CHAPTER III

BASIC THEORY

3.1 Composite Column

Composite column are a combination of two traditional structural form: structural steel and structural concrete. Researched about composite column was started early in the beginning of 20th century. Composite columns can take of two form, a rolled steel shape encased in concrete with both longitudinal reinforcing bars and transverse reinforcement in the form of ties and spirals (as in reinforced concrete column) or a hollow shape filled with plain concrete. In composite column both the steel and concrete would resist the external loading by interacting together.

(Shah, Vakil, & Patel, 2014) said that the general term of 'composite column' refers to any compression member in which the steel element acts compositely with concrete so that both elements contribute to the strength.

Some of the advantages of composite column are:

1. Reduction of the structural steel consumption.
2. Reduction of the structure self-weight and volume.
3. Increase the section stiffness and strength.
4. The elimination or reduction of local buckling in metal profiles.
5. The protection of the steel section against corrosion.

6. Increase the fire protection.
7. Significant economic advantages over either pure structural steel or reinforced concrete alternatives.

3.2 Steel Encased Composite Column

Steel encased composite column is a hot rolled steel section that cover or encased with concrete. Encased composite column section has high bearing resistance, high fire resistance and economical solution with regard to material cost. Encased composite column is better than shear wall in hazards seismic zone and it reduces the construction cost and save time. It proves to be more economical where area is restricted and load is heavy because section size is reduced. The concrete filled steel tubular have many advantages than conventional reinforced column which make them better in strength and economical term. In concrete encased composite column the steel ratio is higher, it will provide more ductility to the structure, according to (Yuvaraj & Jamal, 2018).

There are four main components of concrete encased steel composite column, steel encased section, concrete cover, reinforcement bar and transverse ties or stirrups. In this final project the steel encased section, concrete cover, reinforcement bar and transverse ties or stirrups will be identical with (Soliman, Arafa, & Elrakib, 2013) C4 specimen.

3.3 SNI 1729-2015

Standar Nasional Indonesia (SNI) is the standard or code that is widely use in Indonesia. This SNI specification is for steel structure building, it is the revise version of SNI 03-1729-2002. SNI 1729-2015 was based on AISC 360-10 specification for Structural Buildings that publish by American Institute of Steel Construction. Where a lot of research conclude that the result prediction of AISC 360-10 is conservative. This research will use the formula that is given in SNI for composite column especially the formula to calculate the ultimate axial strength capacity of encased composite member.

Based in the SNI 1729-2015, for steel encased composite column there are some limitation, such as:

1. The cross sectional area of the steel section should be at least 1% of the total composite cross section.
2. Concrete encasement of the steel core shall be reinforced with continuous longitudinal bars and lateral ties or spiral.
3. Maximum spacing of lateral ties should not be greater than 0.5 times the least column dimension.
4. The minimum reinforcement for continuous longitudinal bars (ρsr) 0.004.
5. For determining the available strength, concrete compressive strength (f'_c) should not less than 21 MPa nor more than 70 MPa.
6. The *specified minimum yield stress* of structural steel shall not exceed 525 MPa.

In SNI 1729-2015 the axial compression capacity can be calculated using the following expression:

$$KL/r < 34 \quad (3\text{-}1)$$

Where, KL is effective length of the specimen and r is the radius of gyration.

$$P_o = A_s f_y + A_{sr} f_{yr} + 0.85\, A_c f'_c \quad (3\text{-}2)$$

$$P_e = \pi^2\, (EI)_{eff} / (KL)^2 \quad (3\text{-}3)$$

$$EI_{eff} = E_s I_s + 0.5\, E_{sr} I_{sr} + C_1 E_c I_c \quad (3\text{-}4)$$

$$C_1 = 0.1 + 2\, (A_s / (A_c + A_s)) \leq 0.3 \quad (3\text{-}5)$$

$$\lambda = (P_o / P_e) \quad (3\text{-}6)$$

Where $E_c = 0.043\ W_c^{1.5}\sqrt{f_c'}$, E_c in MPa, W_c is weight of concrete in Kg/m^3, f_c' is in MPa.

$$P_n = 0.658^{\lambda} \text{ for } \lambda \leq 2.25 \quad (3\text{-}7)$$

$$P_n = 0.877 / \lambda \text{ for } \lambda > 2.25 \quad (3\text{-}8)$$

The design compressive strength: $\phi_c P_n$ where $\phi_c = 0.75$.

3.4 Eurocode 4

Eurocode 4 (EC4) is the standard or code that commonly used by researcher in designing composite column. Eurocode 4 applies for the design of composite column and composite compression members with concrete encased sections, partially encased section and concrete filled rectangular and circular tubes.

Eurocode 4 Clause 6.7 is concerning the design of the composite columns using the concepts of limit state using fully plasticized structural steel section and reinforcing steel bars in tension and compression with stress ordinates equal to their yield strengths and a rectangular stress block for concrete compressive stress distribution, having a magnitude of 0.85*fc*

In this Code, General Method and Simplified Method are used for calculating column strength. Simplified Method is used for this study which is limited to columns of doubly symmetrical cross-section and with uniform section over the length. These two methods are both based on the following assumptions:

1. There is full interaction between the steel and concrete sections until failure occurs.
2. Geometric imperfections and residual stresses are taken into account in the calculation, although this is usually done by using an equivalent initial out-of-straightness.
3. Plane sections remain plane while the column deforms.

