Jacketed Offshore Structure Wave Forces, Stress and Displacement Simulation using MATLAB

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Abstract
This study investigates the structural behavior of a jacketed offshore structure subjected to wave loading, focusing on the analysis of nodal forces, displacements, and member stresses. Wave forces were determined using the Morison equation, a widely accepted approach for calculating hydrodynamic loads on slender structures like those found in offshore jackets. The analysis encompasses a detailed examination of pile members, horizontal y-bracing, and diagonal front bracing, considering both the magnitude and distribution of forces and the resulting structural deformations. Key findings reveal significant variations in nodal forces, highlighting areas of high load concentration. Lateral forces on piles, particularly at nodes 2, 4, 7, and 10, reached magnitudes of 5.02e+04 N, emphasizing the importance of considering bending stresses. Axial forces, primarily observed at nodes 5, 8, and 11, peaked at 3.86e+05 N, crucial for assessing pile compressive and tensile capacity. Similar analyses for bracing members identified critical force magnitudes and distributions, with maximum values observed in members 13, 14, 15, and 18. Displacement analysis revealed that while deformations remained relatively small, specific locations, such as members 6, 7, and 13, experienced more pronounced movement. Stress analysis further pinpointed critical members, notably piles 6 and 7, as well as bracing members 13, 14, 15, and 18, where stress concentrations necessitate careful design considerations. These findings underscore the complex interplay of wave forces and structural response in offshore jacket platforms, emphasizing the need for comprehensive analysis to ensure structural integrity and operational safety. The study demonstrates the effectiveness of the Morison equation in predicting wave loads and its importance in the broader structural assessment of offshore structures.

Keywords: *Jacketed Offshore Structure, Wave Force, Nodal Displacement, Member Stress, Morison's Equation, Pile Members, Horizontal Y Bracing Members and Diagonal Front Bracing Members*

I. INTRODUCTION

Jacketed offshore structures are critical components in the development and operation of offshore energy systems, including oil and gas platforms and renewable energy installations. These structures, characterized by their lattice framework, are designed to withstand harsh marine environments, including waves, wind, and currents, while supporting heavy topside loads. The structural integrity and stability of these jacketed frameworks are pivotal to the safety, reliability, and efficiency of offshore operations [1].

Accurate calculation of forces, stress, and displacement in jacketed offshore structures is essential to ensure their performance under diverse loading conditions. These calculations involve understanding the interaction between environmental forces and the structure's response, accounting for material properties, geometric configurations, and boundary conditions. Advanced computational methods, such as those implemented in MATLAB, offer powerful tools to analyze and simulate these dynamics [2].

MATLAB, with its versatile computational capabilities, provides a robust platform for modeling and analyzing the behavior of offshore structures. By employing numerical methods, engineers can calculate hydrodynamic forces, evaluate stress distributions, and predict structural displacements under static and dynamic loading. This approach enables the optimization of design parameters, ensuring that the structure can endure extreme environmental conditions while maintaining structural efficiency [3].

This study focuses on leveraging MATLAB to perform force, stress, and displacement calculations for jacketed offshore structures. It explores the application of numerical methods, including finite element analysis (FEA) and hydrodynamic simulations, to provide accurate and efficient solutions. Through this approach, the research aims to contribute to the advancement of design methodologies for offshore structures, ensuring their resilience and sustainability in demanding marine environments [4].

II. LITERATURE REVIEW

The structural integrity of jacketed offshore structures is crucial for their long-term functionality in harsh marine environments. These structures are exposed to complex combinations of static and dynamic loads, including wave, wind, current, and operational loads, which induce forces, stresses, and displacements in their members. Failures in these structures often result from excessive stress, deformation, or fatigue, making the analysis of these factors pivotal in design and maintenance.

Stress and displacement are the primary metrics used to evaluate the performance and failure risks of structural members. According to Bhattacharyya [3], jacketed structures are particularly susceptible to axial and bending stresses induced by environmental loads. When these stresses exceed material yield strength, localized failures occur, potentially propagating through the structure. Finite Element Analysis (FEA) has been widely employed to predict stress concentrations and member displacement, providing insights into failure mechanisms and mitigation strategies.

[1] emphasizes the importance of accounting for both material and geometric nonlinearities in stress and displacement calculations, as these nonlinearities often exacerbate failure risks under extreme loading scenarios. Additionally, hydrodynamic interactions between the structure and the surrounding fluid can significantly influence stress distribution, particularly in slender members.

Cyclic loading from waves and operational activities often leads to fatigue in structural members. Fatigue failure is one of the most common causes of offshore structural member failures. [5] highlight that high-stress concentration regions, such as joints and welds, are particularly vulnerable. Advanced fatigue analysis tools, integrated with MATLAB and FEA software, are now being used to predict fatigue life and optimize member design.

Displacement-induced failures, often resulting from excessive deflections, can compromise the alignment and stability of offshore structures. According to [4], displacement limits are often prescribed in offshore design standards to ensure structural stability under operational and extreme conditions. Excessive displacement can lead to misalignment, functional failure of connected systems, and increased vulnerability to wave-induced loads.

MATLAB's ability to integrate hydrodynamic, structural, and fatigue analysis makes it an invaluable tool for studying member failures. MATLAB-based simulations have been used to model dynamic responses of jacket structures under combined wave and wind loads. These simulations provide detailed insights into displacement patterns and stress concentrations, enabling engineers to identify and mitigate failure risks [2].

Case studies have highlighted the importance of stress and displacement analysis in failure prevention. For example, the collapse of the Alexander L. Kielland platform in 1980 revealed the devastating consequences of fatigue failure in a single bracing member, which led to a chain reaction of failures across the structure [6]. These incidents underscore the importance of robust stress, displacement, and fatigue analysis in the design and maintenance of offshore structures.

International standards, such as those published by [4] and API (American Petroleum Institute), provide comprehensive guidelines for assessing stress and displacement in offshore structures. These standards emphasize the use of advanced numerical methods and tools, such as MATLAB and FEA, for ensuring compliance and reliability.

III. METHODOLOGY

Horizontal Bracing Members:

Horizontal bracing plays a crucial role in distributing lateral loads and minimizing excessive displacement. The stress distribution in these members is influenced by wave and current forces acting perpendicular to the structure. Properly designed horizontal bracing ensures that the jacketed structure remains stable under fluctuating environmental loads, reducing excessive lateral sway and structural fatigue.

Diagonal Front Bracing Members:

Diagonal bracing members contribute significantly to overall stiffness by resisting shear forces and improving load distribution. These members counteract the torsional effects caused by wave forces and dynamic loading conditions. The analysis reveals that these components experience substantial axial stresses, which must be accounted for to prevent buckling and fatigue failure.

