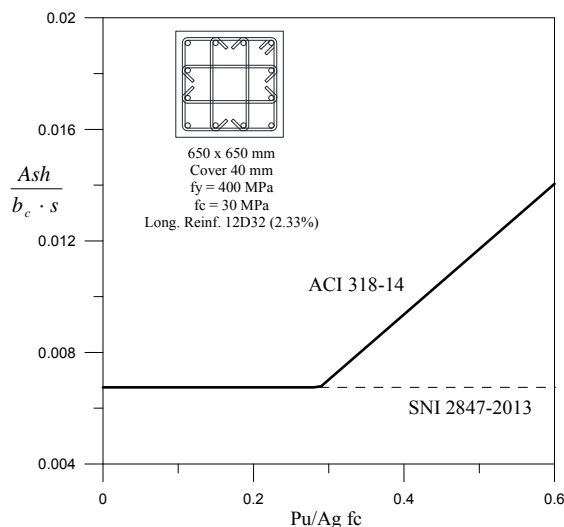

Figure-2. Comparison confinement demand of SNI 2847 2013 [2] and ACI 318-13.

DATABASE EVALUATION

163 data (145 data [6]0, 15 data [7-8], 3 data [9]) of flexural hinging column prior to shear failure were evaluate. Measured drift ratio at a 20% reduction in lateral force resistance after peak was used. Indonesia earthquake design code [10] use 2% drift limit as acceptance criteria for most of building types, and it require multiplying 1.5 times for maximum considered drift limit. Hence, 3% drift limit used to evaluate performance target of confined column.

Figure-3 and Figure-4 shows the columns drift capacity versus ratio of actual confining to confining requirement by SNI 2847-2013[2] and ACI 318-14[4] respectively. All data categorized in 3 axial load level, low axial load ($P_u/A_g f_c < 0.2$), intermediate axial load ($0.2 \leq P_u/A_g f_c < 0.4$), and high axial load ($P_u/A_g f_c > 0.4$). Vertical dashed line represent confining reinforcement satisfy the code requirement. Horizontal dashed line reflect the target drift performance of columns. Data in lower left (R4) show that columns has not enough confining reinforcement than considered by provisions and was not meet the target performance. Data in upper right (R1) indicate that the columns has more confining than provisions required and show the performance more than target drift. The ideal confinement provision supposed to follow the diagonal dashed dot-line from lower left (R4) to upper right (R1). Data in lower right (R2) show that columns has meet the confining provision but was not present a good drift performance, it is indicate that the confining provision might not be conservative for some cases. Data in upper left (R3) indicate that columns has less confining but shows performance more than target, it is show that the provisions may be considered over conservative for some cases.

In Figure 3, SNI 2847-2013 shows 73 of 77 columns in region 3 (R3) that subjected to Pu/Agfc ≤ 0.4 indicate that the provision might over conservative in many cases with axial load level less than 0.4 Pu/Agfc. However, in region 2 (R2), 15 of 17 columns were tested with Pu/Agfc>0.4 indicate that provision perform non-conservative in high axial load columns. Therefore, the confining provision in SNI 2847-2013 must consider axial load effect to ensure the columns can attain 3% drift capacity.

ACI 318-14 accommodates the axial load effect in confining provision that shows in equation (3). Table-1 show the number of columns in region 2 (R2) left has been reduce if ACI 318-14 compared to SNI 2847-2013. It demonstrate the desire trend that the columns data approaching the diagonal dashed dot-line, increasing of confining reinforcement will resulting increases of drift capacity. Expression in equation (3) accommodate for column that have axial load exceed 0.3 Ag fc to sustain drift capacity ratio 3%.
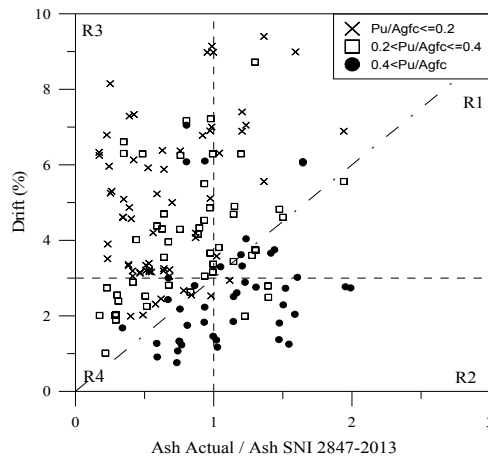
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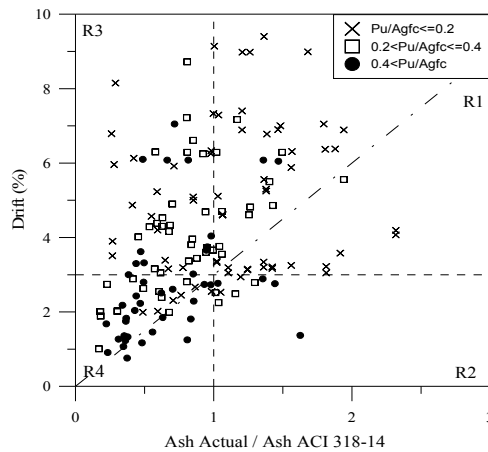**Figure-3.** Drift versus confinement demand of SNI 2847 2013 [2].

Figure-4. Drift versus confinement demand of ACI 318-14 [2].

Table-1. Resume comparison number of columns based on region and axial load level.

e	$P_u/A_g f_c$	Region				
		1	2	3	4	
NI 2847 2013 [1]	$P_u/A_g f_c < 0.2$			0		7
	$0.2 \leq P_u/A_g f_c < 0.4$	2		3	4	2
	$P_u/A_g f_c > 0.4$	0	5		5	4
	Sum	1	9	7	6	63
CI 318-14 [4]	$P_u/A_g f_c < 0.2$	0		9		7
	$0.2 \leq P_u/A_g f_c < 0.4$	1		4	3	2
	$P_u/A_g f_c > 0.4$			2	6	4
	Sum	3	0	5	5	63

CONCLUSION AND FUTURE WORK

Confining provision provided by SNI 2847-2013 [2] does not consider axial load effect resulting some cases of columns does not reach target performance drift. Hence, confining provision in SNI 2847-2013 [2] need to consider the axial load effect and performance target. However, ACI [4] consider axial load effect in confining resulting better performance than SNI.

These code [2] and [4] detailed transverse reinforcement to resist shear force and to confined concrete column separately. However, both functions applied in the same transverse reinforcement might influence each other functions. Further research need to be done to show the correlation between shear and confining in column.

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