Based from EC4, there are some limitation on encased composite column:

1. The steel contribution (δ) ratio should be, $0.2 \leq \delta \leq 0.9$.
2. Every longitudinal bar or bundle of bar in a corner should be held by transverse reinforcement.
3. Maximum spacing of lateral ties should not be greater 400mm.
4. The minimum reinforcement for continuous longitudinal bars is given as $0.003A_c \leq A_{sr} \leq 0.06A_c$, where A_c is the cross sectional area of concrete and A_{sr} is the cross sectional area of longitudinal bars.

5. For determining the available strength, concrete compressive strength (f'_c) should not less than 20 Mpa nor more than 50 Mpa.
6. The *specified minimum yield stress* of structural steel shall not exceed 460Mpa but should be more than 260 MPa.

In EC4 the axial compression capacity can be calculated using the following expression:

$$P_n = 0.85A_c\left(\frac{f_c}{\gamma_c}\right) + A_s\left(\frac{f_y}{\gamma_s}\right) + A_{sr}\left(\frac{f_{yr}}{\gamma_{sr}}\right)$$

$$P_o = 0.85\, A_c f'_c + A_s f_y + A_{sr} f_{yr} \quad (3\text{-}9)$$

$$E_c = 22000 * ((fc` + 8) / 10) \wedge 0.3 \quad (3\text{-}10)$$

$$EI_{eff} = 0.6E_c I_c + E_s I_s + E_{sr} I_{sr} \quad (3\text{-}11)$$

$$P_{cr} = \pi^2 (EI)_{eff} / (KL)^2 \quad (3\text{-}12)$$

$$\lambda = P_o/P_{cr} < 2 \quad (3\text{-}13)$$

$$\phi = 0.5*(1+\alpha*(\lambda-0.2)*\lambda^2 \quad (3\text{-}14)$$

$$\chi = \frac{1}{\phi + (\phi^2 - \lambda^2)^{0.5}} \quad (3\text{-}15)$$

(3-16)

$$\chi_{P_n} \quad (3\text{-}17)$$

Where γ is the partially safety factor.

3.5 ABAQUS

ABAQUS is a finite element analysis (FEA) software package develop by Dassault Systemes that commonly used in various disciplines of engineering. The use of FEA tools has become widespread due to the software ability to simulate complicated components, structures and systems under a wide variety of situation and loading conditions. In this final project ABAQUS will be used to do numerical simulation of compressive test to get axial compression capacity of each concrete encased steel column.

3.5.1 Concrete Stress-Strain

Concrete stress-strain under compression in this final project was calculated using (Tong, Ren, Shen, Zhang, & Yang, 2018) equation:

$$y = \begin{cases} (E_o \varepsilon_Y / f_c)x & (x \leq 1 \text{ and } \leq 0{,}5) \quad (3\text{-}17) \\ \alpha_a x + (3-2a_a)x^2 + (a_a-2)x^3 & (x \leq 1 \text{ and } y > 0{,}5) \quad (3\text{-}18) \\ x/[a_d (x-1)^2 + x]y = & (x > 1) \quad (3\text{-}19) \end{cases}$$

x is the strain / peak compressive strain corresponding to f'_c, $a_a = 2.4-0.0125f'_c$, $a_d = 0.157f'_c{}^{0.785} - 0.905$. y= stress/ultimate compressive stress.

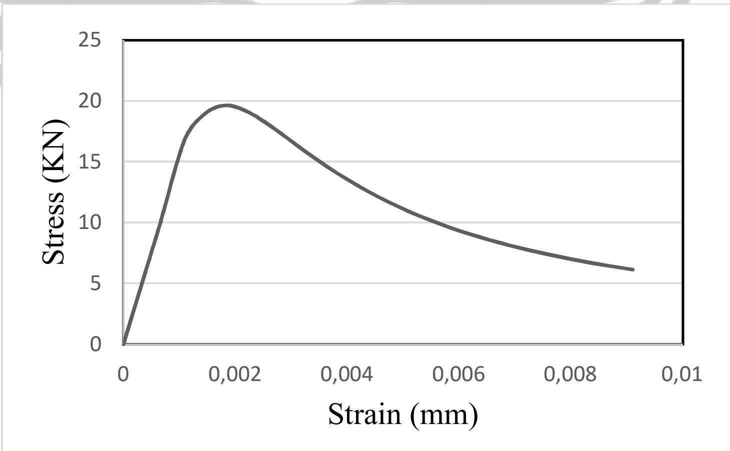

Figure 3.1. Concrete stress-strain under compression

(Source: Tong, Ren, Shen, Zhang, & Yang, 2018)

For stress-strain curve concrete under tension, this final project used linier crack opening law.

$$\frac{\sigma_c^{ef}}{f_t^{ef}} = \frac{f'_t}{W_c}(W_c - W) \quad (3\text{-}20)$$

$$W_c = \frac{2G_f}{f'_t} \quad (3\text{-}21)$$

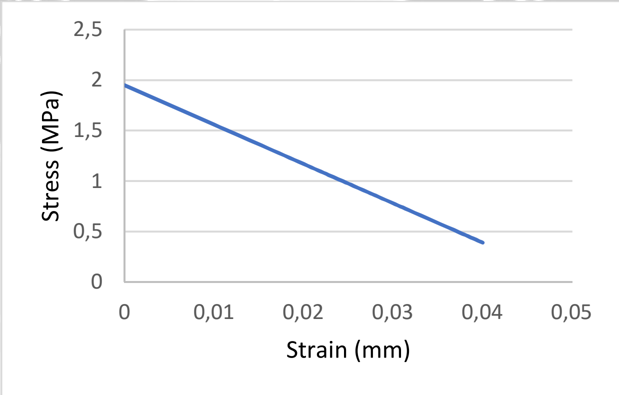

Figure 3.2. Concrete stress-strain under tension

(Source: ABAQUS standard user's manual)