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Study on Buckling Strength at Deck Leg of Fixed Offshore Platform

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ABSTRACT

A deck of fixed offshore platform is location where the all activities are performed, i.e. deck must be supported by leg with adequately strength under vertical or horizontal loading. The present study is focused on the buckling strength taking the deck leg of fixed jacket offshore platform into account. The axial compressive load is applied to the deck leg of the structure. Because dimension front view and side view of the deck structure is completely different, so that the analysis is conducted by two stages. To investigate the critical buckling load and critical buckling stress including its deformation, the plane-frame (2D) analysis is considered. The Non-linear Finite Element Method so-called Structural Analysis Program (SAP) is adopted for the investigation of the structural behaviors. The critical buckling load and stress ratio obtained by Finite Element Analysis (FEA) is compared with the simple formula. As a result, it can be concluded that the stress ratio of the combination between axial compression and bending is less than 1,0 which indicates that the structure is safe.

Keywords: fixed offshore platform, deck leg, finite element method, critical buckling load, stress ratio

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1. INTRODUCTION

Deck design starts with the estimation of the deck loads, such as the drilling rig, production equipment supplies, etc. The deck equipment and process designers calculate these loads in the conceptual engineering phase. An upper bound, distributed load, obtained from the deck equipment and supplies is used for the selection of the size of the deck plate and deck beams. Every single element will against the external loads. Hence, those must be investigated for local and global structural response. The collapsed of structural member due to buckling at the deck leg must be designed in order the deck platform have adequate strength not only supporting but also for safety of human who work in the platform including all facilities.

It is well known that buckling is a mathematical instability, leading to the failure mode. Theoretically, bending is caused by the bifurcation in the solution to the equations of static equilibrium. At some stage under increased load, the load can further be maintained in one of two parts of a balance, a rigid body plate construction or construction-lateral defect. Practically, buckling is characterized by the sudden failure of structural members to experience high compressive stress, where the actual compressive stress at the point of failure is less than the main compressive stress that a material capable of withstanding. Failure mode is also described as a failure due to elastic instability. Mathematical analysis of buckling utilizing axial load eccentricity introduces moment, which does not form part of the main strengths of the construction.

When the load is continuously applied to the construction, such as columns, it will eventually become large enough to give an impact to the instability construction. If the loading is applied more than the capacity of the structure, then it will induce significant deformation and unpredictable, may lead to the loss of load carrying capacity, so that the construction is said to buckling. If the frame structure has a short dimension, then there will be a tendency of material destruction. However, when it is long, the failure will occur due to instability and not because of strength. Thus, buckling phenomenon is very interesting to be studied, particularly for the jacket type of the fixed offshore platform.

The present study is focused on the buckling strength taking the deck leg of fixed jacket offshore platform into account. The axial compressive load is applied to the deck leg of the structure. The analysis is considered by two-dimensional plane frame due to the differences of the front and side view of the deck structure. The Non-linear Finite Element Method so-called Structural Analysis Program (SAP) is adopted for the investigation of the structural behaviors. The critical buckling load and stress ratio obtained by Finite Element Analysis (FEA) is compared with the simple formula.

2. METHODS

So far the discussion about the strength of the joint where the column assumes no rotational restraint moments. Restraints zero moment at the end of the weakest situation for the one-rod press the edges can not move transversely relative to the other end. For endless column joints of this kind, ends bitterly equivalent length kL is the actual length L, thus k = 1.0, the equivalent length L is called the effective length of the joint lead.

For most real situations, restraint moments at the ends of the detained. Where the effective length is reduced. In many situations, it is very difficult or even impossible, to accurately assess the degree of restraint moments contributed by adjacent rod rod that bind to the column, by a local foundation and subsoil and the full interaction of all rods in steel frame structure. Whether the degree determined by the appropriate tip or not, the designer must understand the concept of braced frames (wobble prevented with belt backer) and unbraced frames (without belt backer, wobble is not prevented).