The detailed of equations use in this paper can be gotten from previous published work [7], though a separate language (JAVA) was use as opposed to MATLAB language utilize in this paper work. Readers that are interested in the formation of the methodology should get a copy of the previous work online. The equations (1-3) shown below are only for the global displacement and stress determination while the local forces, displacement and stress analysis can be gotten from [7].

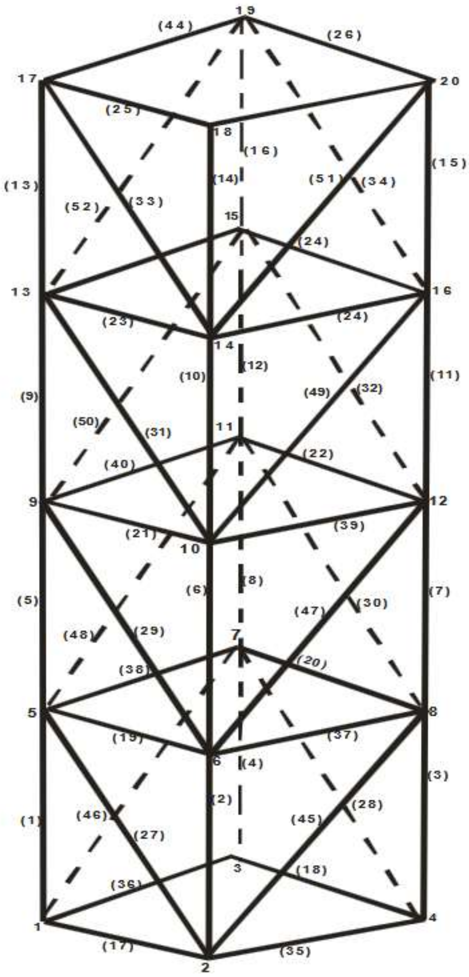

Figure 1: Jacketed Offshore Structure as use in [7]

$$\begin{Bmatrix} F_{xn} \\ F_{yn} \\ F_{zn} \\ F_{xn} \\ F_{yn} \\ F_{zn} \end{Bmatrix} = \frac{E \times A}{L} \times \begin{bmatrix} {C_x}^2 & C_x \times C_y & C_x \times C_z & -{C_x}^2 & -C_x \times C_y & -C_x \times C_z \\ C_x \times C_y & {C_y}^2 & C_y \times C_z & -C_x \times C_y & -{C_y}^2 & -C_y \times C_z \\ C_x \times C_z & C_y \times C_z & {C_z}^2 & -C_x \times C_z & -C_y \times C_z & -{C_z}^2 \\ -{C_x}^2 & -C_x \times C_y & -C_x \times C_z & {C_x}^2 & C_x \times C_y & C_x \times C_z \\ -C_x \times C_y & -{C_y}^2 & -C_y \times C_z & C_x \times C_y & {C_y}^2 & C_y \times C_z \\ -C_x \times C_z & -C_y \times C_z & -{C_z}^2 & C_x \times C_z & C_y \times C_z & {C_z}^2 \end{bmatrix} \times \begin{Bmatrix} \dot{x}_n \\ \dot{y}_n \\ z_n \\ \dot{x}_n \\ \dot{y}_n \\ \dot{z}_n \end{Bmatrix} 1$$

$$\sigma_m = \frac{E}{L} \times \{C_x \quad C_y \quad C_z \quad -C_x \quad -C_y \quad -C_z\} \times \begin{Bmatrix} \dot{x}_n \\ \dot{y}_n \\ \dot{z}_n \\ \dot{x}_n \\ \dot{y}_n \\ \dot{z}_n \end{Bmatrix} \qquad (2)$$

$$\sigma_m = \frac{E}{L} \times [(C_x \times \dot{x}_n) + (C_y \times \dot{y}_n) + (C_z \times \dot{z}_n) + (-C_x \times \dot{x}_n) + (-C_y \times \dot{y}_n) + (-C_z \times \dot{z}_n)] 3$$

