The influence of effective length and reduction factor to buckling on jacket brace

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Abstract. The jacket is one of the fixed typical offshore structures consists of many braces located on not only deck legs but also the jacket itself. Those braces play an essential role in supporting the structure locally and globally from internal and external loads such as deck structure, current, and wave loads. The brace length has a significant influence on local buckling of the brace and will affect the global structure so that this influence should be checked. The objective of the present study is to analyze the influence of effective length and reduction factor to buckling of jacket brace, including the reduction factor according to API RP2A. The analysis is conducted using the analytical method, and the result is compared to the numerical method, including the behavior of jacket braces.

1. Introduction

Generally, the type of offshore jacket structure is fixed at the sea bottom. The structure consists of many elements called braces, and those are connected with nodal or joint with one another. The function of braces is to support and withstand the internal and external loads in horizontal and vertical directions. Besides, the brace also must be analyzed due to the length and its influence on buckling or deflection. Therefore, the influence of effective length and reduction factor to buckling of jacket brace must be considered into account for structural strength and safety.

Fixed offshore structures such as jacket, jack-up, and concrete gravity platform have been studied by some researches. Yang [1] conducted the seismic collapse performance of jacket offshore platforms with a time-variant zonal corrosion model. Eldin [2] conducted the sensitivity analysis on the seismic life-cycle cost of a fixed-steel offshore platform structure. The sensitivity analysis was performed using different methods such as tornado diagram analysis, first-order second moment, and Latin hypercube sampling. Guede [3] presented a method for risk assessment and inspection plan development as part of the risk-based structural integrity management of the offshore jacket platform. Muis Alie [4] analyze the effect of symmetrical and unsymmetrical configuration shapes on buckling and fatigue strength analysis of the fixed offshore platform. Two models of the fixed offshore structure were taken to be analyzed with the same dimension but different configuration shapes. The numerical calculation was performed to investigate the buckling and fatigue strength of both structures. Hezarjaribi [5] performed the nonlinear response of jacket-type platforms against extreme waves that were examined utilizing sensitivity analyses. Muis Alie [6] discussed the configuration effect of fixed offshore structure with symmetrical and unsymmetrical shape toward buckling failure. Two kinds of
the offshore structure were analyzed. The numerical analysis was adopted to calculate buckling failure under axial and lateral load.

The objective of the present study is to analyze the influence of the effective length and reduction factor on buckling of jacket brace. The structure is considered in this study is a fixed jacket offshore structure with four legs and symmetric. The analytical method is used, and the result is compared to the numerical method.

2. Methodology
The fixed jacket structure in this study has four legs and symmetric plane in any direction. The structure is fixed at the sea bottom, as shown in figure 1. The section properties between jacket leg and brace are different, but the material properties are constant. The structure is subjected to constant axial load, and it is applied at the point of the jacket leg.

![Figure 1. Fixed jacket structure](image)

Figure 1. Fixed jacket structure
The analytical method is also performed, for the axial load is applied on the jacket leg structure, and it is calculated by using the following formula,

\[ \sigma = \frac{F}{A} \]  

where \( F \) and \( A \) are the axial force and cross sectional area, respectively. The stress-strain is also represented by the following formula,

\[ \sigma = E \varepsilon \]  

The young’s modulus \( E \) and strain \( \varepsilon \) are expressed by the relationship form the Hooke's law. The equation (2) can be modified to obtain the strain as,

\[ \varepsilon = \frac{\sigma}{E} \]  

To obtain the critical buckling load, the expression is used,

\[ P_{cr} = \frac{\pi^2 EI}{(kL)^2} \]  

Where \( I \), \( k \) and \( L \) are the inertia of the cross-section, a constant concerning support condition, and length of the column.

The combined axial stress and bending stress are determined by the following equation considering the influence of the reduction factor. The combined axial and bending stress in equation (5) is called interaction ratio (IR) and the value should be less than 1 [7]. In this case, the reduction factor \( c_m \) may be taken from 0.40 to 0.85.

\[ \frac{f_a}{F_a} + \frac{c_m \sqrt{f_{bx}^2 + f_{by}^2}}{(1 - \frac{f_a}{f_a'}) F_b} \leq 1 \]  

where

\( f_a \) : axial column buckling stress \( \text{(N/m}^2\text{)} \)
\( F_a \) : axial column allowable buckling stress \( \text{(N/m}^2\text{)} \)
\( f_{bx}^2 \) : mayor bending stress \( \text{(N/m}^2\text{)} \)
\( f_{by}^2 \) : minor bending stress \( \text{(N/m}^2\text{)} \)
\( c_m \) : reduction factor
\( F_b \) : allowable bending stress \( \text{(N/m}^2\text{)} \)
3. Results and discussion
The critical buckling load is obtained using equation 4 and the result is compared to the numerical method. The critical buckling load of fixed jacket structure is shown in table 1 as follow,

| Analytical method | Numerical method | Reduction |
|-------------------|------------------|-----------|
| 772279.05         | 811508.65        | 0.952     |

**Table 2. Reduction factor c_m = 0.4**

| Diagonal brace | Results | Interaction Ratio (IR) |
|----------------|---------|------------------------|
| A              | 0.440   | ok                     |
| B              | 0.441   | ok                     |
| C              | 0.431   | ok                     |
| D              | 0.434   | ok                     |

**Table 3. Reduction factor c_m = 0.5**

| Diagonal brace | Results | Interaction Ratio (IR) |
|----------------|---------|------------------------|
| A              | 0.435   | ok                     |
| B              | 0.436   | ok                     |
| C              | 0.424   | ok                     |
| D              | 0.428   | ok                     |

**Table 4. Reduction factor c_m = 0.6**

| Diagonal brace | Results | Interaction Ratio (IR) |
|----------------|---------|------------------------|
| A              | 0.430   | ok                     |
| B              | 0.432   | ok                     |
| C              | 0.417   | ok                     |
| D              | 0.421   | ok                     |

**Table 5. Reduction factor c_m = 0.7**

| Diagonal brace | Results | Interaction Ratio (IR) |
|----------------|---------|------------------------|
| A              | 0.425   | ok                     |
| B              | 0.427   | ok                     |
| C              | 0.410   | ok                     |
| D              | 0.415   | ok                     |
Table 6. Reduction factor $c_m = 0.85$

| Diagonal brace | Results | Interaction Ratio (IR) |
|----------------|---------|------------------------|
| A              | 0.418   | ok                     |
| B              | 0.420   | ok                     |
| C              | 0.400   | ok                     |
| D              | 0.405   | ok                     |

The results of the interaction ratio to reduction factor on jacket braces are summarized in figure 2 as follow:

Figure 2. IR and reduction factor on jacket braces

Figure 2 shows the comparison of the jacket braces A, B, C, and D with respect to interaction ratio, and the reduction factor decreased. The interaction ratio is higher, with a smaller reduction factor. On the other hand, the higher the reduction factor, the smaller the interaction ratio will be.

4. Conclusion
The analysis of jacket braces on fixed offshore structure considering the influence of effective length and reduction factor has been conducted using analytical and numerical methods. It is found that the critical buckling is almost identical obtained by two methods. The effective length and reduction factor have influenced to interaction ratio on jacket braces of fixed offshore structure.

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