The effective length of the rod column at a leg deck, depending on the type of portals that are reviewed, namely the leg and feet are not sway sway. no sway leg (supported) is foot lateral stability provided by the appropriate connector to the shear walls to the diagonal buttresses, to nearby structures which have adequate lateral stability, or to the slab or roof coverings are fastened horizontally to the wall or with cantilever system parallel to the leg. Or in other words did not sway leg is defined as portal that sway buckling is prevented by the support element which does not include structural framework itself. K factor for leg sway is 0 <K <1. While not sway leg (which are not supported) is a portal that stability depends on the lateral bending stiffness of beams and columns are connected rigidly. K factor to sway portal is K > 1 [1].

The design of an idealized column differs from the actual structure of the column. This difference is due to the presence of numerous small imperfections, defects or deviations. The buckling mode of a column corresponds to the lowest buckling load which is referred to as the critical buckling load. Structural stability should be provided for the structure as a whole and also for each of its structural members. Because of the inevitable presence of geometric imperfections in fabricated structures, actual instabilities may be expected to occur at a load rather less than the load of an ideal column.

A slender member may lose its load-carrying capacity, i.e., the ability to withstand external forces, not as a result of failure of the material, but due to the loss of stability (buckling). The problem of stability of steel structural members is of great significance as its disregarding may lead to disastrous results. If a straight rod is compressed by an axially applied force P, then the bar will initially remain straight, and this is the state of stable equilibrium. The stable state of equilibrium of an elastic bar is characterized by the rod returning to its original position after removal of the external cause. Upon a further increase in the compressive force until it reaches such a value that its work will be equal to the work of deformation in bending induced by any small disturbing factor. In this instance the compressive force reaches its critical value [2]. The critical buckling load firstly introduced by Euler as,

$$P_{cr} = \frac{\pi^2 EI}{Le^2}$$

$$L_e = kL$$

P_E/P_{cr} is the critical buckling load corresponding with young's modulus (E), moment of inertia (I), effective length of column (Le), true length of column (L) and factor depending on the support end condition (k). The effective length is that length at which the length with hinged ends is equivalent in stability to the column with the given end conditions.

Thus a perfect straight bar when loaded with a force up to the critical state has a linear shape in the stable state of equilibrium. When the force reaches its critical value, the linear shape of equilibrium stops being stable, the bar may buckle in the plane of least stiffness and it will now have a new curvilinear shape of stable equilibrium. The magnitude of the force which causes the original stable equilibrium of the bar to become unstable is known as the critical force. If there is a slight initial curvature of the bar (or a slight eccentricity of the point of application of the compressive force) then upon an increase in the load the bar will immediately deflect from a straight position. Structural stability should be provided for the structure as a whole and also for each of its structural members. Because of the inevitable presence of geometric imperfections in fabricated structures, actual instabilities may be expected to occur at a load rather less than the load of an ideal column [2].

Therefore, the critical buckling load for an ideal column can be approaced by using Euler's equation.The stems are depressed will cause buckling behavior both from the direction of the x-axis cross section (lateral buckling), the direction of the y axis (local buckling), and torque (torsional buckling). So as in the analysis, a profile which is designed to have a value greater cross-sectional capacity of the smallest force causes the third bend. If the cross-section capacity does not meet one of the bend at the top, then you can add elements that can raise capacity strengthening cross-section of the weak axis. So that the rod can withstand all that buckling occurs. However, it should be noted that the effectiveness and efficiency of the use of the reinforcement elements must remain on guard, so that the value of safety, servirceability and economical structure can still be retained. To further clarify can be seen in Fig.1.

Properties in cross section taken into account in the design of the stem press are:

- Limitation slimness sectional elements.
- Design effective width.
- Effectiveness stiffener element.
- Effective cross-sectional area.
- Capacity to bend the rod tap on the x axis.
- Capacity to bend the rod tap on the y axis.
- Capacity rods press against buckling torque.