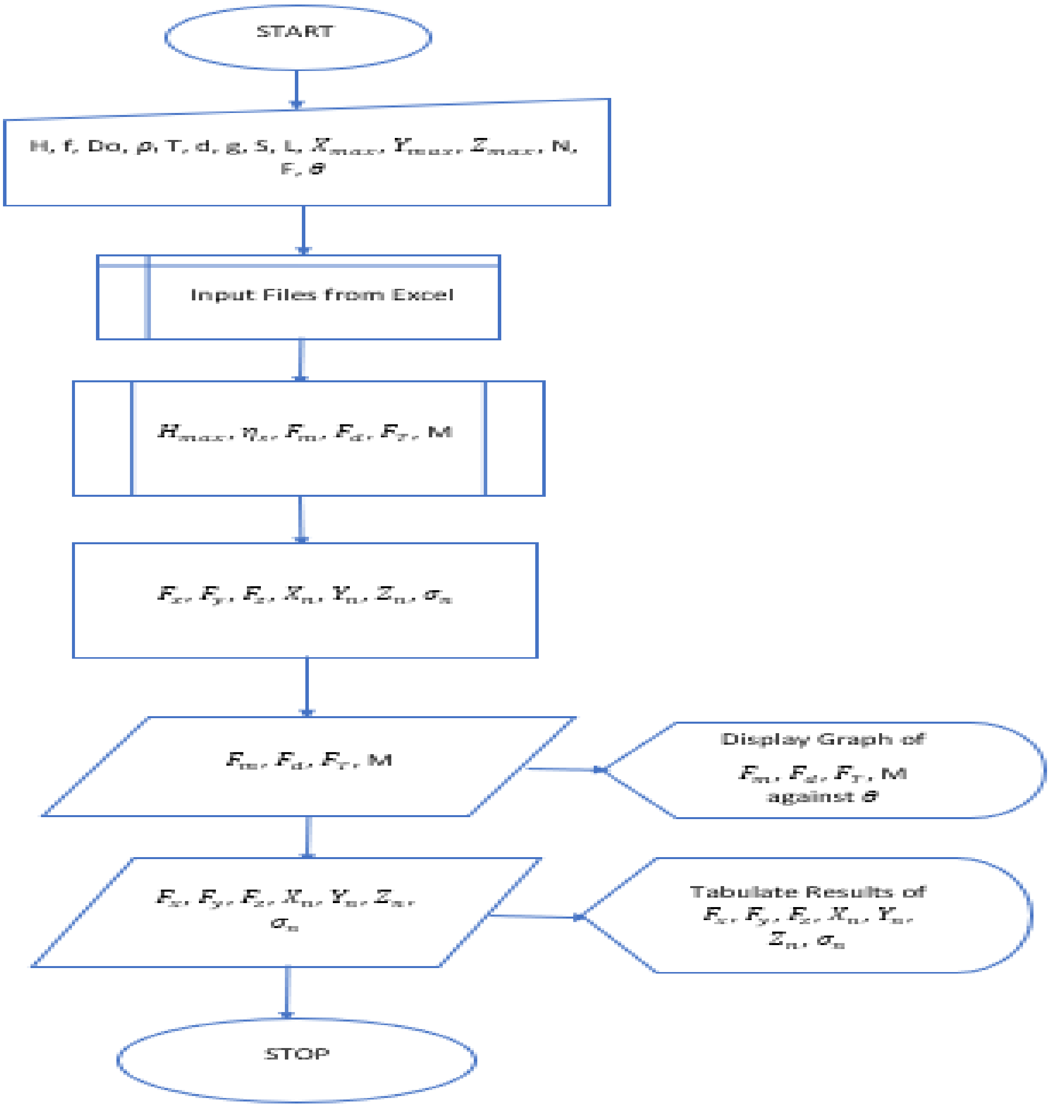

Figure 2: Flowchart of Jacketed Structure, Displacement and Stress

IV. RESULTS

Rresultspileforce =

Memberpile	Nodalpi	Pile_memberxi	Pile_memberyi	Pile_memberzi	Nodalpj	Pile_memberxj	Pile_memberyj	Pile_memberzj
1	1	0	0	-45578	2	0	0	-1.2629e+05
2	4	50175	0	-50175	5	1.1558e+05	0	-1.1558e+05
3	7	50175	0	-50175	8	1.1558e+05	0	-1.1558e+05
4	10	0	0	-45578	11	0	0	-1.2629e+05
5	2	0	0	-3.8122e+05	3	0	0	-2.0361e+05
6	5	3.8611e+05	0	-3.8611e+05	6	2.0455e+05	0	-2.0455e+05
7	8	3.8611e+05	0	-3.8611e+05	9	2.0455e+05	0	-2.0455e+05
8	11	0	0	-3.8122e+05	12	0	0	-2.0361e+05

Table 1: Pile Members Nodal Point Forces

The pile nodal forces presented in the Table 1 represent the forces acting at the ends (i and j) of each pile member in a jacketed offshore structure. These forces are distributed in three directions: x, y, and z, corresponding to lateral and axial components. In the x and y directions, nodes such as 2, 4, 7, and 10 show significant forces, with magnitudes reaching up to **5.02e+04 N** (50.2 kN). These forces likely arise from lateral wave and current loads acting on the piles, which can induce bending stresses. High bending stresses are critical as they often govern the structural design, potentially leading to failure if not adequately considered.

In the z direction, nodes 5, 8, and 11 exhibit the highest axial forces, with magnitudes around **3.86e+05 N** (385.1 kN). These forces are primarily due to vertical loads, such as the weight of the structure and the effects of hydrodynamic pressure from waves and currents. Axial forces are crucial in evaluating the capacity of the piles to withstand compression or tension without buckling or yielding.

The differences in force magnitudes between nodes and directions highlight the varying load distribution across the pile members. Lateral forces are generally lower than axial forces, but their impact on bending and potential pile deflection must not be overlooked. The critical values observed, particularly in the z direction, indicate areas of high stress concentration and possible failure risks if the pile capacities are exceeded. Understanding these forces is essential for assessing the overall stability and safety of the offshore structure.

Rresultshorizontalforce =

Memberhy	Nodalhi	hy_bracingxi	hy_bracingyi	hy_bracingzi	Nodalhj	hy_bracingxj	hy_bracingyj	hy_bracingzj
9	1	-4423.4	4423.4	4423.4	7	0	0	4423.4
10	4	0	4397.4	4397.4	10	-4397.4	0	4397.4
11	2	-6089	6089	6089	8	0	0	6089
12	5	0	5935.8	5935.8	11	-5935.8	0	5935.8
13	3	-8020.5	8020.5	8020.5	9	0	0	8020.5
14	6	0	7769.5	7769.5	12	-7769.5	0	7769.5

Table 2: Horizontal y Bracing Members Nodal Point Forces

Table 2 shows the horizontal forces acting on the y-bracings of a jacketed offshore structure at different nodes. The forces are distributed in three directions (x, y, and z), and values are provided for both ends (i and j) of each member. Significant forces are observed in the x-direction for members 13 and 14, with magnitudes of **-8020.5 N** and **-7769.5 N**, respectively. These forces represent lateral loading, likely induced by waves or currents acting on the horizontal bracings. Such forces contribute to bending stresses within the members, which are critical to their structural performance.

In the z-direction, notable forces include **4423.4 N** for member 9 and **5935.8 N** for member 12. These forces are vertical components and may arise from the coupling of environmental loads with the weight of the structure or hydrodynamic pressures. Vertical forces are essential in determining axial loads in the bracing members and ensuring that they remain within allowable limits to prevent buckling or material yielding.

The largest force magnitude occurs in member 13, indicating a potentially critical region in the structure that requires careful evaluation to ensure it can handle the imposed loading. Understanding the distribution and magnitude of these forces is vital for assessing the structural integrity of the bracings and optimizing their design for the harsh offshore environment.

Rresultsdia_Frontforce =

Memberdf	Nodaldi	dia_frontxi	dia_frontyi	dia_frontzi	Nodaldj	dia_frontxj	dia_frontyj	dia_frontzj
15	1	-17000	17000	24041	5	32769	-32769	46342
16	7	17000	-17000	24041	11	32769	-32769	46342
17	2	-18816	18816	26610	6	29126	-29126	41191
18	8	18816	-18816	26610	12	29126	-29126	41191

Table 3: Diagonal Front Bracing Members Nodal Forces

Table 3 represents the forces acting on the diagonal front members of the offshore jacketed structure at the i and j ends of each member in the x, y, and z directions. These forces are critical for assessing the structural response to loads distributed along the diagonal bracings. In the x-direction, forces at the j ends of the members reach significant magnitudes, with **32,769 N** for members 15 and 16 and **29,126 N** for members 17 and 18. These values suggest the presence of substantial horizontal forces, likely induced by wave or wind loads acting on the diagonal front bracings. Such forces are important contributors to bending stresses in these members.

In the y-direction, the diagonal front members also experience notable forces, with values such as **24,041 N** at both the i and j ends of members 15 and 16. These lateral forces may result from hydrodynamic loads or structural deformation under environmental pressures. In the z-direction, the highest forces are observed for members 15 and 16, with magnitudes of **46,342 N** at the j ends. These vertical forces likely result from the combined effects of axial loading due to the weight of the structure and hydrodynamic pressures. For members 17 and 18, the z-direction forces are slightly lower, with values around **41,191 N**, but they remain significant and could contribute to potential axial compression or tension in the diagonal bracings. The highest magnitude force, **46,342 N**, in the z-direction for members 15 and 16, indicates a critical area where structural performance must be carefully evaluated to avoid failures. These diagonal forces play a key role in maintaining the integrity of the jacket structure and must be considered in design and analysis for resilience under extreme loading conditions.

