CHAPTER II

LITERATURES REVIEW

The structural of building should fulfill the requirement “Strong Column Weak Beam”, it means when building structure get the seismic design load, plastics hinge in the building structure can occur at the end of beams, at the bottom of columns and at the bottom of structural walls. (BSN, 2002).

The selection of structural systems for buildings is influenced primarily by the intended function, architectural considerations, internal traffic flow and also economics aspects. According to Paulay and Priestley (1991) the degree of protection desired and the increase in costs to the resistance of the structures against earthquake during their service life are consists of three parts:

1. Seismic Design Limit State (50 – years – return period earthquake), no damage which is caused by minor intensity of ground shaking. Parameter that determined is stiffness.
2. Damage Control Limit State, for medium intensity of ground shaking, some damage may occur and the building can be repaired, some of reinforcement is designed to be damage to release seismic dissipation energy. Parameter that determined is strength.
3. Survival Limit State, loss of life should be prevented even during the strongest ground shaking feasible the site. Structure do not collapse, parameter that determined is ductility.

2.1 Loading Analysis (According to SNI)

1. Required Strength (U)

    a. To resist dead load:

    $U = 1.4\ D$ ....(2–1)

    b. To resist dead load, live load, roof load and rain load:

    $U = 1.2\ D + 1.6\ L + 0.5\ (A\ or\ R)$ ....(2-2)

    c. To resist dead load, live load, roof load, rain load, and wind load:

    $U = 1.2\ D + 1.0\ L + 1.6\ W + 0.5\ (A\ or\ R)$ ....(2-3)

    $U = 0.9\ D + 1.6\ W$ ....(2-4)

    d. To resist dead load, live load and earthquake load:

    $U = 1.2\ D + 1.0\ L \pm (1.0\ E_x \pm 0.3\ E_y)$ ....(2–5)

    $U = 1.2\ D + 1.0\ L + 1.0\ (\pm E_y \pm 0.3\ E_x)$ ....(2–6)

2. Design Strength

Design strength compute with input the strength reduction factor (ϕ) are as follows:

1. Flexure sections without axial load = 0.80
2. Axial load and axial load with flexure
    a. axial tension and axial tension with flexure = 0.80
    b. axial compression and axial compression with flexure
        i. structural component with spiral reinforcement = 0.70
        ii. other structural component = 0.65

3. Shear and Torsion in structures that rely on special moment resisting frames or special reinforced concrete structural walls to resist earthquake effects, the strength reduction factors shall be modified as given:
   a. The strength reduction factor for shear at any structural member that is designed to resist earthquake effects if its nominal shear strength is less than the shear corresponding to the development of the nominal flexure strength of the member. The nominal flexure strength shall be determined considering the most critical factored axial loads and including earthquake effects = 0.55
   b. The strength reduction factor for shear in diaphragms shall not exceed the minimum strength reduction factor for shear used for vertical components of the primary lateral – force – resisting system.
   c. The strength reduction factor for shear in joints and diagonally reinforced coupling beams shall be = 0.80
4. The strength reduction factor for shear at structural earthquake resisting component that is the nominal shear strength less than shear corresponding to the development of the nominal flexure strength = 0.55

2.2 Earthquake Design (According to SNI 03 - 1726)

According to SNI 03 – 1726 section 4.2.2, the building structure of “Asuransi Astra” is irregular. Irregular building must be analyzed by dynamic analysis. In dynamic analysis we can analyze base on response spectrum analysis or time history analysis.

Modeling of a structure is important. More detail the structure, more accurate the result is. In the real condition, a structure will have unlimited degree of freedom. But it will makes the calculation become very hard to held. For simplicity, eventually we consider floor as a rigid diaphragm, no rotation at the joint, and we neglect axial deformation on columns.

So, we assume to have 3 degree of freedom system. The first is horizontal translation in x direction. Second is horizontal translation in y direction. Third is rotation to vertical axis.