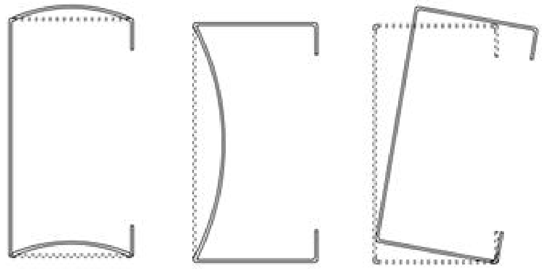


Fig. 1. Buckling behavior of the cross section

Members who are combining cylinder between axial compression and bending should be proportionate in order to meet the following requirements at all points in length.

$$\frac{f_a}{F_a} + \frac{C_m \sqrt{f_{bx}^2 + f_{by}^2}}{(1 - \frac{f_a}{f_e'})\, f_b} \leq 1$$

Where,

f_a : Buckling stresses permit axial column
F_a : Voltage aaksial column buckling
C_m : Reduction factor
F_b : Bending stress field
f_e' : Voltage equivalent
fbx^2 : Minor bending stress
fby^2 : Major bending stress

Determination of the slenderness ratio Kl/r for cylinder compression members shall be in accordance with the AISC. Rational analysis to determine the effective length factor should consider the provision and movement together. In addition, the definition of rational reduction factor should consider the character cross section and the load acting on the section. as a substitute for analysis, the following values can be used in Table 1.

Table 1. Effective Length Factor K for Different Situation

Situation	**Effective Length Factor *K***	**Reduction Factor *Cm*[(1)]**
Superstructure Legs		
Braced	1.0	(a)
Portal	$K^{(2)}$	(a)
Jacket Legs **&** Pilling		
Grouted	1.0	(c)
Composite Section		
Ungrouted	1.0	(c)
Jacket Legs		
Ungrouted	1.0	(b)
Pilling Between Shim Points		
Deck Truss Web Members		
In-Plane Action	0.8	(b)
Out-of-plane Action	1.0	(a) or (b)[(4)]
Jacket Braces		
Face-to-face Length of Main Diagonals	0.8	(b) or (c)[(4)]
Face to leg to Centerline of Joint	0.8	(c)
Length of K Braces[(3)]		(c)
Longer Segment Length of X Braces[(3)]	0.9	(c)
Secondary Horizontals	0.7	(a), (b) or
Deck Truss Chord Members	1.0	(c)[(4)]

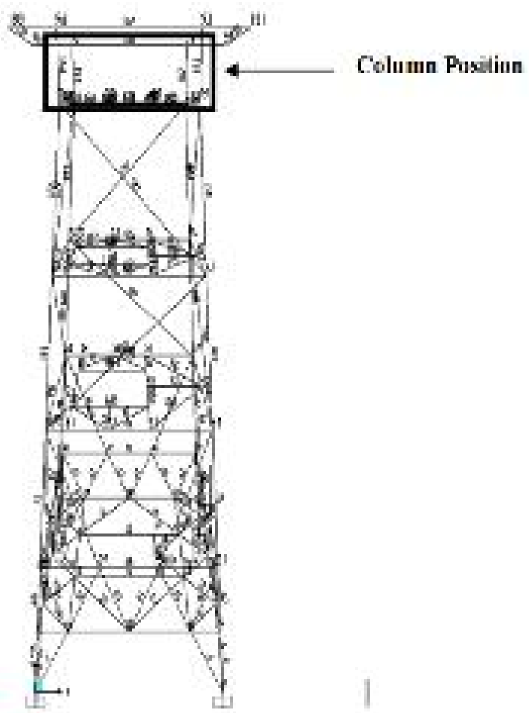
Values Cm reduction factor referred to in the above table are as follows (with the terms as defined by AISC):

a = 0.85

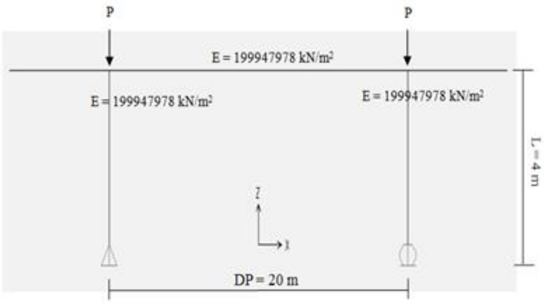
b = 0.6 - 0.4 (m_1/m_2), but not less than 0.4, and no more than 0.85.

c = 1 - 0.4 (f_a/f_e), or 0.85, selected that less.