Rresultspiledisp =

Memberpile	Nodalpi	Pile_memberdxi	Pile_memberdyi	Pile_memberdzi	Nodalpj	Pile_memberdxj	Pile_memberdyj	Pile_memberdzj
1	1	0	0	-2.681e-05	2	0	0	-7.4286e-05
2	4	2.9515e-05	0	-2.9515e-05	5	6.7986e-05	0	-6.7986e-05
3	7	2.9515e-05	0	-2.9515e-05	8	6.7986e-05	0	-6.7986e-05
4	10	0	0	-2.681e-05	11	0	0	-7.4286e-05
5	2	0	0	-0.00022425	3	0	0	-0.00011977
6	5	0.00022712	0	-0.00022712	6	0.00012033	0	-0.00012033
7	8	0.00022712	0	-0.00022712	9	0.00012033	0	-0.00012033
8	11	0	0	-0.00022425	12	0	0	-0.00011977

Table 4: Pile Member Nodal Point Displacement

Table 4 presents the nodal displacements of pile members in a jacketed offshore structure, showing displacements in the x, y, and z directions at the i and j ends of each member. These displacements are key indicators of structural deformation under applied loads and provide insights into the structural behavior and potential failure risks.

In the x-direction, displacements are observed for members 2 and 3 at the i end, with values of **2.9515e-05 m**, and for members 6 and 7, with higher values around **0.00022712 m**. At the j end, displacements are slightly higher for members 6 and 7, reaching **0.00012033 m**. These values indicate relatively small lateral deformations, suggesting that the structure maintains stability under horizontal loads.

In the z-direction, critical displacements occur at the j ends of members 6 and 7, with values of **-0.00011977 m**. This indicates vertical deformation due to axial loads, which could be caused by a combination of structural weight and environmental pressures. The smaller values, such as **-2.681e-05 m** for members 1 and 4, suggest minimal vertical displacement at those points.

The largest displacement is observed in the x-direction for members 6 and 7 at the i end, with a magnitude of **0.00022712 m**. While the displacements are small, they represent critical points in the structure where deformation is relatively higher and may require closer monitoring to ensure the structural performance remains within acceptable limits. Understanding these displacements is crucial for assessing the integrity of the piles and their ability to resist applied forces.

Rresultshorizontaldisp =

Memberhy	Nodalhi	hy_bracingdxi	hy_bracingdyi	hy_bracingdzi	Nodalhj	hy_bracingdxj	hy_bracingdyj	hy_bracingdzj
9	1	-2.0106e-06	2.0106e-06	2.0106e-06	7	0	0	2.0106e-06
10	4	0	1.9988e-06	1.9988e-06	10	-1.9988e-06	0	1.9988e-06
11	2	-2.7677e-06	2.7677e-06	2.7677e-06	8	0	0	2.7677e-06
12	5	0	2.6981e-06	2.6981e-06	11	-2.6981e-06	0	2.6981e-06
13	3	-3.6457e-06	3.6457e-06	3.6457e-06	9	0	0	3.6457e-06
14	6	0	3.5316e-06	3.5316e-06	12	-3.5316e-06	0	3.5316e-06

Table 5: Horizontal-y Bracing Member Nodal Point Displacement

Table 5 provides the nodal displacements for horizontal y-bracing members of a jacketed offshore structure, showing displacements in the x, y, and z directions at the i and j ends of each member. These displacements are critical for assessing the structural behavior under lateral and vertical loads. In the x-direction, the highest displacements are observed for member 13 at the i end, with a value of -3.6457e-06 m, and at the j end, with a value of -3.5316e-06 m for member 14. These values indicate minor lateral deformations, likely caused by horizontal wave and wind forces acting on the structure.

In the y-direction, displacements remain symmetric across members, with notable values such as 2.7677e-06 m for member 11 at the i end and 3.6457e-06 m for member 13. These values indicate slight lateral deformations due to environmental loads distributed along the y-bracing members. In the z-direction, the displacements are consistent across nodes, with maximum values of 3.6457e-06 m for member 13 and 3.5316e-06 m for member 14. These deformations arise from the vertical components of wave and structural loads and are relatively small compared to typical structural tolerances.

Overall, the largest displacement occurs for member 13 in the x-direction at the i end, with a value of -3.6457e-06 m, indicating the most critical region of deformation. Although these displacements are minor, they provide valuable insights into how the horizontal y-bracings respond to lateral and vertical loading. Proper evaluation ensures that deformations remain within acceptable limits for operational safety and structural integrity.

RresultsDia_Frontdisp =

Memberdf	Nodaldi	dia_frontdxi	dia_frontdyi	dia_frontdzi	Nodaldj	dia_frontdxj	dia_frontdyj	dia_frontdzj
15	1	-2.1118e-05	2.1118e-05	2.9866e-05	5	4.0707e-05	-4.0707e-05	5.7569e-05
16	7	2.1118e-05	-2.1118e-05	2.9866e-05	11	4.0707e-05	-4.0707e-05	5.7569e-05
17	2	-2.3374e-05	2.3374e-05	3.3056e-05	6	3.6183e-05	-3.6183e-05	5.117e-05
18	8	2.3374e-05	-2.3374e-05	3.3056e-05	12	3.6183e-05	-3.6183e-05	5.117e-05

Table 6: Diagonal Front Bracing Member Nodal Point Displacement

The diagonal front bracing member nodal point displacement results in Table 6 indicate how the structure deforms under applied wave forces. The displacement values at different nodes show variations in movement along the x, y, and z axes, which are critical in assessing structural stability. At Node 1, the displacement components are −2.1118×10−^5 in the x-direction, 2.1118×10−^5 in the y-direction, and 2.9866×10−^5 in the z-direction. A similar pattern is observed at Node 7, but with opposite signs in x and y, indicating a symmetric displacement response.

Nodes 5 and 11 exhibit the highest displacement in the x and y directions, reaching 4.0707×10−^5 and −4.0707×10−^5 respectively, while their z-direction displacements peak at 5.7569×10−^5. These values suggest that these nodal points experience the most significant movement, likely due to the combined effects of axial and lateral forces. Nodes 6 and 12 display somewhat lower displacement magnitudes in comparison, with values in the range of 3.6183×10−^5 for x and y directions, while their z-displacements reach 5.117×10−^5. This variation in nodal displacement suggests that while the diagonal front bracing members effectively distribute the wave-induced forces, certain nodes experience higher deformations, which could indicate areas of increased stress concentration.