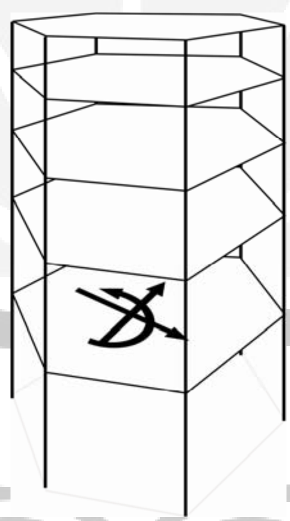


Figure 2.1 degree of freedom system

For system that has N-degree of freedom, it will also have N mode of vibration. For multistory building, commonly mode of vibration will be like in the figure 2.2.

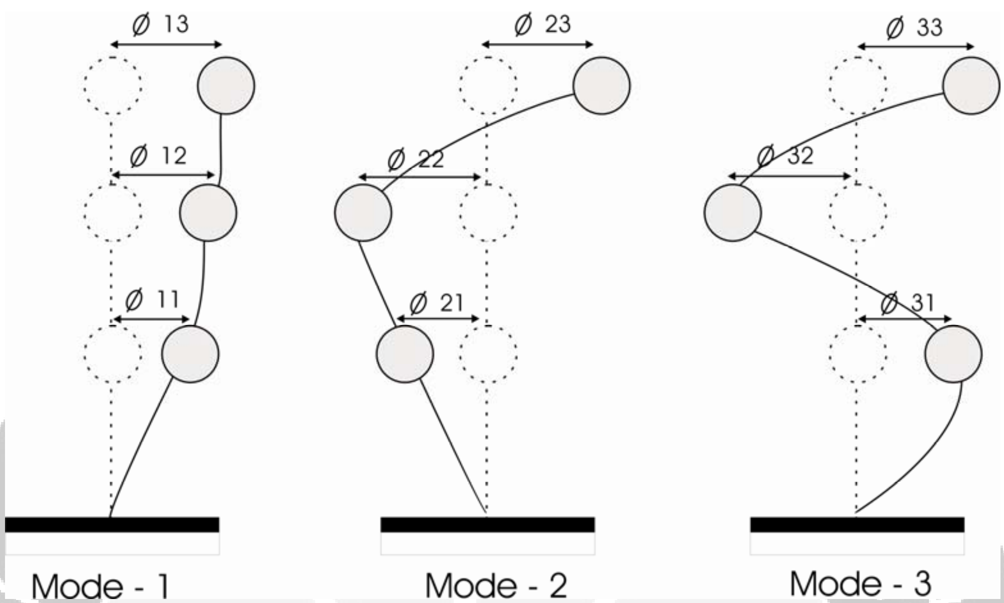


Figure 2.2. mode vibration of 3 stories building

In order to held dynamic analysis, we will use response spectrum analysis. In response spectrum analysis we can fid the maximum base shear using modal analysis by:

1. Find base shear from dynamic analysis :

$$Vm = \frac{Lm^2}{M_m} S^r{}_{am}$$

where:

Vm = base shear

Lm = earthquake excitation value

$$= \sum_{i=1}^{n} w_i \, \Phi_{im}$$

Mm = matrix mass

$$= \sum_{i=1}^{n} w_i \, \Phi_{im}^2$$

where :

w_i = weight for level i

Φ_{im} = mode shapes

S^r_{am} = modal seismic design coefficient

$$= \frac{\text{spectral acc}}{R_w}$$

where :

Rw = reinforced concrete structural system factor for its earthquake zone.

