Determination of Cross-Section for a Rod which is Subjected to Buckling

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Abstract - *Buckling is the deformation of the structure which occurs due to the instability of the material. Determining cross-section is the important task for anyone in order to design structures, components etc. This paper deals with the discussion of linear buckling of a rod of length 10m which is made of concrete and determining the perfect cross section of the rod in order to resist the buckling. The calculations are done not only by using theoretical formulae but also using Simulation software (ANSYS).*

***Key Words*: Linear buckling analysis, BLF (Buckling load factor), load multiplier, Total deformation, Modes.**

1. INTRODUCTION

[4] When a structure is subjected to compressive stress, buckling may occur. Buckling is characterized by a sudden sideways deflection of a structural member. This may occur even though the stresses that develop in the structure are well below those needed to cause failure of the material of which the structure is composed. As an applied load is increased on a member, such as a column, it will ultimately become large enough to cause the member to become unstable and it is said to have buckled. Further loading will cause significant and somewhat unpredictable deformations, possibly leading to complete loss of the member's load-carrying capacity. If the deformations that occur after buckling do not cause the complete collapse of that member, the member will continue to support the load that caused it to buckle. If the buckled member is part of a larger assemblage of components such as a building, any load applied to the buckled part of the structure beyond that which caused the member to buckle will be redistributed within the structure.

1.1 Linear buckling analysis or Eigen value Buckling

[2] Linear-buckling analysis calculates buckling load magnitudes that cause buckling and associated buckling modes. FEA programs provide calculations of a large number of buckling modes and the associated buckling-load factors (BLF). The BLF is expressed by a number which the applied load must be multiplied by (or divided — depending on the particular FEA package) to obtain the buckling-load magnitude.

1.2 Mode

Here buckling modes are considered as failure modes in which the column gets collapsed in that form.

1.3 LOAD MULTIPLIER

The term “load multiplier” used in ANSYS refers to the load at which buckling occurs. In other words, BLF and load multiplier sense same. For example, if you apply 1N force and you obtained the load multiplier value as 3, this means that buckling occurs at (1N * 3) = 3N.

1.4 BUCKLING LOAD FACTOR (BLF)

The buckling load factor is an indicator of factor of safety against buckling or the ratio of the buckling loads to the currently applied loads. While designing any structure, it’s better to have high value of BLF as much as possible.

2. Calculation of Buckling load

Linear buckling analysis can be analytically performed by using Euler’s formula:

$$F = n\pi^2 EI/L^2 \quad \text{or} \quad F = \pi^2 EI/(KL)^2 \quad \text{where } K = (1/n)^{1/2}$$

Here, we have performed these calculations for a rod of length 10m, which is made of concrete and considering different cross-sections (Square, Circle) of same area.

Where, F = Allowable Buckling load

n= factor

E= Modulus of elasticity of concrete= 30Gpa

L= length of the column= 10m

For Square cross-section:

I = Moment of inertia (m^4) ($I=L^4/64$)

L= Length of the cross-section = 0.7m

Factor (n) for one end fixed, other end free, n=0.25

The theoretical allowable Buckling load value obtained is 14804406.6N

Therefore, buckling load factor (BLF) = F/Fa, where Fa is the applied load= 10000N

BLF= 14804406.6/10000= 1480.44

For Circular cross-section:

I = Moment of inertia (m^4) ($I= \pi D^4/64$)

D= Diameter of circle= 0.79m

Factor (n) for one end fixed, other end free, n=0.25

The theoretical allowable load value obtained is 14212230.34N

Therefore, buckling load factor (BLF) = F/Fa, where Fa is the applied load= 10000N

BLF= 14212230.34/10000= 1421.22

2.1 Optimization of Cross-section

Comparing the obtained values, the BLF for square cross-sectional rod is higher than that of the circular cross-sectional rod. Therefore, the concrete rod of square cross-section is resistible to Buckling rather than the circular cross-sectional rod. In order to control the weight of the Rod, we can make the solid cross-section into hollow.

Let consider the concrete rod of length 10m with hollow square cross section of area equal to the previously considered cross sections (Solid Square, Solid circle).