A fixed offshore platform namely tetrapod is used as the object to be analyzed for the assessment of the critical buckling load and critical buckling stress or Euler buckling stress as shown in Fig. 2. The boundary conditions are assumed to be fixed at bottom level and the material and dimensions are taken based on the structural component. To investigate the buckling strength including its behavior, the structure is setup in two plane-section and symmetric at any plane. In this case, only x-z and/or y-z plane is selected. As a fundamental case, buckling strength analysis is carried out in the x-z plane. The axial compressive load is applied to the jacket legs as shown in Fig. 3. In the FEM analysis, the property modification factor for area is set to be 100000 and the property modification factor for shear area is set to be 0. These properties modification factor are imposed for all structural members especially for the front and side appear of deck leg.

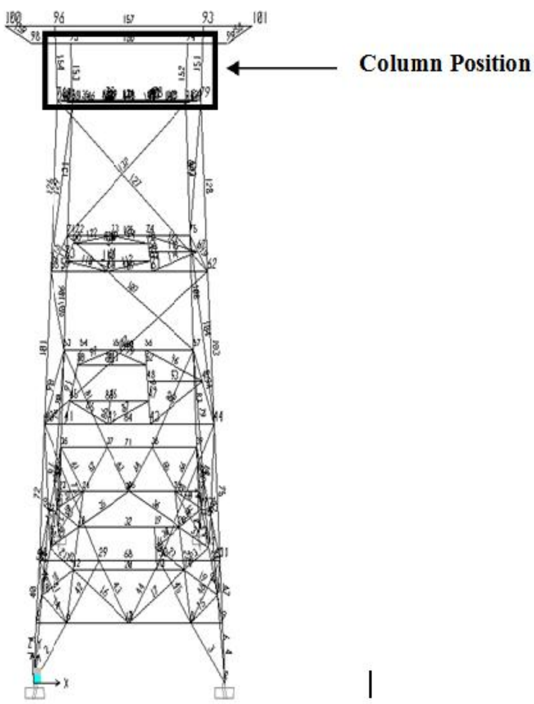


(a) 3D view

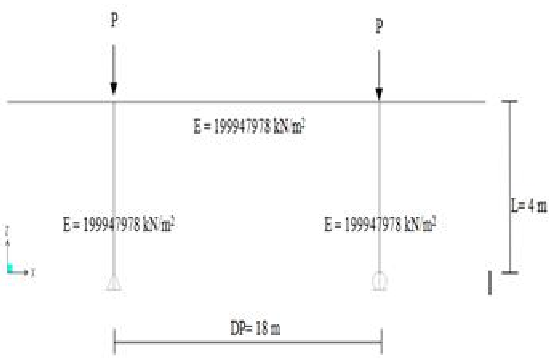


(b) 2D view front appear

Fig. 2. A tetrapod, material and column length front appear of the structures



(a) 3D view



(b) 2D view front appear

Fig. 3. A tetrapod material and column length side appear of the structures

To calculate the critical buckling load on the column structure especially column for deck leg, the FEM is carried out and the result will be compared with the analytical solution with the effect of effective length and reduction factor.

3. RESULTS AND DISCUSSION

Buckling strength analysis is conducted by applying the Finite Element Method to assess the critical buckling load and critical buckling stress or Euler buckling stress for tripod column structure. The result obtained by FEA is therefore compared with the analytical solution. As the fundamental case, the result obatined by FEA and analytical solution is taken for the effect of effective length and reduction factor column. The critical buckling load (Pcr) for the front appear of deck leg jacket structure obtained by FEM is shown by the following Fig. 4.