2. Find the maximum base shear combination

While to find maximum response combination from each mode, we can use Complete Quadratic Combination (if there is correlation between modes which can be known by w1 $\approx$ w2) or Square Root of the Sum of the Square. (if there is no correlation between modes)

For CQC method, the maximum base shear response combination from each mode can be defined as :

$$v_{rmax} = \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{n}\rho_{ij}\, v_{rimax}\, v_{rjmax}}$$

where :

v_{rmax} = maximum base shear response in r degree of freedom

ρ_{ij} = correlation mode response of i and j

u_{rimax} = maximum response mode for i

u_{rjmax} = maximum response mode for j

r = number of degree of freedom

n = the amount of maximum mode that's computed

For SRSS method, the maximum base shear response combination from each mode can be defined as :

$$v_{imax} = \sqrt{v_{i1max}^2 + v_{i2max}^2 + \ldots v_{inmax}^2}$$

3. Calculate base shear as the dynamic first mode response

In according to SNI 03 – 1726 section 7.1.3 earthquake nominal horizontal base shear force can be calculated using dynamic response analysis:

$$Vt \geq 0.8\ V_1 \quad \text{...(2-7)}$$

$$V_1 = \frac{C_1.I}{R}.\ W_t \quad \text{...(2-8)}$$

where:

Vt = dynamic horizontal base shear force

V_1 = horizontal base shear force as the dynamic first mode response

C_1 = base shear coefficient

I = building type factor

R = earthquake reduction factor

W_t = total weight of the building

According to SNI 03 – 1726 section 7.2.3 nominal base shear force obtained from response spectrum analysis in a certain way should be multiplied by a scale factor:

$$\text{Scale Factor} = \frac{0.8V_1}{V_t} \geq 1 \quad \text{...(2-9)}$$

where: V_1 = horizontal base shear force from first mode response

V_t = dynamic base shear force obtain from response spectrum analysis.

The member of significant modes to be considered is required to be the number of modes that will include at least 90% of the participating mass of the structure.

4. Distribute base shear throughout the height of the structure

$F_{xm} = C_{vxm}.V_m$

where :

Fxm = lateral force at floor level x, corresponding to mth mode

$$Cvxm = \frac{w_x Ö_{xm}}{\sum_{i=1}^{n} w_i Ö_{im}}$$

2.3 Roof structure design

The analysis of steel structure is based on SNI 03 - 1729 - 2002, where it consists of purlin design, obtain load combination, compute truss profile and compute steel connection.

2.3.1 Axially loaded compression members

According to SNI 03 – 1729 – 2002, section 9.1 designs for compression force shall satisfy:

$N_u \leq \phi_n N_n$ ....(2-10)

where:

ϕ_n = strength reduction factor (0.85)

N_n = nominal compression member

According to SNI 03 – 1729 – 2002, section 7.6.2 nominal bearing capacity of compression member, can be calculated:

$$N_n = A_g f_{cr} = A_g \frac{f_y}{\omega} \quad \text{.......(2-11)}$$

$$\text{for } \lambda_c \leq 0.25 \text{ so } \omega = 1 \quad \text{.......(2-12)}$$

$$\text{for } 0.25 < \lambda_c < 1.2 \text{ so } \omega = \frac{1.43}{1.6 - 0.67\lambda_c} \quad \text{.......(2-13)}$$

$$\text{for } \lambda_c \geq 1.2 \text{ so } \omega = 1.25\lambda_c^2 \quad \text{.......(2-14)}$$

2.3.2 Tension members

According to SNI 03 – 1729 – 2002, section 10.1 designs for tension force shall satisfy:

$$N_u \leq \phi \; N_n \quad \text{.......(2-15)}$$

where:

ϕ = strength reduction factor

N_n = nominal tension member

ϕ = 0.90

$N_n = A_g \,.\, f_y$

Choose smallest …………………...(2-16)

ϕ = 0.75

$N_n = A_e \,.\, f_u$

where:

A_g = gross plane area

A_e = effective plane area

f_u = failure of tension stress

According to SNI 03 – 1729 – 2002, section 10.2 effective section area are determined:

$$A_e = AU \quad \text{(2-17)}$$

$$U = 1 - \frac{\chi}{L} \leq 0.90 \quad \text{(2-18)}$$

where:

A = plane area

U = reduction factor

χ = eccentricity of connection

L = length of connection in tension force

2.4 Concrete Slab

Slabs are elements of buildings that can be supported by beams, girders or columns. Slabs experience bending and shear. Tension side in flexural slabs may be reinforced with steel. The shear stress in slab normally must be resisted by the concrete itself. Therefore, generally, there is no shear reinforcement in slab. (Arfiadi, 2005)

2.4.1 Slab Design (According to SNI 03 – 2847 – 2002)

Steps to design floor slab are as follows:

1. Obtain ratio of l_y and l_x

   If $l_y/l_x \leq 2 \leftrightarrow$ two way slab ....(2-19)

   If $l_y/l_x > 2 \leftrightarrow$ one way slab ....(2-20)

2. Obtain the thickness of slab (in accordance with SNI 03 – 2847 -2002)
3. Obtain load combination

   q_u = 1.2 DL + 1.6 LL ....(2-21)

4. Obtain the moment

   Ml_x or $Ml_y = 0.001q(l_x)^2$ x c ....(2-22)

   dx = h – concrete cover – ½ of reinforcement in x direction ....(2-23)

   dy = h – concrete cover – reinforcement in x direction – ½ of reinforcement in y direction ....(2-24)

5. Obtain the reinforcement, and fill the requirement $\rho \leq \rho_{max}$

   $R_n = \dfrac{M_n}{bd^2}$ ....(2-25)

   $\rho = \dfrac{0.85.f_c'}{f_y}\left[1-\sqrt{1-\dfrac{2R_n}{0.85f_c'}}\right]$ ....(2-26)

   there is no clear provision in SNI 03 2847 – 2002 use ρ_{min} 0.0025

   $\rho_b = \left[\dfrac{0.85.f_c'.\beta_1}{f_y}\left(\dfrac{600}{600+f_y}\right)\right]$ ....(2-27)

   $\rho_{max} = 0.75\ \rho_b$ .... (2-28)

   If $\rho_{min} < \rho < \rho_{max}$

   Use $A_s = \rho.b.d$ .... (2-29)

If $\rho < \rho_{min}$

Use $A_s = \rho_{min}.b.d$ .... (2-30)

If $\rho > \rho_{max}$

Use $A_s = \rho_{max}.b.d$ .... (2-31)

2.5 Stair Design (According to SNI 03 – 2847 – 2002)

Stair is modeled as thick beam with 1000 mm of width. The analysis will be based on SNI 03 – 2847 – 2002.

2.6 Beam

A beam is a structural element that carries load primarily in bending (flexure). Beams generally carry vertical gravitational forces but can also be used to carry horizontal loads (i.e. loads due to an earthquake or wind). The loads carried by a beam are transferred to columns, walls, or girders, which then transfer the force to adjacent structural compression members.

Five assumptions are taken as follows (Macgregor, 1997):

1. Section perpendicular to the axis of bending which are plane before bending remain plane after bending
2. The strain in the reinforcement is equal to the strain in the concrete at the same level
3. The stresses in the concrete and reinforcement can be computed from the strains using stress - strain curves for concrete and steel.
4. The tensile strength of concrete is neglected in flexural strength calculations

5. Concrete is assumed to fail when the compressive strain reaches a limiting value.

Depending on the properties of a beam, flexural failures may occur in three different ways, there are:

1. Tension failure, reinforcement yields before concrete crushes (reaches its limiting compressive strain) such a beam is said to be under - reinforced
2. Compressive failure, concrete crushes before steel yields. Such a beam is said to be over - reinforced
3. Balance failure, concrete crushes and steel yields simultaneously. Such a beam has balanced reinforcement.