L= length of the column= 10m

I = Moment of inertia (m^4), ($I=a^4-b^4/12$)

a= length of outer square= 0.8m

b= length of inner square= 0.3873m

Factor (n) for one end fixed, other end free, n=0.25

The theoretical allowable load value obtained is 23884881N

Therefore, buckling load factor (BLF) = F/Fa, where Fa is the applied load= 10000N

BLF= 23884881/10000= 2388.4

The BLF for hollow square rod is almost 1.6times the BLF for solid square rod. Therefore we consider the concrete rod with hollow square cross section.

Reasons for considering Euler's formula are:

- Euler's formula is applicable for long columns.
- Columns can be divided as long and short columns based on the slenderness ratio.
- Slenderness ratio is the ratio of the effective length of the column to the least lateral dimension.
- If the slenderness ratio is greater than 12, then those columns are long columns and vice versa.

The obtained slenderness ratio is 28.57 for square, 25.32 for circle and 51.64 for Hollow Square; therefore we preferred Euler's formula.

Table -1: Interpretation of Buckling load factor

BLF VALUE	BUCKLING STATUS	REMARKS
>1	Buckling not predicted	The applied loads are less than the estimated critical loads
=1	Buckling predicted	The applied loads are exactly equal to the critical loads. Buckling is expected
<1	Buckling predicted	The applied loads exceed the estimated critical loads. Buckling will occur.
-1<BLF<0	Buckling possible	Buckling is predicted if you reverse the load directions
-1	Buckling possible	Buckling is expected if you reverse the load directions
<-1	Buckling not predicted	The applied loads are less than the estimated critical loads, even if you reverse their directions.

2.2 Results obtained from simulations:

ANSYS software is used for calculating the buckling load factor. The rod is modeled in "Design modeler" provided in ANSYS.

For Solid square rod cross-section:
The BLF obtained in simulation is 1480.2

For Solid Circular rod cross-section:
The BLF obtained in simulation is 1414.7

For Hollow square rod cross-section:
The BLF obtained in simulation is 2378.7

For Hollow square rod cross-section with rounded corners:
The BLF obtained in simulation is 2360.3

