The analysis of 2D frame structure subjected to point load

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Abstract. The offshore structure, like the jacket, jack-up, gravity, and tower, can be categorized as a column structure subjected to vertical or horizontal load, i.e., the structure is identical with the frame structure. Those structures may be idealized as a frame structure with axial or lateral loads acting on the braces. The present study focuses on the analysis of the 2D frame structure subjected to point loads. The support conditions are fixed and hinged at the bottom joint. The point loads of 1 Ton are applied at the vertical and horizontal braces of the frame structure. All point loads are applied in the middle of the brace, either on a horizontal brace or vertical brace. The breadth and depth are 1 m and 1 m, respectively. The result obtained by the numerical method for three models is compared in terms of support reactions, joint displacement, and deformation.

1. Introduction

The type of offshore structure like the jacket, jack-up, concrete gravity platform, and tower may be idealized as a column structure subjected to vertical and horizontal loads. The development of the PFCC structures from the component level to structure level, and better accelerate the application of these innovative composite structures in engineering, eleven PCCBCJs under eccentric compression are experimentally and numerically studied by Yu [1] based on the author’s previous researches. A new FBE model for nonlinear analysis of concentrically loaded stub and slender columns was proposed by Lin [2], in which the side effects on the effective stress-strain relationships of steel tube and core concrete were well incorporated. Abouhussien [3] presented the results from an experimental program conducted to assess the cracking behavior of reinforced concrete beam-column connections cast with engineered cementitious composites (ECC). A precast prestressed beam-to-column joint for seismic-resistant RC framed structures was proposed by Wang [4]. To consider the joint transfer mechanisms existing in the common core directly and comprehensively, and to calculate the effects of axial force effectively in each iteration step of numerical simulation, a component-based macro beam-column joint model has been proposed by Zhao [5] on OpenSees platform.

Guede [6] 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 [7] 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. Yang [8] conducted the seismic collapse performance of jacket offshore platforms with a time-variant zonal corrosion model. Eldin [9] 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. The numerical calculation was performed to investigate the buckling and fatigue strength of both structures. Hezarjaribi [10] performed the nonlinear response of jacket-type platforms against extreme waves that were examined utilizing sensitivity analyses. Muis Alie [11] discussed the configuration effect of fixed offshore structure with symmetrical and unsymmetrical shape toward buckling failure. Two kinds of offshore structures 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 a two-dimensional frame structure subjected to eccentric point load on the horizontal and vertical brace. Three models are analyzed with different support conditions. The support conditions are fixed and hinged place at the bottom joint of the frame structure. The analysis is conducted using the numerical method. The result obtained by the numerical method for three models is compared in terms of joint reactions, joint displacements, and deformations.

2. Methodology
The frame structures are illustrated in figure 1 with different support conditions. The support conditions are fixed and hinged. The frame structures consist of three elements and four nodes. It is assumed that the structure is analyzed in the two-dimensional plane. The eccentric point loads are applied in the middle of the horizontal and vertical braces with 1 Ton. Dimensions of frame structure are 1 m and 1 m for depth and breadth respectively and those constant for three models.

![Frame Structure Models](image)

Figure 1. Models of frame structure

3. Results and discussion
There are three models of frame structures that are analyzed in the present study. The frame structures consist of four nodes and three elements. The nodes number is labeled with the circle, while for elements are noted by a rectangular shape. The support conditions are placed at the bottom, as shown in figure 1.

| Joint Text | F1 Ton | F2 Ton | F3 Ton | M1 Ton-m | M2 Ton-m | M3 Ton-m |
|------------|-------|-------|-------|---------|---------|---------|
| 1          | 0.28  | 0     | 0.59  | 0       | 0.14    | 0       |
| 4          | 0.72  | 0     | 0.41  | 0       | 0.27    | 0       |
Table 2. Joint reactions in model 2

| Joint Text | F1 (Ton) | F2 (Ton) | F3 (Ton) | M1 (Ton-m) | M2 (Ton-m) | M3 (Ton-m) |
|------------|----------|----------|----------|------------|------------|------------|
| 1          | 0.51     | 0        | 0.71     | 0          | 0.29       | 0          |
| 2          | 0.49     | 0        | 0.29     | 0          | 0          | 0          |