2.6.1 Beam Design

According to SNI 03 - 2847 - 2002 section 23.3.(1) for special moment resisting frame which resist earthquake induced force and proportion primary to resist flexure, these frame members shall satisfy:

1. $P_u < 0.1\ A_g\ f_c'$ ➔ Factored axial compressive force on member is very small
2. Clear span of member $l_n > 4d$
3. Ratio $\frac{b_w}{h} > 0.3$
4. $b_w > 250$ mm
5. $b_w <$ width of supporting member + ¾ d

2.6.2 Shear Reinforcement Design

According to SNI 03-2847 – 2002 section 13.1(1), design of shear section shall apply:

$\varnothing V_n \geq V_u$ .... (2-32)

where:

V_n is nominal shear strength, which obtain from:

$V_n = V_c + V_s$ .... (2-33)

where V_c is concrete shear strength.

According to SNI 03 – 2847 – 2002 section 13.5(6(2)), shear reinforcement perpendicular to axis of member is used, shall apply:

$$V_s = \frac{A_V . f_y . d_p}{s} \quad \text{.......... (2-34)}$$

Shear reinforcement shall apply section 13.5(4(3)) and section 13.5(6(9)):

$$V_s < (\sqrt{f_c'}/3) b_w d_p \quad \text{.......... (2-35)}$$

$$V_s < (2/3)\sqrt{f_c'} b_w d_p \quad \text{.......... (2-36)}$$

where:

A_V = area of shear reinforcement within a distance ***s***, or area of shear reinforcement perpendicular to flexural tension reinforcement within a distance ***s*** for deep flexural members

s = spacing of shear or torsion reinforcement measured in a direction parallel to longitudinal reinforcement

2.7 Column

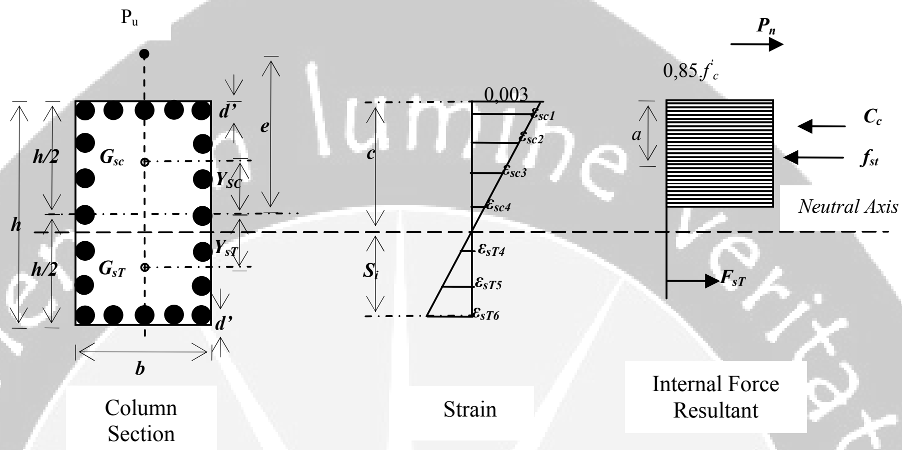
A column is a vertical structural element that transmits, through compression, the weight of the structure above to other structural elements below. Column normally support combined bending moment and axial load, under certain conditions column may support axial tension and bending moment, for example under earthquake and wind load.

Generally columns have several types there are tied columns, spirally columns and composite columns. For spiral columns are used when ductility is important or where high loads make it economical to utilize the extra strength resulting from the higher strength reduction factor, and also for seismic area.

It is highly desirable that plastic hinges form in the beams rather than in the columns, because the dead load must always be transferred down through the columns, the damage to the column should be minimized. That is why the structural of building should fulfill the requirement "Strong Column Weak Beam", it mean when building structure load the seismic design, plastics hinge in the building structure can occur at the end of beams and at the bottom of columns and structural walls. (BSN, 2002).