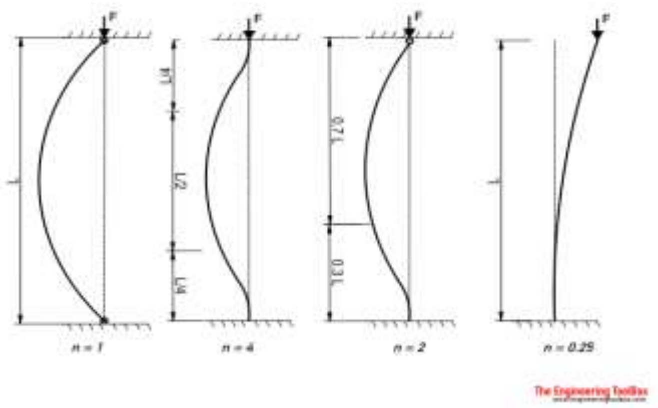

Fig-1: The Euler end column factors

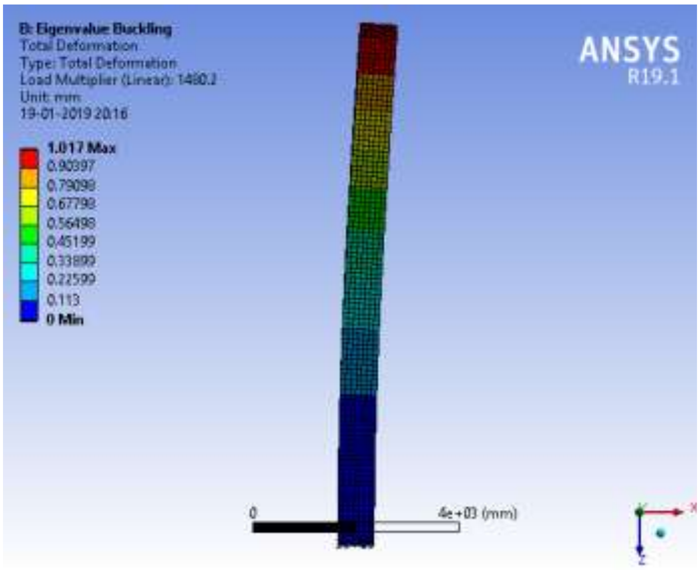

Fig-2: BLF for Solid square rod

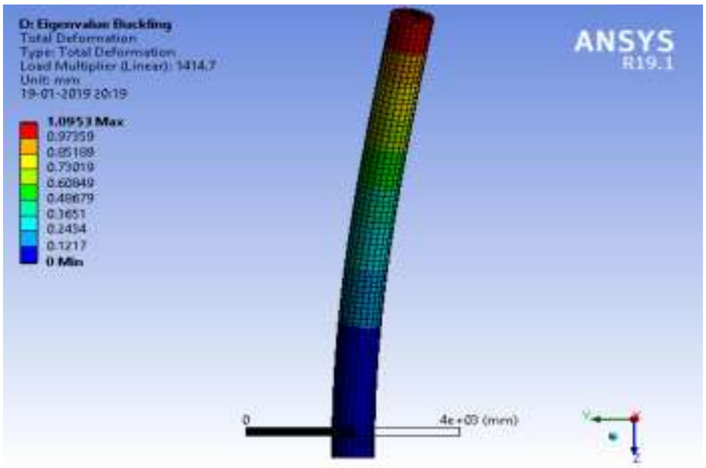

Fig-3: BLF for Solid circular rod

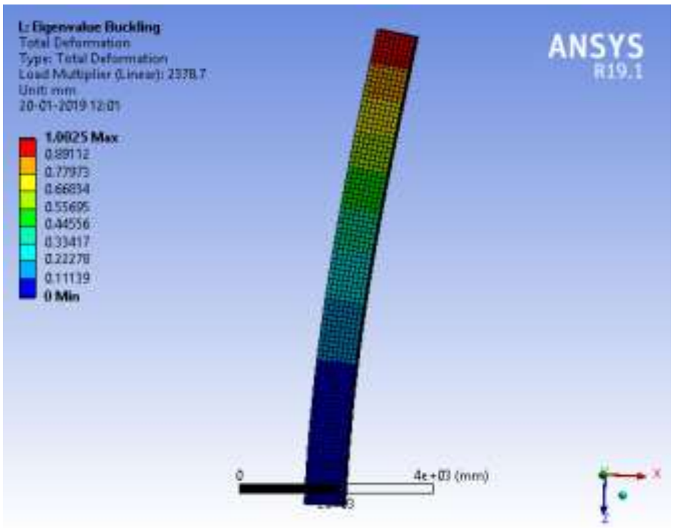

Fig-4: BLF for Hollow square rod

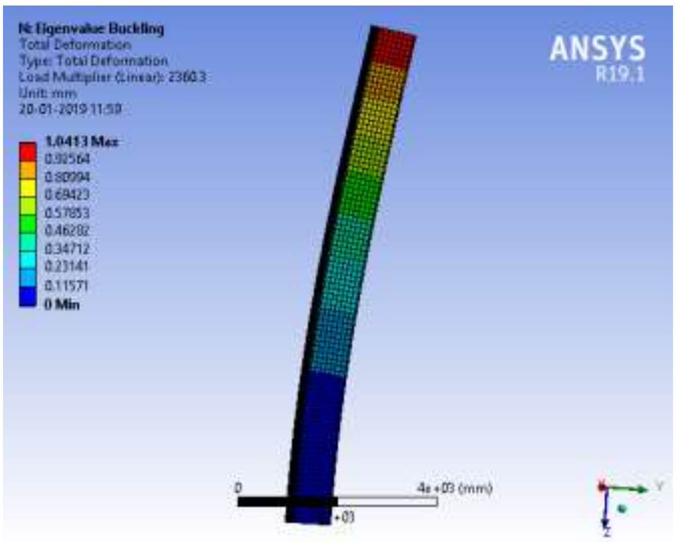

Fig-5: BLF for Hollow square rod with rounded corners.

3. CONCLUSION

From the theoretical calculations and results from simulation, it is proved that SQUARE is suitable as cross section for columns in order to resist buckling and also hollow columns are more resistant to buckling than solid columns. Combination of hollow columns with square cross section with rounded corners will provide better results.

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