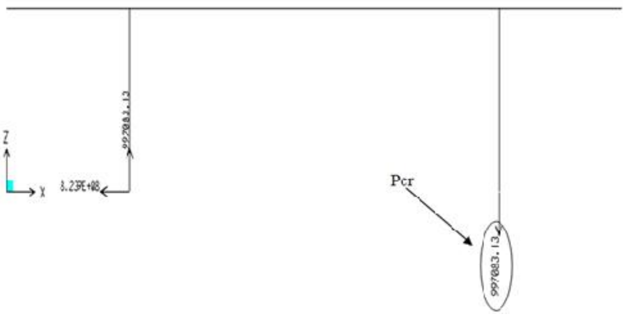


Fig. 4. P_{cr} for the front appear of deck leg jacket structure obtained by FEM

According to those figures, the critical buckling load obtained by FEA is compared to the analytical solution for the front appears of deck leg jacket structure. The following summary can be drawn:

Table 2. Comparison of the critical buckling load for the front appear of deck leg jacket structure

Parameters	Values
FEA (kN)	985,703.5
FEM (kN)	997,083.13
Quarrel Percentation	1.14%

The critical buckling load (P_{cr}) for the front appear of deck leg jacket structure obtained by FEM is shown by the following figures.

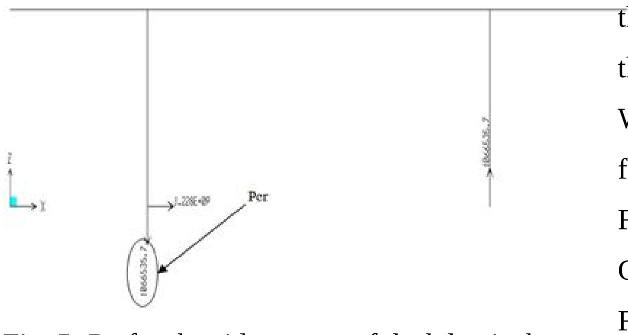


Fig. 5. P_{cr} for the side appear of deck leg jacket structure obtained by FEM

From the analyze result using the program, deformation shape of the column as a consequence of critical buckling load it shown on figure below.

Table 3. Comparison of the critical buckling load for the side appear of deck leg jacket structure.

Parameters	Values
FEA (kN)	985,703.5
FEM (kN)	1,066,535.7
Quarrel Percentation	1,14%

Fig. 6. Deformation shape of column as a consequence of critical buckling load

With analyze result by using auxiliary program SAP 2000 it can be calculation buckling stresses permit axial column, voltage axial column buckling, reduction factor bending stress field, voltage equivalent, minor bending stress, and major bending stress so by them we can calculation the reduction factor of the column is fill by using the equation (1).

Where,

fa : 148,922.2 kN/m^2

Fa : 345,777 kN/m^2

Cm : 0.85

Fb : 186,158.46 kN/m^2

fe ' : 6096420,48 kN/m^2

fbx^2 : 0 kN/m^2

fby^2 : 1,249E-11 kN/m^2

So the result is 0.002321863 ≤ 1.0

The buckling phenomenon also had been investigated by [3], the frame structure was taken into account by considering the axial compressive load and the critical buckling load was calculated. The frame structure made by him was validated by [4]. The C_{si} validate the model by investigating the critical buckling load in two dimensional (2D). The software verification result for the critical buckling load obtained by CSI was compared to

Timoshenko's result based on the model that had been made before. It was found that the result between two methods was identic for critical buckling load. Therefore, this becomes a good basis for the assessment of the buckling strength for frame structure especially for fixed offshore platform.

It should be noted that the frame structure made by Timoshenko is a typical of frame structure where the vertical brace is perpendicular. Unlike the tripod structure, the structure has a batter so that the jacket legs is sloped, i.e. the jacket has an angle toward the vertical direction. It is shown that the critical buckling load obtained by FE Analysis smaller than analytical solution. However, that the critical buckling load obtained by FE Analysis is in good agreement with the analytical solution based on the table 2. The reduction of the critical buckling load does not exceed more than 5%.

4. CONCLUSION

From the result buckling analysis of the top building deck leg of the jacket structure as a due reduction reactor and effective length, it can be concluded that:

a. In the calculation results of critical buckling load there are differences between the results of manual calculations and using the auxiliary program SAP 2000, the difference because the program takes into account the value of the moment, finite element and the distance between deck leg.
b. From the analyze result the critical buckling load with calculation and using the auxiliary program SAP 2000 of the column between front and side appear of deck leg jacket structure, differences result between both of them is because the length of the deck plate included calculation by the auxiliary program.
c. In the calculation by entering values for the reduction factor and the effective length of the building front and side view result proved fill the value under number 1.

5. REFERENCES

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