2.7.1 Longitudinal Reinforcement Design

In practical work, usually column is given reinforcement on its four sides. To get it's nominal axial load and nominal axial moment, we need to do some trial and adjustment. Strain capability checking is needed to do for every layer of reinforcement on every loading. To illustrate column and its reinforcement on its four sides, it can be seen in the picture 3.2 :



picture 2.3 column section analysis with reinforcement on its four sides

Where :

Gsc = Center of force gravity in compression reinforcement

Gst = Center of force gravity in tension reinforcement

Fsc = Force resultant in compression reinforcement = $\sum As' . f_{sc}$

Fst = Force resultant in tension reinforcement = $\sum As . f_{st}$

f_{st} = Stress in tension reinforcement

f_{sc} = Stress in compression reinforcement

Balancing of internal and external forces govern an equation :

$Pn = (0.85 . fc' . b . \beta 1 . c) + F_{SC} + F_{ST}$ ……………………...….(2-37)

Balancing of internal and external moments govern an equation :

$Mn = Pn . e$

$= 0.85\ fc'\ b . \beta 1 . c\ (h/2 - ½ . \beta 1.c) + F_{SC}.Y_{SC} + F_{ST}.Y_{ST}$ ....(2-38)

For this column calculation usually we do a trial and adjustment process, with firstly assume c value, and then we calculate a value. Value of every strain on each reinforcement layer will be counted by using linear strain distribution as in figure 2.3.

Stress on each reinforcement can be counted by using equation :

Fsi.. = Es. εsi = Es. εc .(Si / c) = 600. (Si / c) .... (2-39)

where :

Si = distance from the center of tension reinforcement to the neutral axis.

c = height of neutral axis that is counted from the edge of compression zone.

Then we count the value of Pn based on the value of c that was assumed. The value of Vn is inputted to the Mn equation to gain the value of c that is unknown.

From the above concept we can make a P-M interaction diagram that will shows capacity of concrete column section. That diagram shows the relationship between axial load and flexural moment in the ultimate condition.

Based on "Capacity Design" principal, where column must have enough strength so column won't fail before beam (*strong column weak beam)*.

$$\Sigma M_e \geq \frac{6}{5}\Sigma M_g \quad \text{..} (2\text{-}40)$$

where :

ΣM_e = Amount of moment in the center of beam column connection, in relationship with flexural nominal strength of column that is reinforced in that beam column connection center. Flexural strength of column must be counted for factored axial forces, that is according to lateral forces direction, that yield smallest flexural strength.

ΣM_g = Amount of moment in the beam column connection center, in relationship with beams flexural nominal strength that is reinforced in that beam column connection.

Column reinforcement ratio boundary SNI 03-2847-2002 section 12.9(1) is can't be less than 0,01 and can't be more than 0,08 times section gross area.

2.7.2 Transversal Reinforcement

SNI 03-2847-2002 section 23.4(4(1b)) said that the total section area of closed rectangular stirrup can't be less than :

$$A_{sh1} = 0,3\left(s.h.c.\frac{f_c^{'}}{f_y.h}\right)\left(\frac{A_g}{A_{ch}}-1\right) \qquad \text{(2-41)}$$

$$A_{sh2} = 0,009\left(s.h.c\frac{f_c^{'}}{f_y.h}\right) \qquad \text{(2-42)}$$

where :

A_g = gross section area

A_{ch} = area of section from outside to outside transversal reinforcement

s = transversal reinforcement spacing

h_c = column center section dimension that is measured from as to as of stirrup reinforcement.

$f_c^{'}$ = concrete compression strength

f_{yh} = transversal reinforcement yield strength

According to SNI 03-2847-2002 section 23.4(4(2)), transversal reinforcement should be put with spacing that can be less than :

a. A quarter from structural component smallest dimension,

b. Six times of longitudinal reinforcement diameter,

c. $s_x = 100 + \frac{350 - h_x}{3}$

value of s_x no need to be more than 150 mm and no need to be less than 100 mm.