Overall, the displacement pattern suggests that the diagonal front bracing members contribute significantly to the overall stability of the jacketed offshore structure by resisting lateral forces. However, the critical values observed at Nodes 5 and 11 indicate potential points of concern, where reinforcement or design adjustments may be necessary to ensure structural integrity under extreme wave conditions.

RresultspileStress =

Memberpile	Pile_memberSTp
1	-2.681e+05
2	-5.903e+05
3	-5.903e+05
4	-2.681e+05
5	-2.2425e+06
6	-4.5425e+06
7	-4.5425e+06
8	-2.2425e+06

Table 7: Pile Member Stresses

The pile member stress results for the jacketed offshore structure indicate variations in loading experienced by different members. The stress values, measured in Pascals (Pa), range from -2.681 × 10^5 Pa to -4.542 × 10^6 Pa, showing significant differences in force distribution across the pile elements. The least stressed pile members are Members 1 and 4, each experiencing -2.681 × 10^5 Pa, while Members 2 and 3 experience slightly higher stress values of -5.903 × 10^5 Pa. The most critical stress values are observed in Members 6 and 7, which undergo the highest compression with stresses reaching -4.542 × 10^6 Pa, followed closely by Members 5 and 8, each with -2.242 × 10^6 Pa.

These stress values indicate that certain pile members are subjected to significantly higher loads, particularly those deeper in the structure or exposed to greater hydrodynamic forces. The high stress concentration in Members 6 and 7 suggests potential areas of structural vulnerability that require careful design consideration and reinforcement to prevent material fatigue or failure. Proper assessment of these stress distributions ensures the structural integrity and long-term stability of the jacketed offshore platform.

RresultshorizontalmemberStress =

Memberhy	hy_bracingSTh
9	40213
10	-39977
11	55355
12	-53962
13	72914
14	-70631

Table 8: Horizontal-y Bracing Member Stresses

Table 8 presents stress results for different members within a horizontal bracing y members, of an offshore structure. The values represent the stress experienced by each member, numbered 9 through 14. Looking at the data, we can see a considerable range in stress values, both positive and negative. Positive values indicate tensile stress, meaning the member is being pulled or stretched, while negative values denote compressive stress, where the member is being pushed or compressed. The magnitudes of these stresses vary significantly, suggesting that different members are carrying different loads within the bracing system. For instance, member 13 experiences the highest tensile stress at 72,914, while member 14 is subjected to the largest compressive stress at -70,631.

The variation in stress magnitude and sign is crucial for understanding the behavior of the horizontal y bracing members. It implies a complex distribution of forces within the structure. Some members are primarily acting in tension, helping to resist pulling forces, while others are primarily in compression, resisting squashing forces. This distribution is essential for the overall stability and load-carrying capacity of the structure. The relatively high stress values, particularly those exceeding 70,000, suggest these members are under significant load.

RresultsDia_FrontmemberStress =

Memberdf	dia_frontSTd
15	-4.2299e+05
16	3.052e+05
17	-2.7658e+05
18	3.7068e+05

Table 9: Diagonal Front Bracing Member Stresses

Table 9 presents stress data for diagonal front members, numbered 15 through 18, forming part of a bracing system in a larger structure, for jacketed offshore structure shown in Figure 1. The values shown represent the stress experienced by each member, with both positive and negative values indicating tensile and compressive stresses, respectively. Member 15 experiences the highest compressive stress at -4.2299e+05, while member 18 is subjected to the highest tensile stress of 3.7068e+05. The other members also exhibit significant stress magnitudes, though not as extreme.

The variation in both the magnitude and sign of the stresses across these members suggests a complex distribution of forces within the bracing system. This is typical in such structures, where different members play varying roles in resisting loads. Some members are primarily under tension, effectively being pulled, while others are primarily under compression, being pushed together. Understanding this distribution is crucial for assessing the overall stability and strength of the structure. The data indicates that these diagonal members are significantly loaded, and this load distribution plays a key role in the overall structural behavior.

V. CONCLUSION

In conclusion, the comprehensive analysis of nodal forces, displacements, and stresses across various structural elements of the jacketed offshore structure reveals critical insights into its structural behavior under applied loads. The pile nodal force analysis highlighted significant lateral and axial forces, particularly at nodes 2, 4, 7, 10, 5, 8, and 11, emphasizing the importance of considering both bending and axial stresses in pile design. Similarly, the horizontal y-bracing analysis identified substantial forces in members 9, 12, 13, and 14, reinforcing the need to understand load distribution for optimal bracing design. The diagonal front member analysis further underscored this point, revealing large forces in members 15, 16, 17, and 18, which contribute significantly to the structure's overall stability. Displacement analysis for both piles and y-bracings confirmed relatively small deformations, but identified critical locations like members 6, 7, and 13 where deformation is more pronounced, requiring careful monitoring. Stress analysis of the piles pinpointed members 6 and 7 as experiencing the highest compressive stresses, highlighting potential vulnerability. Finally, stress analysis of the horizontal y-bracing and diagonal front members revealed a complex interplay of tensile and compressive forces, with maximum stress values observed in members 13, 14, 15, and 18, demanding thorough evaluation. Taken together, these results emphasize the complex load paths and stress concentrations within the offshore structure. The identified critical members and nodes require detailed scrutiny in design and fabrication to ensure the long-term integrity, stability, and safety of the jacketed offshore platform under harsh environmental conditions. Further investigation, including fatigue and buckling analyses, is recommended to fully characterize the structural response and ensure robust performance throughout the structure's operational life.