Table 3. Joint reactions in model 3

| Joint Text | F1 (Ton) | F2 (Ton) | F3 (Ton) | M1 (Ton-m) | M2 (Ton-m) | M3 (Ton-m) |
|------------|----------|----------|----------|------------|------------|------------|
| 1          | 0.35     | 0        | 1        | 0          | 0          | 0          |
| 2          | 0.65     | 0        | -8E-16   | 0          | 0          | 0          |

The eccentric point loads are applied in the middle of the horizontal and vertical braces of the frame structures. The result obtained by the numerical method is presented in terms of support reactions, joint displacements, and deformations of the frame structures. Tables 1, 2, and 3 are expressed the joint reactions at support conditions of the frame structures. It is observed that all support reactions in vertical directions are exits for three models. Also, the displacements of the nodes are summarized in tables 4, 5, and 6, respectively. According to tables 4, 5, and 6, the displacements of nodes are exits for translations of U1, U3, and rotation of R2.

Table 4. Joint displacements in model 1

| Joint Text | U1 (m)     | U2 (m)     | U3 (m)     | R1 (Radians) | R2 (Radians) | R3 (Radians) |
|------------|------------|------------|------------|--------------|--------------|--------------|
| 1          | 0          | 0          | 0          | 0            | 0            | 0            |
| 2          | -3.785E-09 | 0          | -6.907E-10 | 0            | -1.953E-10   | 0            |
| 3          | -4.116E-09 | 0          | -4.82E-10  | 0            | -2.546E-09   | 0            |
| 4          | 0          | 0          | 0          | 0            | 0            | 0            |

Table 5. Joint displacements in model 2

| Joint Text | U1 (m)     | U2 (m)     | U3 (m)     | R1 (Radians) | R2 (Radians) | R3 (Radians) |
|------------|------------|------------|------------|--------------|--------------|--------------|
| 1          | 0          | 0          | 0          | 0            | 0            | 0            |
| 2          | -9.067E-09 | 0          | -1.043E-09 | 0            | -3.229E-09   | 0            |
| 3          | -9.813E-09 | 0          | -4.228E-10 | 0            | -4.21E-09    | 0            |
| 4          | 0          | 0          | 0          | 0            | 0            | 0            |

Table 6. Joint displacements in model 3

| Joint Text | U1 (m)     | U2 (m)     | U3 (m)     | R1 (Radians) | R2 (Radians) | R3 (Radians) |
|------------|------------|------------|------------|--------------|--------------|--------------|
| 1          | 0          | 0          | 0          | 0            | -2.431E-08   | 0            |
| 2          | -2.111E-08 | 0          | -1.466E-09 | 0            | -7.634E-09   | 0            |
| 3          | -2.162E-08 | 0          | 0          | 0            | -9.943E-09   | 0            |
| 4          | 0          | 0          | 0          | 0            | -2.893E-08   | 0            |
Figure 2. Deformations of frame structures

It is found that the displacements of the nodes of the frame structures are small, both translations and rotations. Furthermore, figure 2 shows the deformations of the three models of frame structures. It is observed that the deformation is larger, found in model 3, followed by model 2 and model 1. Models 2 and 3, the deformations are larger than model 1. This is because of the support condition.
where model 1 is completely fixed. It is also found that model 1 deforms mostly in vertical direction compared to in horizontal one.

4. Conclusion
The analysis of frame structures for three models subjected to eccentric point loads in the middle of the braces has been conducted. The following conclusions can be drawn; It is observed that the deformation is larger found in model 3 follow by model 2 and model 1. For models 2 and 3, the deformations are larger than model 1 due to the support condition.

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