2.7.3 Shear Reinforcement Design

Shear force design (V_e) to determine column shear reinforcement need must be determined from maximum moment strength M_n from every edge of structural component that are joined in the beam column connection. Column M_n is defined based on factored axial load that is taken equal with balanced moment interaction diagram from that column. Shear force design (V_e) can not be more than shear force design that is defined from beam column connection but based on M_n of transversal beams and can not be less than from factored shear force from structural analysis (Purwono, 2002).

According to SNI 03-2847-2002 section 13.1(1), design of section against shear must fulfill :

$\varnothing V_n \geq V_u$ ………………………………………………………………..……....(2-43)

where :

V_n is nominal shear strength that is counted from :

$V_n = V_c + V_s$ ……………………………………………………..……...……..(2-44)

where V_c is shear strength from concrete.

According to SNI 03-2847-2002 section 13.3(2), concrete shear strength for structural component that is loaded by axial compression load :

$$V_c = \left(1 + \frac{N_u}{14.A_g}\right)\left(\frac{\sqrt{f_c'}}{6}\right)b_w.d \text{ ……………...……………..……..…..……….(2-45)}$$

According to SNI 03-2847-2002 section 23.10(3) figure 47, column shear force for Special Moment Resisting Frame must fulfill :

$$V_e = \frac{M_{prt} + M_{pr2}}{l_n} \text{ …………………….……………………..…....……..(2-46)}$$

where :

V_e = shear force

M_{pr1} = flexural strength of top moment

M_{pr2} = flexural strength of bottom moment

l_n = column height

According to SNI 03-2847-2002 section 23.4(5(2)), on the plastic hinges area, shear contribution from concrete $V_c = 0$, if shear force due to earthquake that is counted is half or more than maximum required shear strength along that area, and factored axial force, including due to earthquake, is less $A_g f_c'/20$.

SNI 03-2847-2002 section 23.10(4(4)) said that the length of λo in the column area in the Special Moment Resisting Frame (SMRF) can not be less than the biggest value of :

a. $1/6$ of column clear height,

b. Largest dimension from column section,

c. 500 mm

SNI 03-2847-2002 section 23.4(4(2)), arrange about maximum spacing of stirrup that is installed in span λo I the Special Moment Resisting Frame (SMRF) from face of beam column connection is s_o. Spacing s_o can not be more than :

a. $s \leq$ ¼ x column dimension

b. $s \leq$ 6 x longitudinal reinforcement

c. $s \leq s_x = 100 + \dfrac{350 - h_x}{3}$

value of s_x no need to be more than 150 mm and no need to be less than 100 mm

According to SNI 03-2847-2002 section 23.4(4(6)), maximum spacing of stirrup that is installed outside λo in the Special Moment Resisting Frame (SMRF) from face of beam column connection is s_o. Spacing s_o can not be more than :

a. $s \leq$ 6 x longitudinal reinforcement = 6.25 = 150 mm

b. $s \leq$ 150 mm

2.8 Beam Column Connection Design

Beam column connection in the Moment Resisting Frame (MRF) system, forces in the beam longitudinal reinforcement on the face of beam column connection is defined by assuming stress in the flexural tension reinforcement is f_y.

SNI 03-2847-2002 section 23.5(3(1)), nominal shear strength of beam column connection can not be taken more than those criteria for normal weight of concrete :

1. For connection that is bridled on its four sides $1{,}7\sqrt{f_c^{'}}A_j$

   ……………………………………………………..…....(2-47)

2. For connection that is bridled on its three sides or two opposite sides

   $1{,}25\sqrt{f_c^{'}}A_j$ ……………………………………………………..…...(2-48)

3. For the other connection

   $1{,}0\sqrt{f_c^{'}}A_j$ …………………………………………….………(2-49)

SNI 03-2847-2002 section 23.4(4(2)), transversal reinforcement must be placed with spacing that can not be more than :

a. A quarter from the smallest of structural component dimension,
b. Six times of longitudinal reinforcement dimension,
c. $s_x = 100 + \frac{350 - h_x}{3}$ ……………………………………...…….…..(2-50)

value of s_x no need to be more than 150 mm and no need to be less than 100 mm

2.9 Shear Wall

Shear Wall is a wall designed to resist lateral forces parallel to the plane of the wall (sometimes referred to as vertical diaphragm or structural wall).