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MATLAB CODE

```
%% FATIGUE FAILURE ASSESSMENT OF JACK UP DRILLING RIG
clc;
clear all;
Hs=7.5;
T=15;
d=50;
D=1.8;
g=9.81;
S=1025;
E=200*10^9;
Hmax=1.85*Hs;
L=g/(2*pi)*T^2;

if (d/L)>0.5
disp('Deep Water')
   Ln=L;
elseif (d/L)<=0.5 && (d/L)>=0.05
disp('Transitional Water')
elseif (d/L)<0.05
disp('shallow Water')
end
i=2;
   L0(i-1)=L;
   L0(i)=g*(T^2)/(2*pi)*tanh(2*pi*d/L0(i-1));
   Ln=L0(i);
while(abs((L0(i)-L0(i-1))/L0(i))*100)>0.1
i=i+1;
        L0(i)=g*(T^2)/(2*pi)*tanh(2*pi*d/L0(i-1));
        Ln=L0(i);
end
disp(Ln)
k=(2*pi)/Ln;
w=sqrt(g*k*tanh(k*d));
t= sqrt((2*pi*Ln)/g);
Umax=(Hmax*T*g)/(2*Ln);
Kc=(Umax*T)/D;
Re =(Umax*D)/S;
if Kc>25 &&Re>1.5*10^6
  Cm=1.8, Cd=0.62
elseif Kc>25 && 10^5<Re<1.5*10^6
   Cm=1.8, Cd=0.4
elseif (5<Kc) && (Kc<25) &&Re>1.5*10^6
  Cm=1.8, Cd=0.62
elseif Kc<5
  Cm=2.0, Cd=0
end
```

```
%% Total Forces on the Jacketed Structures
O= 0:5:720;%linspace(0,360,(360/30)+1);
A1=(pi*D)/(4*Hmax);
A2=((2*k*d)+(sinh(2*k*d) ))/(16*(sinh(k*d))^2 );
A3=(pi*D*1+(k*d*sinh(k*d))-cosh(k*d))/(4*Hmax*sinh(k*d));
A4=((2*k^2*d^2 )+(2*k*d*sinh(2*k*d))+1-cosh(2*k*d))/(64*(sinh(k*d))^2);
Fm=(D*pi*S*(Hmax)^2*Ln)/T^2 *A1*Cm.*sind(O);
Fd=(D*pi*S*(Hmax)^2*Ln)/T^2*(A2*Cd.*abs(cosd(O)).*cosd(O));
FT=Fm+Fd;
figure(1)
plot(O,Fm)
title('Inertia Force on Jecketed Structure Against Phase Angle');
ylabel('Inertia Forces_1 [N]');
xlabel('Phase Angle [Degree]');
figure(2)
plot(O,Fd)
title('Drag Force on Jecketed Structure Against Phase Angle');
ylabel('Drag Forces_1 [N]');
xlabel('Phase Angle [Degree]');
figure(3)
plot(O,FT)
title('Total Force on Jecketed Structure Against Phase Angle');
ylabel('Total Forces_1 [N]');
xlabel('Phase Angle [Degree]');
%% Pile Member Force computation
pile_member=[20,1.8,1.6,90,180,0,1,2,0,20,0,0,1;20,1.8,1.6,180,180,0,4,5,0,20,10,10,2;20,1.8,1.6,180,180,0,7,8,0,20,10,10,3;20,1.8,1.6,90,180,0,10,11,0,20,0,0,4;20,1.8,1.6,90,180,0,2,3,20,30,0,0,5;20,1.8,1.6,180,180,0,5,6,20,30,10,10,6;20,1.8,1.6,180,180,0,8,9,20,30,10,10,7;20,1.8,1.6,90,180,0,11,12,20,30,0,0,8];

xi = pile_member(:,11);
xj = pile_member(:,12);
Fpt=zeros(6,6);
di= pile_member(:,9);
dj= pile_member(:,10);
Nodalpi=pile_member(:,7);
Nodalpj=pile_member(:,8);
Memberpile=pile_member(:,13);
zi=(k*xi)-(w*t);
zj=(k*xj)-(w*t);
  Op=180;
  Do=2.0;
A11i=sinh(k*(di+zi))/(2*k*sinh(k*di));
A11j=sinh(k*(dj+zj))/(2*k*sinh(k*dj));
A22i=(2*k*(di+zi)+sinh(2*di.*(di+zi)))./(32*(sinh(k*di)).^2);
A22j=(2*k*(dj+zj)+sin(2*dj.*(dj+zj))).(32*(cosh(k*dj)).^2);
```

```
Fmpi=Cm*S*(pi*(Do)^2)/4*Hmax*w^2*A11i*sin(Op);
Fmpj=Cm*S*(pi*(Do)^2)/4*Hmax*w^2*A11j*sin(Op);
% Op is the Pile member angle Column D, E and F
Fdpi=(Cd*S*Do*w^2*(Hmax)^2)/k*A22i*abs(cos(Op))*cos(Op);
Fdpj=(Cd*S*Do*w^2*(Hmax)^2)/k*A22j*abs(cos(Op))*cos(Op);
FTpzzi=Fmpi+Fmpj;
FTpzi=FTpzzi(:,5);
% member angles of vriousoritenttion
Oxi = pile_member(:,4);
Oyi = pile_member(:,5);
Ozi = pile_member(:,6);
FTpxi=cosd(Oxi).*FTpzi;
FTpyi=sind(Oyi).*FTpzi;
Fmpjj=Fmpj(:,5);
FTpzj=(Fmpjj+Fdpj);
FTpxj=cosd(Oxi).*FTpzj;
FTpyj=sind(Oyi).*FTpzj;
Lp = pile_member(:,1);
Do = pile_member(:,2);
Di = pile_member(:,3);
Ap=(Do.^2-Di.^2)./4;
dispxi=(FTpxi.*Lp)./(E.*Ap);
dispyi=(FTpyi.*Lp)./(E.*Ap);
dispzi=(FTpzi.*Lp)./(E.*Ap);
dispxj=(FTpxj.*Lp)./(E.*Ap);
dispyj=(FTpyj.*Lp)./(E.*Ap);
dispzj=(FTpzj.*Lp)./(E.*Ap);
Ox = pile_member(:,4);
Oy = pile_member(:,5);
Oz = pile_member(:,6);
Cxpi=cosd(Ox);
Cypi=cosd(Oy);
Czpi=cosd(Oz);
Cxpj=sind(Ox);
Cypj=sind(Oy);
Czpj=sind(Oz);
STpm=(E./Lp).*((Cxpi.*dispxi)+(Cypi.*dispyi)+(Czpi.*dispzi)+(-Cxpj.*dispxj)+(-
Cypj.*dispyj)+(-Czpj.*dispzj));

% Pile Force Tabulated Results
Pile_memberxi=FTpxi;
Pile_memberyi=FTpyi;
Pile_memberzi=FTpzi;
Pile_memberxj=FTpxj;
Pile_memberyj=FTpyj;
Pile_memberzj=FTpzj;
```

```
Rresultspileforce=table(Memberpile,Nodalpi,Pile_memberxi,Pile_memberyi,Pile_memberzi,
Nodalpj,Pile_memberxj,Pile_memberyj,Pile_memberzj)