2.9.1 Structural Wall Design

According to SNI 03 – 2847 – 2002 section 23.6, the requirements of reinforced concrete structural walls serving as parts of the earthquake resisting system are as follows:

1. Reinforcement

1. a. Ratio Reinforcement

The distributed web reinforcement ratios, ρ_v and ρ_n, for structural walls shall not be less than 0.0025, except if the design shear force does not exceed $(1/12)A_{cv}\sqrt{f_c'}$, the minimum reinforcement for structural walls shall be permitted to be reduced to the minimum vertical and horizontal reinforcement shall be in accordance with:

- Minimum ratio of vertical reinforcement area to gross concrete area shall be:
  0.0012 for deformed bars not larger than D16 with a specified yield strength not less than 400 MPa, or
  0.0015 for other deformed bars, or
  0.0012 for welded wire fabric (plain or deformed) not larger than P16 or D16.
- Minimum ratio of horizontal reinforcement area to gross concrete area shall be:
  0.0020 for deformed bars not larger than D16 with a specified yield strength not less than 400 MPa, or
  0.0025 for other deformed bars, or
  0.0020 for welded wire fabric (plain or deformed) not larger than P16 or D16.
  Unless a greater amount is required for shear if $V_u < \Phi V_c/2$ and $V_u > \Phi V_c/2$, so shear reinforcement for wall shall be provided in accordance with

$$V_s = \frac{A_v . f_y . d}{s} \quad \text{...(2-51)}$$

$$\Phi V_n \geq V_u \quad \text{...(2-52)}$$

$$V_n = V_c + V_s \quad \text{...(2-53)}$$

where: V_s = nominal shear strength that contributed by shear reinforcement

V_n = nominal shear force

V_c = nominal shear strength that contributed by concrete

A_v = area of horizontal shear reinforcement

s = spacing of horizontal shear reinforcement

$$\rho_n = 0.0025 + 0.5[2.5 - \frac{h_w}{\lambda_w}]\ [\rho_h - (0.0025)] \quad \text{...(2-54)}$$

Reinforcement spacing in structural walls shall not exceed 450 mm. Reinforcement provided for shear strength shall be continuous and shall be distributed across the shear plane.

1. b. At least two curtains of reinforcement shall be used in a wall if the plane factored shear force assigned to the wall exceeds $(1/6)A_{cv}\sqrt{f_c'}$

1. c. All continuous reinforcement in structural walls shall be anchorage or spliced in accordance with the provision for reinforcement in tension.

2. Shear Strength

Nominal shear strength Vn of structural wall shall not exceed:

$$V_n = A_{cv}\ [\alpha_c \sqrt{f_c'} + \rho_n f_y] \quad \text{...(2-55)}$$

where: α_c = 0.25 for $(h_w/\lambda_w) \leq 1.5$

α_c = 0.167 for $(h_w/\lambda_w) \geq 2.0$

A_{cv} = the total cross – sectional area

3. Boundary elements of special reinforced concrete structural walls

Compression zones shall be reinforced with special boundary elements where:

$$c > \frac{\lambda_w}{600(\delta_u / h_w)} \quad \text{...(2-56)}$$

where: the quantity δ_u/h_w shall not be taken less than 0.007

h_w = height of walls totality or segment of wall that is observed

λ_w = length of walls totality or segment of wall that is observed in shear direction

δ_u = design displacement.