% Pile Nodal Displacement Tabulated Results
Pile_memberdxi=dispxi;
Pile_memberdyi=dispyi;
Pile_memberdzi=dispzi;
Pile_memberdxj=dispxj;
Pile_memberdyj=dispyj;
Pile_memberdzj=dispzj;
Rresultspiledisp=table(Memberpile,Nodalpi,Pile_memberdxi,Pile_memberdyi,Pile_memberd
zi,Nodalpj,Pile_memberdxj,Pile_memberdyj,Pile_memberdzj)
% Pile Member Stresses Tabulated Results
Pile_memberSTp=STpm;
RresultspileStress=table(Memberpile,Pile_memberSTp)
%% Horizontal Y Bracing Member
hy_bracing=[10,1.2,1,180,0,90,1,7,0,0,0,0,9;10,1.2,1,270,0,90,4,10,0,0,10,10,10;10,1.2,1,180
,0,90,2,8,20,20,0,0,11;10,1.2,1,270,0,90,5,11,20,20,10,10,12;10,1.2,1,180,0,90,3,9,30,30,0,0,
13;10,1.2,1,270,0,90,6,12,30,30,10,10,14];

xhi =hy_bracing(:,11);
xhj =hy_bracing(:,12);
Doh=hy_bracing(:,2);
Ch=Cd*S.*Doh./2;
Ka=Cm*S*(pi.*Doh)./4;
OHi=(k.*xhi)-(w*t);
OHj=(k.*xhj)-(w*t);
% is x first value from reference point corresponding to first nodal point Column K
zHi = Hmax/2*cos(OHi);
zHj = Hmax/2*cos(OHj);
dhi = hy_bracing(:,9);
dhj = hy_bracing(:,10);
Oxhi = hy_bracing(:,4);
Oyhi = hy_bracing(:,5);
Ozhi = hy_bracing(:,6);
Nodalhi=hy_bracing(:,7);
Nodalhj=hy_bracing(:,8);
Memberhy=hy_bracing(:,13);
% OH is the Horizontal y bracing member angle Column D, E and F
Vxhi=(pi*Hmax)/T*cosh(k*(dhi+zHi))/sinh(k*dhi)*cos(OHi);
Vzhi=(pi*Hmax)/T*sinh(k*(dhi+zHi))/sinh(k*dhi)*sin(OHi);
axhi=(2*pi^2*Hmax)/T^2*cosh(k*(dhi+zHi))/sinh(k*dhi)*sin(OHi);
Vnhi= sqrt((Vxhi.^2+Vzhi.^2));
Fhzi=(Ch.*abs(Vnhi).*Vnhi)+(Ka.*axhi);
Vxhj=(pi*Hmax)/T*cosh(k*(dhj+zHj))/sinh(k*dhj)*cos(OHj);
Vzhj=(pi*Hmax)/T*sinh(k*(dhj+zHj))/sinh(k*dhj)*sin(OHj);
axhj=(2*pi^2*Hmax)/T^2*cosh(k*(dhj+zHj))/sinh(k*dhj)*sin(OHj);
```

```
Vnhj= sqrt((Vxhj.^2+Vzhj.^2));
Fhzj=(Ch.*abs(Vnhj).*Vnhj)+(Ka.*axhj);
Fhxi=cosd(Oxhi).*Fhzi;
Fhyi=cosd(Oyhi).*Fhzi;
Fhxj=sind(Oxhi).*Fhzj;
Fhyj=sind(Oyhi).*Fhzj;
Lh = hy_bracing(:,1);
Dih = hy_bracing(:,3);
Ah=(Doh.^2-Dih.^2)./4;
disphxi=(Fhxi.*Lh)./(E.*Ah);
disphyi=(Fhyi.*Lh)./(E.*Ah);
disphzi=(Fhzi.*Lh)./(E.*Ah);
disphxj=(Fhxj.*Lh)./(E.*Ah);
disphyj=(Fhyj.*Lh)./(E.*Ah);
disphzj=(Fhzj.*Lh)./(E.*Ah);
Cxhi=cosd(Oxhi);
Cyhi=cosd(Oyhi);
Czhi=cosd(Ozhi);
Cxhj=sind(Oxhi);
Cyhj=sind(Oyhi);
Czhj=sind(Ozhi);
SThm=(E./Lh).*((Cxhi.*disphxi)+(Cyhi.*disphyi)+(Czhi.*disphzi)+(-Cxhj.*disphxj)+(-
Cyhj.*disphyj)+(-Czhj.*disphzj));
% Horizontal Y Bracing Force Tabulated Results
hy_bracingxi=Fhxi;
hy_bracingyi=Fhyi;
hy_bracingzi=Fhzi;
hy_bracingxj=Fhxj;
hy_bracingyj=Fhyj;
hy_bracingzj=Fhzj;
Rresultshorizontalforce=table(Memberhy,Nodalhi,hy_bracingxi,hy_bracingyi,hy_bracingzi,N
odalhj,hy_bracingxj,hy_bracingyj,hy_bracingzj)
% Pile Nodal Displacement Tabulated Results
hy_bracingdxi=disphxi;
hy_bracingdyi=disphyi;
hy_bracingdzi=disphzi;
hy_bracingdxj=disphxj;
hy_bracingdyj=disphyj;
hy_bracingdzj=disphzj;
Rresultshorizontaldisp=table(Memberhy,Nodalhi,hy_bracingdxi,hy_bracingdyi,hy_bracingdz
i,Nodalhj,hy_bracingdxj,hy_bracingdyj,hy_bracingdzj)
% Pile Member Stresses Tabulated Results
hy_bracingSTh=SThm;
RresultshorizontalmemberStress=table(Memberhy,hy_bracingSTh)
%% Diagonal Front Bracing Member
```

```
dia_front=[0,1,0.8,135,315,45,1,5,0,20,0,10,15;0,1,0.8,45,225,315,7,11,0,20,0,10,16;0,1,0.8,
135,315,45,2,6,20,30,0,10,17;0,1,0.8,45,225,315,8,12,20,30,0,10,18];

% yd length of diagonal front member
xdi = dia_front(:,11);
xdj = dia_front(:,12);
dfi = dia_front(:,9);
dfj = dia_front(:,10);
Ymax =max(dia_front(:,12));
L1=max(pile_member(:,1));
Oxdi = dia_front(:,4);
Oydi = dia_front(:,5);
Ozdi = dia_front(:,6);
Dod=dia_front(:,2);
Did=dia_front(:,3);
Nodaldi=dia_front(:,7);
Nodaldj=dia_front(:,8);
Memberdf=dia_front(:,13);
Cdi=Cd*S.*Dod./2;
Kad=Cm*S*(pi.*Dod)./4;
if dfi<d
yd=sqrt(Ymax^2+L1^2);
% BDF angle of Diagonal front member
BDF= atan(Ymax/L1);
%Co-ordinate in x-direction
Cxf=0;
%Co-ordinate in y-direction
Cyf= cos(BDF);
%Co-ordinate in z-direction
Czf= sin(BDF);
% ODF Phase angle of water wave on the diagonal front face member
ODFi = (k*xdi)-(w*t);
ODFj = (k*xdj)-(w*t);
% Instantaneous wave height
zDFi= Hmax/2.*cos(ODFi);
zDFj= Hmax/2.*cos(ODFj);
% Velocity in x-direction Vxf
Vxfi=(pi*Hmax)./T.*cosh(k.*(dfi+zDFi))./cosh(k.*dfi).*cos(ODFi);
Vxfj=(pi*Hmax)./T.*cosh(k.*(dfj+zDFj))./cosh(k.*dfj).*cos(ODFj);

% Velocity in z-direction Vzf
Vzfi=(pi*Hmax)./T.*sinh(k.*(dfi+zDFi))./cosh(k.*dfi).*sin(ODFi);
Vzfj=(pi*Hmax)./T.*sinh(k.*(dfj+zDFj))./sinh(k.*dfj).*sin(ODFj);
% Acceleration in x-direction axf
axfi=(2*pi^2*Hmax)./T^2.*sinh(k.*(dfi+zDFi))./cosh(k.*dfi).*sin(ODFi);
axfj=(2*pi^2*Hmax)./T^2.*sinh(k.*(dfj+zDFj))./cosh(k.*dfj).*sin(ODFj);
```

```
% Velocity magnitude Vnf
Vnfi= sqrt((Vxfi.^2+Vzfi.^2));
Vnfj= sqrt((Vxfj.^2+Vzfj.^2));
anfi=((Cyf.*Czf)-(1-Czf.^2)).*axfi;
anfj=((Cyf.*Czf)-(1-Czf.^2)).*axfj;
% Total force per unit length on diagonal member bracing before waterline section
Fbdfi=(Cdi.*abs(Vnfi).*Vnfi)+(Kad.*anfi);
Fbdfj=(Cdi.*abs(Vnfj).*Vnfj)+(Kad.*anfj);
% Total force on diagonal front face member bracing before waterline section
Fdfzi=Fbdfi.*yd;
Fdfzj=Fbdfj.*yd;
Fdfxi=cosd(Oxdi).*Fdfzi;
Fdfyi=cosd(Oydi).*Fdfzi;
Fdfxj=sind(Oxdi).*Fdfzj;
Fdfyj=sind(Oydi).*Fdfzj;
% Note Tabulate the result FDB
elseif dfi>=d
% Sb Number of section before waterline
   Sb=d/L1;
% Lb Length before waterline section
   Lb=L1*Sb;
% Z Length left between the waterline section
   Z=d-Lb;
% Ld Diagonal front member length on waterline
Ldi=(Z+zDFi)/(2*cos(ODFi));
Ldj=(Z+zDFj)/(2*cos(ODFj));
   Z1i=(Z+zDFi)/2;
   Z2i=-(Z1i/2-zDFi);
   Z1j=(Z+zDFj)/2;
   Z2j=-(Z1j/2-zDFj);
% Velocity in x-direction Vxfa
Vxfai=(pi*Hmax)./T.*cosh(k.*(dfi+Z2i))./sinh(k.*dfi).*cos(ODFi);
Vxfaj=(pi*Hmax)./T.*cosh(k.*(dfj+Z2j))./sinh(k.*dfj).*cos(ODFj);
% Velocity in z-direction Vzfa
Vzfai=(pi*Hmax)./T.*sinh(k.*(dfi+Z2i))./sinh(k.*dfi).*sin(ODFi);
Vzfaj=(pi*Hmax)./T.*sinh(k.*(dfj+Z2j))./sinh(k.*dfj).*sin(ODFj);
% Acceleration in x-direction axfa
   axfai=(2*pi^2*Hmax)./T^2.*cosh(k.*(dfi+Z2i))./sinh(k.*dfi).*sin(ODFi);
   axfaj=(2*pi^2*Hmax)./T^2.*cosh(k.*(dfj+Z2j))./sinh(k.*dfj).*sin(ODFj);
% Velocity magnitude Vnfa
Vnfai= sqrt((Vxfai.^2+Vzfai.^2));
Vnfaj= sqrt((Vxfaj.^2+Vzfaj.^2));
anfai=((Cyf.*Czf)-(1-Czf.^2)).*axfai;
anfaj=((Cyf.*Czf)-(1-Czf.^2)).*axfaj;
% Total force per unit length on diagonal member bracing before waterline section
Fbdfai=(C.*abs(Vnfai).*Vnfai)+(Ka.*anfai);
```

```
Fbdfaj=(C.*abs(Vnfaj).*Vnfaj)+(Ka.*anfaj);
% FDO Total force on diagonal front side member bracing on waterline section
FDOi= Fbdfai.*Ldi;
FDOj= Fbdfaj.*Ldj;
%     FDO= Fbdfa.*Ld
%Tabulate the result FDO value of member angle ODF and water depth d
% Stress and Displacement
end
% compute diagonal front displacement and stress
Ad=(Dod.^2-Did.^2)./4;
dispdxi=(Fdfxi.*yd)./(E.*Ad);
dispdyi=(Fdfyi.*yd)./(E.*Ad);
dispdzi=(Fdfzi.*yd)./(E.*Ad);
dispdxj=(Fdfxj.*yd)./(E.*Ad);
dispdyj=(Fdfyj.*yd)./(E.*Ad);
dispdzj=(Fdfzj.*yd)./(E.*Ad);
Cxdi=cosd(Oxdi);
Cydi=cosd(Oydi);
Czdi=cosd(Ozdi);
Cxdj=sind(Oxdi);
Cydj=sind(Oydi);
Czdj=sind(Ozdi);
STdm=(E./yd).*((Cxdi.*dispdxi)+(Cydi.*dispdyi)+(Czdi.*dispdzi)+(-Cxdj.*dispdxj)+(-
Cydj.*dispdyj)+(-Czdj.*dispdzj));
% Diagonal Front Bracing Force Tabulated Results
dia_frontxi=Fdfxi;
dia_frontyi=Fdfyi;
dia_frontzi=Fdfzi;
dia_frontxj=Fdfxj;
dia_frontyj=Fdfyj;
dia_frontzj=Fdfzj;
Rresultsdia_Frontforce=table(Memberdf,Nodaldi,dia_frontxi,dia_frontyi,dia_frontzi,Nodaldj,
dia_frontxj,dia_frontyj,dia_frontzj)
% Pile Nodal Displacement Tabulated Results
dia_frontdxi=dispdxi;
dia_frontdyi=dispdyi;
dia_frontdzi=dispdzi;
dia_frontdxj=dispdxj;
dia_frontdyj=dispdyj;
dia_frontdzj=dispdzj;
RresultsDia_Frontdisp=table(Memberdf,Nodaldi,dia_frontdxi,dia_frontdyi,dia_frontdzi,Noda
ldj,dia_frontdxj,dia_frontdyj,dia_frontdzj)
% Pile Member Stresses Tabulated Results
dia_frontSTd=STdm;
RresultsDia_FrontmemberStress=table(Memberdf,dia_frontSTd)
```